

 $\bigcirc \textcircled{1} \bigcirc \textcircled{2} \bigcirc \textcircled{3}$ 

# Evaluation of Admission Brain Computed Tomography Findings to Predict the Long-term Outcomes of Patients with Traumatic Brain Injury

# Avaliação de achados em tomografia de crânio admissional para predizer o prognóstico a longo prazo de paciente com trauma cranioencefálico

Rafael de Souza Dantas<sup>1</sup> Thais Cristina de Souza Melo<sup>1</sup> Isabella Fontes de Santana Lins<sup>1</sup> Letícia Adrielle dos Santos<sup>1</sup> José Nolasco de Carvalho Neto<sup>1</sup> Bruno Fernandes de Oliveira Santos<sup>1,2,3</sup> Robson Luis Oliveira de Amorim<sup>4</sup> Arthur Maynart Pereira Oliveira<sup>1,2</sup>

<sup>4</sup> Neurosurgery Service, Hopital Universitário Getúlio Vargas, Universidade Federal do Amazonas, Manaus, AM, Brazil

Arq Bras Neurocir 2024;43(3):e157-e163.

Address for correspondence Arthur Maynart Pereira Oliveira, MD, PhD, Department of Neurosurgery, Hospital de Cirurgia, Fundação de Beneficência Hospital de Cirurgia, Av. Desembargador Maynard 174, Aracaju, Sergipe, 49055-210, Brazil (e-mail: arthurmaynart@icloud.com).

#### Abstract **Objective** To evaluate the admission brain computed tomography (CT) scan findings in patients with traumatic brain injury (TBI) in a low- and middle-income country (LMIC) to predict long-term neurological outcomes. **Materials and Methods** Patients admitted to a tertiary emergency hospital between March 2017 and April 2018 who had suffered a TBI and had undergone a brain CT scan within 12 hours of the trauma were prospectively evaluated. All of the patients who were hospitalized for at least 24 hours were contacted by phone after 12 months to evaluate their neurological condition. **Results** We achieved a 12-month follow-up with 180 patients, most of them male (93.33%). The brain changes identified by CT, such as brain contusion (BC; p = 0.545), epidural hemorrhage (EDH; p = 0.968) and skull base fracture (SBF; p = 0.112) were not **Keywords** associated with worse neurological outcomes; however, subdural hemorrhage (SDH; ► traumatic brain injury p = 0.041), subarachnoid hemorrhage (SAH; $p \le 0.001$ ), brain swelling (BS; $p \le 0.001$ ), computed effacement of cortical sulci (ECS; p = 0.006), effacement of basal cisterns (EBC; p tomography $\leq$ 0.001), depressed skull fracture (DSF; p = 0.017), and a brain midline shift > 5 mm► outcome (p = 0.028) were associated with worse outcomes. developing countries

received February 11, 2023 accepted June 21, 2023 article published online April 29, 2024 DOI https://doi.org/ 10.1055/s-0043-1776278. ISSN 0103-5355. © 2024. Sociedade Brasileira de Neurocirurgia. All rights reserved. This is an open access article published by Thieme under the terms of the Creative Commons Attribution-NonDerivative-NonCommercial-License, permitting copying and reproduction so long as the original work is given appropriate credit. Contents may not be used for commercial purposes, or adapted, remixed, transformed or built upon. (https://creativecommons.org/ licenses/by-nc-nd/4.0/)

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

<sup>&</sup>lt;sup>1</sup> Department of Medicine, Fundação Universidade Federal de Sergipe, Lagarto, SE, Brazil

<sup>&</sup>lt;sup>2</sup>Department of Medicine, Universidade Tiradentes, Aracaju, SE, Brazil

<sup>&</sup>lt;sup>3</sup>Department of Neurosurgery, Hospital de Cirurgia, Aracaju, SE, Brazil

**Conclusion** Findings such as SAH, BS and DSF were independent predictors of worse neurological outcomes. The rate of 70% of patients lost to follow-up shows the difficulties of conducting long-term research in LMICs.

ResumoObjetivoAvaliar as variáveis de tomografia computadorizada (TC) cerebral admissi-<br/>onal em pacientes com trauma cranioencefálico (TCE) em um país de baixa e média<br/>renda (PBMR) para prever os resultados neurológicos de longo prazo.

**Materiais e Métodos** Foram avaliados prospectivamente pacientes admitidos em um hospital terciário de emergência entre março de 2017 e abril de 2018, que sofreram TCE e realizaram tomografia de crânio em até 12 horas após o trauma. Todos os pacientes que permaneceram internados por pelo menos 24 horas foram contatados por telefone após 12 meses para avaliação de sua condição neurológica.

**Resultados** Conseguimos um acompanhamento de 12 meses com 180 pacientes, a maioria deles do sexo masculino (93,33%). As alterações cerebrais identificadas pela TC, como contusão cerebral (CC; p = 0,545), hemorragia peridural (HPD; p = 0,968) e fratura da base do crânio (FBC; p = 0,112) não foram associadas a piores desfechos neurológicos; no entanto, hemorragia subdural (HSD; p = 0,041), hemorragia subaracnóidea (HSA;  $p \le 0,001$ ), edema cerebral (EC;  $p \le 0,001$ ), apagamento de sulcos corticais (ASC; p = 0,006), apagamento de cisternas (AC;  $p \le 0,001$ ), fratura craniana deprimida (FCD; p = 0,017) e desvio da linha média do cérebro > 5 mm (p = 0,028) foram associados a piores resultados.

prognóstico
países em desenvolvimento
desenvolvimento
Conclusão Achados como HSA, EC e FCD foram preditores independentes de piores desfechos neurológicos. A taxa de perda de acompanhamento de 70% indica as dificuldades de se conduzir pesquisas de longo prazo em PBMRs.

## Introduction

**Palavras-chave** 

lesão cerebral

traumática

computadorizada

tomografia

Traumatic brain injury (TBI) is defined as a change in brain function or other evidence of encephalopathy caused by an external force.<sup>1</sup> These injuries can be caused by a bump, blow, or jolt to the head, or they may be penetrating head injuries that disrupt the normal function of the brain.<sup>2</sup> They represent an important public health problem, and are a significant cause of morbidity and mortality, especially among men and young adults.<sup>3–5</sup> Data from the TBI Model Systems National Data and Statistical Center (TBINDSC) in the United States, show that, in 2017, the cases among male patients greatly outnumbered those among female patients, accounting for more than 73% of all TBIs reported.<sup>6</sup> Patients who survive a moderate to severe TBI often experience a broad spectrum of cognitive and behavioral changes due to diffuse injury. These deficits include slow information processing, as well as impaired long-term memory, attention, functional memory, executive functions, social cognition, and selfawareness.<sup>1</sup>

Upon admission to the hospital, the severity of the TBI is commonly graded according to the Glasgow Coma Scale (GCS), a measure of the level of consciousness. This is purely a descriptive scale; it does not provide any structural information on potential intracranial lesions.<sup>7,8</sup> Due to its accessibility and speed, computed tomography (CT) is the routine imaging modality used to assess structural lesions in acute TBI;<sup>8</sup> it is important in the early identification of patients with significant intracranial damage at risk of deterioration, but CT can also identify lesions that are relevant to the patient's prognosis and rehabilitation but do not necessarily require neurosurgical intervention.<sup>9</sup> Knowledge of the relationship between the clinical signs presented by the patient in the first hours after trauma and the morphological changes identified by brain CT is important for the early diagnosis of TBI; however, CT has to be used with caution due to the increased risk of developing cancer resulting from exposure to ionizing radiation, especially in children.<sup>10</sup>

In 1991, Marshall et al.<sup>11</sup> used tomographic findings to classify patients with TBI. Initially, the purpose of the classification was descriptive; however, it also started to be used as a predictor of mortality. The study<sup>11</sup> used the term *diffuse brain* injury, which was divided into four categories: Marshall I, without any changes on brain CT; and Marshall II, III and IV, with certain degrees of brain damage. In the original study, the authors<sup>11</sup> noticed a direct relationship between the diagnosis of TBI and the mortality rate; however, other studies<sup>12-15</sup> have shown that the status of the basal cisterns, the midline shift, traumatic subarachnoid or intraventricular hemorrhage, and the presence of different types of mass lesions could produce a more accurate prognostic prediction. Other classifications were later created, such as the Rotterdam CT score (2005), which reweighted the components of the Marshall CT classification and added traumatic subarachnoid hemorrhage (tSAH) and intraventricular hemorrhage, becoming part of the International Mission for Prognosis and Analysis of Clinical Trials in TBI (IMPACT) outcome model for TBI patients.<sup>12,13</sup> More recently, new CT classifications have emerged, including the Stockholm CT score, in 2010,<sup>14</sup> and the Helsinki CT score, in 2014.<sup>15</sup> However, none of these scales have been extensively evaluated.

To objectively assess the functionality of patients with TBI, Jennett and Bond<sup>16</sup> (1975) developed the Glasgow Outcome Scale (GOS),<sup>7,16,17</sup> which was modified over time to provide a more detailed categorization, becoming the Glasgow Outcome Scale-Extended (GOSE),<sup>17,18</sup> a global scale for the functional evaluation of TBI patients.<sup>19</sup>

The purpose of the present study was to evaluate the potential association between morphological brain changes identified through CT and the long-term functional neurological outcomes of patients with TBI.

## **Materials and Methods**

## **Study Design**

We conducted a prospective cohort study of TBI patients admitted to a Brazilian tertiary hospital – Hospital de Urgências de Sergipe Governador João Alves Filho. Patients were recruited between March 2017 and April 2018 and were followed up until 12 months after the injury.

### Sample

The study included patients who had suffered a TBI, were referred to the emergency unit to undergo a brain CT scan within 12 hours of the injury, and were then admitted to the hospital for at least 24 hours. After 12 months, we attempted to contact all the patients by phone.

#### **Exclusion Criteria**

We excluded patients who: reported or presented CT changes from a previous TBI; had other neurological or neurosurgical conditions, were aged  $\leq$  18 years; did not agree to participate in the study (or whose legal guardian/next of kin did not agree); and had suffered the head trauma more than 12 hours before the Brain CT scan.

#### **Data Collection**

All data about the admission brain CT scan were collected during the study period, including the grade on the Marshall classification and 12 radiological variables (brain contusion, epidural hemorrhage, subdural acute hemorrhage, subarachnoid hemorrhage, brain swelling, basal cistern effacement, cortical sulci effacement, brain midline shift > 5 mm, brain midline shift < 5 mm, skull fracture, depressed skull fracture, and skull base fracture). Twelve months later, the patients/next of kin were contacted by phone and assessed through a structured questionnaire to obtain the GOSE score: 1–death; 2–vegetative state; 3–severe disability (low); 4–severe disability (high); 5–moderate disability (low); 6–moderate disability (high); 7–good recovery (low); and 8–good recovery (high). They were then divided into 2 groups: good recovery (GOSE score  $\geq$  7) and poor recovery (GOSE score < 7).

#### **Statistical Analysis**

Data were systematized, analyzed, and statistically tested using the IBM SPSS Statistics for Windows (IBM Corp., Armonk, NY, United State) software, version 23.0. The variables were expressed as absolute and relative frequencies, and median, arithmetic mean, and standard deviation (SD) values. The results of interest were analyzed using the Chi-squared ( $\chi^2$ ) test and logistic regression. A multivariate analysis was performed to create a model of the CT variables regarding the functional outcomes at the 12month follow-up. Values of p < 0.05 were considered statistically significant.

## Results

From the initial 600 subjects who had suffered a TBI and had undergone CT, we achieved a 12-month follow up with 180 (30%) patients (**-Fig. 1**). Most patients were male (93.3%), with a mean age of 36 (SD:  $\pm$  16.2) years. As aforementioned, the patients were divided into two groups: good recovery (42.7%), defined by a GOSE score  $\geq$  7; and poor recovery (56.3%), defined by a GOSE score < 7 (38.9% had moderate to severe disability, 0.56% were in a vegetative state, and 17.8% had died). At baseline, 168 patients (93.3%) presented pathological findings on the brain CT and 12 (6.7%) presented completely normal images. Among the patients with TBI-related CT alterations, 99 (58.9%) had a good recovery (GOSE score < 7), while 69 patients had disability or death (GOSE score < 7). The distribution of the patients in terms of functionality is shown in **-Table 1**.



**Fig. 1** Flowchart of the data cohort and the 180 patients included in the study.

Variable	Included patients: GOSE score < 7 (n = 103)	Included patients: GOSE score $\geq$ 7 ( $n =$ 77)	<i>p</i> -value
Ages in years: mean $\pm$ standard deviation	36.6±16.2)	36.06±16.2)	0.738
Sex: n (%)			0.637
Male	87 (84)	63 (82)	
Female	16 (16)	14 (18)	
Changes on CT: n (%)	99 (96)	69 (90)	0.083
Contusion	57 (56)	39 (51)	0.545
EDH	23 (22)	17 (22)	0.968
SDH	33 (32)	14 (18)	0.041
SAH	69 (67)	30 (39)	< 0.001
Swelling	23 (22)	03 (04)	< 0.001
Effacement of cortical sulci	44 (43)	18 (23)	0.006
Effacement of basal cisterns	17 (17)	01 (01)	< 0.001
Brain midline shift > 5 mm	20 (19)	06 (08)	0.028
Brain midline shift < 5 mm	15 (15)	05 (07)	0.084
Skull fracture	65 (63)	34 (44)	0.011
Depressed skull fracture	17 (17)	04 (05)	0.017
Skull base fracture	60 (59)	36 (47)	0.112
Marshall grade 1	13 (13)	15 (19)	0.219
Marshall grade 2	51 (50)	52 (67)	0.019
Marshall grade 3	21 (20)	04 (05)	0.003
Marshall grade 4	17 (17)	11 (15)	0.040

Table 1 Demographics, changes in computer tomography in the patients included, and associations with neurological outcomes

Abbreviations: CT, computed tomography; EDH, epidural hemorrhage; GOSE, Glasgow Outcome Scale-Extended; SDH, subdural hemorrhage; SAH, subarachnoid hemorrhage.

Note: p-values in bold indicate statistical significance.

#### **Brain CT and Neurological Prognosis**

There were no significant associations regarding brain contusions (p = 0.545), epidural hemorrhage (p = 0.968), skull base fractures (p = 0.112), and a worse outcome. In patients with a GOSE score <7 there was an increased frequency of subdural hemorrhage (p = 0.041) and subarachnoid hemorrhage ( $p \le 0.001$ ). Conditions that are related with increased intracranial pressure and a worse neurological prognosis, such as brain swelling ( $p \le 0.001$ ), effacement of cortical sulci (p = 0.006), effacement of basal cisterns ( $p \le 0.001$ ), and brain midline shift > 5 mm (p = 0.028) were also observed. Skull fracture (p = 0.011) and depressed skull fracture (p = 0.017) were also associated with worse outcomes at 12 months. A summary of all changes in the brain CT scans (including the Marshall grade) and the associations with neurological outcomes are shown in **-Table 1**.

After a multivariate analysis of the CT variables, only the presence of subarachnoid hemorrhage, swelling, and depressed skull fracture were independent predictors of outcomes (**~Table 2**).

#### Secondary Analysis

Age, baseline GOSE scores, and the main baseline CT variables were analyzed for the group of patients lost to follow-up, and no statistically significant differences were found ( $\succ$  Table 3).

Table 2 Computed tomography variables that were independent predictors of outcome after a multivariate analysis

Variable	Odds ratio	95% confidence interval	<i>p</i> -value
Subarachnoid hemorrhage	2.38	1.24–4.55	0.009
Swelling	4.39	1.20–15.99	0.025
Depressed skull fracture	3.30	1.02–10.70	0.046

Variable	Not lost to follow-up $(n = 180)$	Lost to follow-up $(n = 420)$	<i>p</i> -value
Ages in years: mean $\pm$ standard deviation	36.5±16.1)	34.75 ± 16.5)	0.23
Sex: n (%)			0.77
Male	354 (84.3)	150 (83.3)	
Severe traumatic brain injury: n (%)	159 (37.9)	66 (36.7)	0.81
Changes on computed tomography: n (%)			
Subdural hemorrhage	119 (28.3)	47 (26.2)	0.70
Subarachnoid hemorrhage	217 (51.7)	99 (55.0)	0.45
Swelling	50 (11.9)	26 (14.4)	0.56
Effacement of cortical sulci	148 (35.2)	62 (34.4)	0.79
Effacement of basal cisterns	77 (18.3)	39 (21.7)	0.59
Brain midline shift > 5 mm	49 (11.67)	26 (14.4)	0.52
Skull fracture	233 (55.5)	99 (55.0)	0.79
Depressed skull fracture	62 (14.8)	22 (12.2)	0.46
Marshall grade 1	72 (17.1)	28 (15.56)	0.89
Marshall grade 2	250 (59.52)	103 (57.22)	0.78
Marshall grade 3	47 (11.2)	25 (13.9)	0.72
Marshall grade 4	50 (11.9)	22 (12.2)	0.93

Table 3 Comparison of baseline clinical and radiological findings of the patients recruited regarding loss or not to follow-up

## Discussion

The present study investigated the associations involving morphological changes in the brain identified by CT and the functional outcomes after 12 months measured through the GOSE, which was chosen because it is the most cited and accepted scale to measure functional outcomes following TBI. A simplified Portuguese version of the scale has been validated for use in Brazil.<sup>20–22</sup> It is a very flexible scale that can help to improve follow-up, as it can be applied face to face or by telephone. McMillan et al.<sup>19</sup> found no differences between these two interview modalities in terms of results. Rainer et al.,<sup>23</sup> in 5-year prospective cohort, reported that the best functional improvement occurs 6 to 12 months after the TBI, data that supports the time chosen by us to conduct the follow-up. In the present study, 12 months after the TBI, we found that 42.7% of the patients had good recovery, a figure that is in agreement with the results of the study by Samanamalee et al.<sup>24</sup>

Regarding the Marshall CT classification in a study with a large sample (n = 2269), Mass et al.<sup>13</sup> (2005) confirmed that it had a good predictive value, although they recommended making more use of the characteristics underlying the classification and including other predictors, such as intraventricular and traumatic subarachnoid hemorrhage, as well as a clearer differentiation between basal and mass lesions, to produce a better prognostic tool. The results of the present study are in line with most of the results found by Mass et al.,<sup>13</sup> showing the importance of including the effacement of basal cisterns (p < 0.001), midline shift > 5 mm (p < 0.028) and subarachnoid hemorrhage (p < 0.001); however, unlike

Mass et al.,<sup>13</sup> we did not find epidural hemorrhage to be associated with better outcomes and intravascular hemorrhage to be related to worse outcomes. In fact, we found a similar percentage of patients with these abnormalities in both groups in the present study, with no association with the outcomes.<sup>13</sup> According to Gennarelli et al.,<sup>25</sup> the worst TBI they observed was subdural hematoma, as it was not only responsible for the majority of all deaths in their series of patients, but it was associated with the greatest impact on quality of life among the survivors. Another study, also conducted in Brazil, Amorim et al.<sup>26</sup> reported an associations regarding epidural, subdural, subarachnoid, and intracerebral hemorrhage and higher levels of mortality in 14 days, as well as with worse GCS scores, findings similar to those of the present study.

Increased intracranial pressure due to a mass effect from swelling or hematoma can lead to displacement of the brain parenchyma into a different compartment, resulting in a worse prognosis. The signs of increased pressure that were analyzed on the CT scans in the present study included brain swelling, effacement of cortical sulci and basal cisterns, and brain midline shift > 5 mm. These alterations were related to functional decline, especially basal cistern effacement, which was the variable most associated with poor recovery. Cordobés et al.<sup>27</sup> found a mortality rate of 76% in the presence of basal cistern effacement. Murphy et al.<sup>28</sup> showed that basal cistern effacement had a close relationship with increased intracranial pressure, being an important independent prognosis factor in first hours after a TBI.

Vascular injury with hemorrhage is an important complication in TBI, and it can be caused by several mechanisms. Arterial lesions as a result of a direct laceration or skull base fracture are among the most common causes, leading to other complications, such as cerebrospinal fluid leak, which increases the risk of developing meningitis or orthostatic headaches months to years after the lesion.<sup>29</sup> Although a basilar skull fracture was not associated with either good or poor recovery in the data (p = 0.112) of the present study, we found that depressed skull fracture, which could indicate a high-energy trauma and a possible parenchyma lesion, was associated with poor recovery (p = 0.017). Most of the studies on TBI prognosis<sup>10,11,13</sup> do not report skull fracture as an important indicator of neurological prognosis. In the present study, among the CT variables, depressed skull fracture was found to be an independent predictor of outcome; however, this anomalous finding should be interpreted with caution, and needs to be better evaluated in future studies.

The present cohort study has some limitations which could reduce the impact of our findings. The successful follow-up rates were lower than expected when compared with other studies, such as that the one by Rainer et al.,<sup>23</sup> which reported a loss of only 56% with the same follow-up period, against the rate of 70% observed in the present study. The main reason for the low level of successful follow-up in the present study was the lack of correct contact information in medical records and difficulty accessing the patients' data in general. In low- middle-income countries (LMICs), longterm follow-up may be more challenging than in highincome countries, since telecommunication networks, including mobile phone use and the internet, are not as developed.<sup>26</sup> Moreover, the regular contact that may be maintained by patients visiting rehabilitation centers in countries with better resources is more difficult in LMICs such as Brazil, where the health infrastructure is less developed, as described by Conforto et al.<sup>30,31</sup> Despite the rate of patients lost to follow-up, no statistically significant differences were observed regarding the baseline characteristics of the individuals in the follow-up group and lost to followup group. A final limitation is the fact that external factors, such as socioeconomic condition, level of schooling, access to a multidisciplinary team (physiotherapist, physiatrist, or occupational therapist), which could affect functional recovery in the long term, were not assessed in the present study. These important variables could be included in future studies. One important strength of the study was the fact that we used self-reported measures, such as the GOSE, in the followup. These are important, as they introduce the direct perspective of the patients, which is often missing in studies which only include provider-driven measures, thus introducing a potential bias.

## Conclusion

The present study showed that subarachnoid hemorrhage, brain swelling, and depressed skull fracture were the main morphological abnormalities identified on admission CT scans and the strongest independent predictors of functional outcomes measured at follow-up 12 months after the TBI. Although there was an important rate of patients lost to followup, a common difficulty in studies in LMICs, there were no statistically significant differences at baseline regarding the characteristics of the overall sample and the follow-up group. Further studies with larger samples and longer follow-up are warranted to provide a higher level of evidence regarding the important variables identified in the present study.

#### **Ethical Considerations**

The present study was approved by the Ethics Committee of Fundação Universidade Federal de Sergipe (in accordance with the Helsinki Declaration, revised in 1983), and all patients or their legal guardian/next of kin signed an informed consent form.

#### **Authors Contribution**

All authors contributed to the conception and design of the study. Material preparation and data collection and analysis were performed by RSD, TCSM, IFSL, JNCN, LAS, BFOS,RLOA, and AMPO. The first draft of the manuscript was written by RSD, and all authors commented on previous versions of the manuscript. The final draft of the manuscript was written by LAS. All authors read and approved the final manuscript.

#### Funding

The authors declare that they have received no funding for the performance of the present study.

#### **Conflict of Interests**

The authors have no conflict of interests to declare.

#### Acknowledgments

We would like to thank Cassandra Schaly for her contribution in reviewing the language used in the article, and the Research Coordination Department (Coordenação de Pesquisa, COPES, in Portuguese) at Fundação Universidade Federal de Sergipe for the encouragement to complete the study.

#### References

- 1 Azouvi P, Arnould A, Dromer E, Vallat-Azouvi C. Neuropsychology of traumatic brain injury: An expert overview. Rev Neurol (Paris) 2017;173(7-8):461–472
- 2 Capizzi A, Woo J, Verduzco-Gutierrez M. Traumatic Brain Injury: An Overview of Epidemiology, Pathophysiology, and Medical Management. Med Clin North Am 2020;104(02):213–238
- 3 Gaudêncio TG, Leão Gde MA epidemiologia do Traumatismo Crânio-Encefálico: Um Levantamento bibliográfico no Brasil. Revista Neurociencias. 2013;21(03):427–434
- 4 Feitas JPP, Ribeiro LA, Jorge MT. Vítimas de acidentes de trânsito na faixa etária pediátrica atendidas em um hospital universitário: aspectos epidemiológicos e clínicos. Cad Saude Publica 2007;23 (12):3055–3060
- 5 Melo JRT, de Santana DLP, Pereira JLB, Ribeiro TF. Traumatismo craniencefálico em crianças e adolescentes na cidade do Salvador -Bahia. Arq Neuropsiquiatr 2006;64(04):994–996
- 6 National database: 2017 profile of people within the traumatic brain injury model systems. Traumatic brain injury model systems National Data and Statistical Center. Center. Available at: https:// msktc.org/lib/docs/Data\_Sheets\_/2017\_TBIMS\_ National\_Databa.

- 7 Teasdale G, Jennett B. Assessment and prognosis of coma after head injury. Acta Neurochir (Wien) 1976;34(1-4):45–55
- 8 Thelin EP, Nelson DW, Vehviläinen J, et al. Evaluation of novel computerized tomography scoring systems in human traumatic brain injury: An observational, multicenter study. PLoS Med 2017;14(08):e1002368
- 9 Kolias AG, Guilfoyle MR, Helmy A, Allanson J, Hutchinson PJ. Traumatic brain injury in adults. Pract Neurol 2013;13(04):228–235
- 10 Zhu H, Gao Q, Xia X, Xiang J, Yao H, Shao J. Clinically-important brain injury and CT findings in pediatric mild traumatic brain injuries: a prospective study in a Chinese reference hospital. Int J Environ Res Public Health 2014;11(04):3493–3506
- 11 Marshall LF, Marshall SB, Klauber MR, et al. A new classification of head injury based on computerized tomography. J Neurosurg 1991;75(Supplement):S14–S20
- 12 Steyerberg EW, Mushkudiani N, Perel P, et al. Predicting outcome after traumatic brain injury: development and international validation of prognostic scores based on admission characteristics. PLoS Med 2008;5(08):e165, discussion e165
- 13 Maas AIR, Hukkelhoven CWPM, Marshall LF, Steyerberg EW. Prediction of outcome in traumatic brain injury with computed tomographic characteristics: a comparison between the computed tomographic classification and combinations of computed tomographic predictors. Neurosurgery 2005;57(06):1173–1182, discussion 1173–1182
- 14 Nelson DW, Nyström H, MacCallum RM, et al. Extended analysis of early computed tomography scans of traumatic brain injured patients and relations to outcome. J Neurotrauma 2010;27(01): 51–64
- 15 Raj R, Siironen J, Skrifvars MB, Hernesniemi J, Kivisaari R. Predicting outcome in traumatic brain injury: development of a novel computerized tomography classification system (Helsinki computerized tomography score). Neurosurgery 2014;75(06):632--646, discussion 646-647
- 16 Jennett B, Bond M. Assessment of outcome after severe brain damage. Lancet 1975;1(7905):480–484
- 17 Jennett B, Snoek J, Bond MR, Brooks N. Disability after severe head injury: observations on the use of the Glasgow Outcome Scale. J Neurol Neurosurg Psychiatry 1981;44(04):285–293
- 18 Wilson JTL, Pettigrew LEL, Teasdale GM. Structured interviews for the Glasgow Outcome Scale and the extended Glasgow Outcome Scale: guidelines for their use. J Neurotrauma 1998;15(08): 573–585

- 19 McMillan T, Wilson L, Ponsford J, Levin H, Teasdale G, Bond M. The Glasgow Outcome Scale - 40 years of application and refinement. Nat Rev Neurol 2016;12(08):477–485
- 20 de Sousa RM. Comparação entre instrumentos de mensuração das consequências do trauma crânio-encefálico. Rev Esc Enferm USP 2006;40(02):203–213
- 21 de Sousa RM, Koizumi MS. Recuperação das vítimas de traumatismo crânio-encefálico no período de 1 ano após o trauma. Rev Esc Enferm USP 1996;30(03):484–500
- 22 de Sousa RMC, Koizumi MS. Recuperação das vítimas de trauma cranioencefálico entre 6 meses a 1 ano. Braz Neurosurg 1998;17 (02):72–80
- 23 Rainer TH, Hung KKC, Yeung JHH, et al. Trajectory of functional outcome and health status after moderate-to-major trauma in Hong Kong: A prospective 5 year cohort study. Injury 2019;50 (05):1111–1117
- 24 Samanamalee S, Sigera PC, De Silva AP, et al. Traumatic brain injury (TBI) outcomes in an LMIC tertiary care centre and performance of trauma scores. BMC Anesthesiol 2018;18(01):4
- 25 Gennarelli TA, Spielman GM, Langfitt TW, et al. Influence of the type of intracranial lesion on outcome from severe head injury. J Neurosurg 1982;56(01):26–32
- 26 Amorim RL, Oliveira LM, Malbouisson LM, et al. Prediction of Early TBI Mortality Using a Machine Learning Approach in a LMIC Population. Front Neurol 2020;10(01):1366
- 27 Cordobés F, de la Fuente M, Lobato RD, et al. Intraventricular hemorrhage in severe head injury. J Neurosurg 1983;58(02): 217–222
- 28 Murphy S, Thomas NJ, Gertz SJ, et al; Investigators of the Approaches and Decisions in Acute Pediatric Traumatic Brain Injury (ADAPT) Study. Tripartite Stratification of the Glasgow Coma Scale in Children with Severe Traumatic Brain Injury and Mortality: An Analysis from a Multi-Center Comparative Effectiveness Study. J Neurotrauma 2017;34(14):2220–2229
- 29 Vella MA, Crandall ML, Patel MB. Acute Management of Traumatic Brain Injury. Surg Clin North Am 2017;97(05):1015–1030
- 30 Conforto AB, Anjos SM, Saposnik G, et al. Transcranial magnetic stimulation in mild to severe hemiparesis early after stroke: a proof of principle and novel approach to improve motor function. J Neurol 2012;259(07):1399–1405
- 31 Conforto AB, Paulo RB, Patroclo CB, et al. Stroke management in a university hospital in the largest South American city. Arq Neuropsiquiatr 2008;66(2B):308–311