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Correlation between the Profile of Intracranial Hemorrhages Resulting from Traumatic Brain Injury and the Glasgow Outcome Scale (GOS) at Discharge

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ABSTRACT

Objectives: To establish a relationship between patient profiles, patterns of intracranial hemorrhage resulting from traumatic brain injury (TBI), and the outcomes measured by GOS.

Background: TBI can cause hemorrhages, which exhibit different clinical patterns and imaging findings, typically associated with a worse prognosis. The GOS is an important tool for measuring the functional capacity of post-TBI patients.

Methods: Retrospective cohort study. Included individuals above 18 years old with intracranial hemorrhage from TBI in the admission CT. The collected data were: gender; age; comorbidities; mechanism of trauma; GCS at the scene; presence of cranial fracture; presence, location, and extent of subdural, epidural, subarachnoid, and intraparenchymal hemorrhages; and number of affected lobes. At discharge, the association of these characteristics with 4 out of 5 GOS classifications was evaluated: death; severe disability; moderate disability; and mild disability/good recovery.

Results: 193 patients were included, with an average age of 49±20 years, predominantly male (78.8%). The majority (74.1%) were discharged with mild disability/good recovery, 6.2% with moderate disability, 5.2% with severe disability, 0.5% in a vegetative state, and 14% died. There was a significant association between having one injury and mild disability (residual: 4.1), two injuries and moderate disability (residual: 2.4), three injuries and severe disability (residual: 2.9), and four or more injuries and death (residual: 4.5). Another association was observed between mild TBI and mild disability (residual: 6.6), and between severe TBI and severe disability and death (residuals: 4.0 and 5.9, respectively). Death was also associated with cranial fracture (p=0.022 and residual: 2.6), temporal lobe injury (p=0.014 and residual: 2.5), tentorial subarachnoid hemorrhage (p=0.012 and residual: 2.8), and injuries in other locations (p=0.022 and residual: 3.0).

Conclusions: It was found that the more severe the TBI and the greater the number of cranial injuries, the worse the patient outcomes.

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Introduction

Traumatic brain injury (TBI) is defined as an injury caused by abrupt or continuous external forces [1] that result in damage to the skull, meninges, brain, and/or intracranial vessels, potentially causing temporary or permanent cognitive and/or functional impairments [2]. The main mechanisms of trauma involved include motor vehicle accidents, falls, and assaults, making TBIs currently one of the leading causes of death and disabilities across various age groups, representing a significant global public health issue [3,4]. It is estimated that between 2008 and 2012, approximately 125,000 individuals who were victims of TBI were hospitalized in Brazil, with approximately 9,715 deaths per year, according to DATASUS data [1].

The pathophysiology of TBI involves primary brain injuries, directly resulting from the trauma, and secondary injuries, which are long-term consequences of mechanisms occurring during the trauma [5]. Primary injuries encompass damage caused by the movement of the brain against other cranial structures, including vessel rupture, cerebral parenchymal laceration, and involvement of other local structures. Secondary injuries, on the other hand, result from intra and extracerebral factors that begin to evolve shortly after the accident, potentially causing long-term damage, such as arterial hypotension, hypoxemia, and electrolyte disturbances [5].

To assess the severity of TBI patients, it is necessary to perform a computed tomography (CT) scan, gather data related to the mechanism of trauma, and apply the Glasgow Coma Scale (GCS). The GCS is currently the most widely used scale for assessing the level of consciousness, based on the following parameters: eye opening, verbal response, and motor response [3]. Scores on this scale range from 3 to 15, with scores of 13 to 15 considered mild TBIs, 9 to 12 as moderate, and 3 to 8 as severe [6].

CT, in turn, is an essential imaging examination for the rapid and accurate diagnosis and subsequent selection of appropriate therapeutic management. Moreover, due to its high sensitivity in detecting intracranial bleeding, it is crucial for assessing the severity of trauma by visualizing possible vascular damage, responsible for the high mortality and sequelae rates [7,8]. These damages cause hemorrhages that differ based on the affected blood vessels, leading to distinct clinical patterns and findings in imaging exams. Types of traumatic intracranial hemorrhages include subdural hematomas, epidural hematomas, subarachnoid hemorrhages (SAH), and intraparenchymal hematomas [9,10]. Since these hematomas can cause secondary brain injuries, such as compression of structures, hypoxia, and hemodynamic disturbances, prompt patient care becomes crucial for therapeutic success [9,11].

Subdural hematomas are caused by the rupture of cortical veins crossing the space between the dura mater and arachnoid, accumulating blood in this meningeal space [9]. In its acute phase, these bleedings typically appear on CT as a hyperdense collection with a concavo-convex lens-like shape [10]. Epidural hematomas (also called extradural) result from the rupture of meningeal arterial branches or venous sinuses located between the inner surface of the cranial vault and the endosteal layer of the dura mater, accumulating blood in this space. On CT, the epidural hematoma presents as a hyperdense collection in the shape of a biconvex lens, capable of compressing the cerebral cortex [10]. SAH occurs due to laceration of arteries or cortical veins traversing this space or resulting from hemorrhages from cortical contusions. They can be observed on CT as hyperdense content filling the cisterns and brain sulci. Intraparenchymal hematomas, on the other hand, are bleedings within the brain parenchyma, seen on CT as intra-axial hyperdense collections, occurring more frequently in the frontal and temporal lobes [9].

Understanding the existing mechanisms and patterns of brain hemorrhages makes it easier to comprehend clinical manifestations, which can occur acutely or chronically. Acute symptoms, depending on the type of hematoma, include severe headaches, decreased level of consciousness, focal neurological deficits, vomiting, Cushing's triad, and other visceral and motor changes resulting from the compression of brain structures such as the brainstem and cerebellum. Chronic symptoms include amnesia, psychological changes, sleep disturbances, decreased intellectual function, and seizures [12,13].

With the goal of assessing the functional capacity of post-TBI patients, considering the morbidity and mortality resulting from this type of accident, the Glasgow Outcome Scale (GOS) is an important tool for understanding the consequences and outcomes of trauma, both at the time of hospital discharge and subsequently [3]. The interpretation of GOS is based on scores from 1 to 5, with 5 corresponding to mild disability/good recovery, 4 suggesting moderate disability, 3 related to severe disability, 2 to a vegetative state, and 1 to the outcome of death, as illustrated in table 1 [14,15].

Table 1: Glasgow Outcome Scale

Score	GOS	Description
1	Death	-
2	Vegetative State	Absence of function in the cerebral cortex. Unresponsive/speechless for weeks or months.
3	Severe Disability	Dependent for daily support by reason of mental or physical disability. Conscious but disabled.
4	Moderate Disability	Pacient independent in daily life. Disabled but independent.
5	Mild Disability/ Good Recovery	Resumption of normal life ± minor neurological/psychological deficits

Therefore, the aim is to assess the characteristics observed in CT scans of intracranial hemorrhages resulting from TBI, as well as factors related to the mechanism of trauma and hospitalization of these patients, with the goal of correlating this data with the Glasgow Outcome Scale (GOS) at the time of hospital discharge. Thus, this study seeks to understand the variables involved in these injuries to provide data that may help predict the patient's prognosis.

Objectives

Establish a relationship between the profile of intracranial hemorrhage resulting from TBI and the outcome presented in the GOS.

Secondary Objectives

Establish a connection with other factors that potentially interfere with the outcome obtained through GOS, such as patient age, comorbidities, mechanism of trauma, and Glasgow Coma Scale at admission.

Methodology

A Cohort Study was conducted over a one-year period (August 2021 – March 2022) using data from the medical records of TBI patients treated at the Emergency Department of Cajuru University Hospital. The project was approved by the ethical committee under the number 4,805,973. A total of 313 TBI patients were admitted, including individuals of both genders, aged 18 and above, with intracranial hemorrhage resulting from TBI as observed in the admission CT. Patients with only subgaleal hematoma were excluded, resulting in a total of 193 patients for analysis.

From the medical records of these selected patients, the following variables were collected: gender, age, comorbidities (hypertension, drug/alcohol consumption, epilepsy, smoking, diabetes, cardiovascular disorders), mechanism of trauma (motor vehicle accident, pedestrian accident, same-level fall, fall from one level to another, assault, firearm injury, bicycle fall, object

falling on the head, motorcycle accident, and others), and Glasgow Coma Scale at the scene. From the admission CT, the following data were collected: type of hemorrhage (including the presence of more than one concurrent type), extension, location, number of lesions (frontal lobe, Parietal lobe, temporal lobe, occipital lobe, inter-hemispheric, tentorial region, other regions), and the presence of cranial fracture.

The extent of hemorrhages was evaluated according to their pattern. Epidural hematomas were classified as laminar when the thickness was less than 0.5 cm and non-laminar when it was greater than 0.5 cm. Subdural hematomas were divided into laminar (thickness < 0.5 cm), non-laminar with a volume less than 30 cm^3 in supratentorial areas or less than 16 cm^3 in infratentorial areas, and non-laminar with a volume greater than 30 cm^3 in supratentorial areas or greater than 16 cm^3 in infratentorial areas. Intraparenchymal hematomas were separated into those with a volume less than 30 cm^3 in supratentorial areas or less than 16 cm^3 in infratentorial areas and those with a volume greater than 30 cm^3 in supratentorial areas or greater than 16 cm^3 in infratentorial areas. Finally, subarachnoid hemorrhages were only assessed for their presence or absence, without considering their extension.

TBI severity was assessed according to the Glasgow Coma Scale at scene, classified as mild with scores from 13 to 15, moderate with scores from 9 to 12, and severe with scores from 3 to 8. The association of each admission characteristic with 4 of the 5 GOS classifications was evaluated: death; severe disability; moderate disability; and mild disability/good recovery. The "vegetative state" classification was not included in the analysis due to having only one case in the sample.

Quantitative variable results are described by mean, standard deviation, median, minimum value, and maximum value, while qualitative variables are described by frequency and percentage. Age, being a continuous variable with a normal distribution, was compared among the 4 groups established by GOS using one-way analysis of variance (ANOVA), and Glasgow at scene, being of discrete nature, was compared among the same 4 groups using the non-parametric Kruskal-Wallis test, with subsequent pairwise comparisons by Dunn's post hoc test.

The Chi-square test was used to compare the proportion of each of the four GOS categories between groups established by each categorical variable evaluated at admission. For analyses that showed statistical significance in the Chi-square test ($p < 0.05$), residuals were analyzed, considering an association between variables in cells with adjusted standardized residuals greater than 1.96.

A significance level of $p < 0.05$ indicated statistical relevance. Data were organized in an Excel® spreadsheet and analyzed using the IBM SPSS Statistics v.28.0 software. Armonk, NY: IBM Corp.

Results

This study included 193 patients for statistical analysis, with a mean age of 49±20 years, predominantly male (78.8%). Regarding comorbidities in this group, 16.1% had diabetes mellitus, 19.2% were hypertensive, and 4.7% were smokers.

The mechanisms of trauma involved in the TBI of the selected patients were: same-level fall (n=56), fall from one level to another (n=33), assault (n=25), motorcycle accident (n=24), pedestrian accident (n=17), bicycle accident/fall (n=14), motor vehicle accident (n=11), firearm injury (n=6), object falling on the head (n=5), others (n=2).

Based on the Glasgow Coma Scale obtained at the scene of the accident, TBI severity was graded, with 66.3% of traumas considered mild, 13.5% moderate, and 20.2% severe. The type of intracranial hemorrhage presented in the admission cranial CT at the hospital emergency was also evaluated, with subarachnoid hemorrhage being the predominant type (60.6%), followed by subdural hemorrhage (49.7%), intraparenchymal hemorrhage (23.8%), and epidural hemorrhage (11.9%).

Considering the brain regions affected by hemorrhage in each patient, there was a notable involvement of the frontal region in 60.5%. The parietal and temporal regions were affected in 51.6% of patients. The occipital region was affected in 15.3% of cases, the tentorial region in 8.4%, and the inter-hemispheric region in 5.3%. Other locations were affected in 7.9% of patients. Associated with hemorrhages, 92 patients had cranial fractures.

Assessing the extent of hemorrhages, 73.9% of epidural hemorrhages were classified as non-laminar. Of intraparenchymal hemorrhages, 86% had a volume < 30cm^3 (supratentorial) and < 16cm^3 (infratentorial), while 14% had measures higher than these. In subdural hemorrhages, 64.3% were classified as non-laminar, with 42.9% having a volume < 30cm^3 (supratentorial) and < 16cm^3 (infratentorial).

Regarding patient outcomes, classified according to the GOS, the majority of patients had mild disability/good recovery (74.1%), followed by cases of death (14%), moderate disability (6.2%), severe disability (5.2%), and vegetative state (0.5%). For statistical analysis, the classification of the vegetative state, observed in only 1 patient in the sample, was not considered.

For the remaining 192 patients, the association of each admission characteristic with 4 of the 5 GOS classifications was evaluated (excluding the vegetative state).

Table 2: Comparison between Age and the Groups Established by GOS

Glasgow Outcome Scale (GOS)	n	Age Mean ± SD (min - max)	p
Death	27	56 ± 20,7 (18 - 86)	0,195*
Severe disability	10	46 ± 17,8 (24 - 71)	
Moderate disability	12	49,6 ± 21,4 (18 - 79)	
Mild disability / Good recovery	143	47,3 ± 19,1 (18 - 89)	

Abreviations: SD: standard deviation; min: minimum; max: maximum.
* Relevance by Analysis of Variance (ANOVA) p<0,05

The results presented in Table 2 did not show a statistically significant difference in mean ages between the groups.

Table 3: Comparison between the groups established by GOS and the Glasgow Coma Scale at the scene

Glasgow Outcome Scale (GOS)	n	Glasgow at the scene Mean; Med. (min - max)	p* value	p value**
Death	27	7,4; 7 (3 - 15)		Death vs. Severe Disability: 1,0
Severe Disability	10	6,6; 5 (3 - 14)		Death vs. Moderate Disability: 0,549
Moderate Disability	12	11,6; 13 (6 - 15)		Death vs. Mild Disability: <0,001
			<0,001	Severe Disability vs. Moderate Disability: 0,487
Mild Disability / Good Recovery	143	13,3; 14 (3 - 15)		Severe Disability vs. Mild Disability: <0,001
				Moderate Disability vs. Mild Disability: 0,072

Abreviations: med: median; min: minimum; max: maximum
* Relevance by Analysis of Variance (ANOVA) p<0,05
** Relevance of pairwise comparison of the groups by the post hoc of Dunn test, p<0,05

The results presented in Table 3 demonstrate a globally significant difference between the groups regarding the Glasgow Coma Scale (GCS) value at the scene (p<0.001). Patients who had a mild disability/good recovery outcome had a significantly higher GCS at the scene compared to those who developed severe disability (p<0.001) or died (p<0.001). The other pairwise comparisons did not show a significant difference.

The proportion of each of the 4 GOS classifications was also compared between groups established by each variable evaluated at admission. Excluding the vegetative state case (n=192), there is a significant direct association between mild TBI (GCS: 13-15) and mild disability (residual: 6.6) and severe TBI (GCS: 3-8) with severe disability and death (residuals: 4.0 and 5.9, respectively). The outcome of death was associated with the presence of cranial fracture (p=0.022 and residual: 2.6), temporal lobe injury (p=0.014 and residual: 2.5), tentorial subarachnoid hemorrhage (HSA) (p=0.012 and residual: 2.8), and lesions in other locations (p=0.022 and residual: 3.0). There was a significant association between having one lesion and mild disability (residual: 4.1), 2 lesions and moderate disability (residual: 2.4), 3 lesions and severe disability (residual: 2.9) and 4 or more lesions with death (residual: 4.5). There was no significant association between GOS and the other variables.

Discussion

Traumatic brain injury (TBI) represents the leading cause of death and sequelae in children and young adults in Western industrialized countries [5]. In Brazil, according to DATASUS, between 2010 and 2019, there were 1,045,070 hospitalizations for TBI, with 76.23% corresponding to males and mostly in the age group up to 40 years [18]. These data are similar to the present study, which resulted in a sample of 78.8% of men hospitalized for traumatic brain injury, with a mean age of 49 ± 20 years.

The definitive brain injury resulting from trauma is the outcome of pathophysiological mechanisms that occur from the event to days or weeks afterward. For the evaluation of the post-recovery status of the patient, the Glasgow Outcome Scale (GOS) can be used, allowing the objectification of the consequences of trauma for a specific case.

In this study, a significant association was found between the GOS outcome and the number of affected brain regions, as well as between the GOS and the severity of TBI. It can be concluded that the more brain regions affected by hemorrhage and the greater the severity of TBI, the worse the patient's outcome, indicating a greater need for care. In a study conducted by Oliveira et al. at the Hospital das Clínicas UNICAMP, a comparison was made between the GOS at the time of hospital discharge and GOS in a second evaluation of the patient later on, resulting in a significant statistical association between these data, with p=0.0274 [4]. Therefore, the sample in this study is likely to remain with the same GOS classification, emphasizing the importance of patients showing some degree of recovery while still in the hospital setting, as their status at discharge is associated with their prognosis in the long term.

Another factor associated with a worse prognosis and death in the analysis was the presence of cranial fractures (p=0.022). Thus, it is concluded that a greater number of brain regions affected, greater severity of TBI, and the presence of cranial fractures are related not only to a worse immediate outcome but also to a long-term prognosis, with poorer GOS classifications on these occasions.

Limitations

This is a retrospective cohort study based on medical record analysis. Therefore, given its observational nature, there was limited control over exposure factors. The retrospective analysis of patients prevented the standardization of data recorded in medical records, as could have been stipulated beforehand in a prospective cohort, constituting a potential limitation. In addition, a series of professionals not involved in the study participated in the specific care of patients, so the collection of variables and outcomes recorded in the online medical records, in a non-standardized manner, may have been affected by the subjectivity of the assessors, potentially introducing confounding factors and selection biases.

Conclusion

Traumatic brain injuries (TBIs) continue to be one of the leading causes of death and sequelae worldwide, representing a serious global public health problem [4]. The extent of the sequelae can be more objectively assessed by the Glasgow Outcome Scale (GOS), indicating the degree of disability in patients after trauma.

Through data collection and statistical analysis, it was found that the greater severity of TBI, a higher number of cranial lesions, and the presence of cranial fractures are associated with a worse outcome for patients. This association suggests that classifications

of severe disability in the GOS are more related to the trauma itself than to in-hospital care, emphasizing the need for greater efforts in the prevention of these traumatic events.

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