Predictors of Outcome of Decompressive Craniectomy Following Traumatic Brain Injury

Ibrahim Najm Abed[a], Walid Hemdan [b], Abdelrahman Ahmed Momtaz [c] , Abdallah Wael Kamar [c], Ahmad Wadhah Yahya[D]
[a] M.B.Ch. B, FIRM, Neuro Surgery, Doctorate of Board in Neurosurgery.
[b] Researcher in Neurosurgery.
[c] Researcher & General Practitioner in Neurosurgery.
[D] MRCS, medical content creator.
Corresponding author: Ahmad Wadhah Yahya
Email: dr.ayahya@yahoo.com

Abstract

Background: For those less than 45 years old, traumatic brain injury (TBI) ranks first when it comes to causing death and disability. poses a significant threat to public health and places a heavy financial strain on people and countries alike. This research set out to identify factors that might have an impact on the prognosis and longevity of patients undergoing decompressive craniectomy (DC) after a TBI.
Methods: This retrospective study was performed after collection of the medical records of 113 patients from which data on demographics, clinical presentations, comorbidities, vital signs, initial neurological status, time of operation, results from radiologic testing, and outcomes were retrieved and examined retrospectively. We gathered all of the patients' medical and radiological records who had DC for TBI.
Results: Significantly fewer hospital and intensive care unit (ICU) stays were seen in the group with a positive outcome compared to the group with a negative outcome (P0.001, 0.001). Glasgow coma scale (GCS) values were considerably higher in the positive group both upon admission and following rest (P<0.001, <0.001). Finally, the ISS scores of the two groups were significantly different; the group that experienced a positive outcome had lower values (P=0.002).
Conclusions: DC in patients with TBI is associated with favourable outcome in most of them. Age, heart rate, hemoglobin, platelet, albumin, sodium, high prothrombin time, intraoperative blood loss, GCS on admission and ISS are significant predictors of the outcome in TBI patients undergoing DC.
Keywords: Predictors; Outcome; Decompressive Craniectomy; Traumatic Brain Injury.

Introduction:

Death and disease among those less than 45 years old are most commonly caused by traumatic brain injuries (TBIs). Injuries to the brain affect about 60 million individuals globally and cost the healthcare system around $76.5 billion in the United States alone. TBIs are therefore a serious public health concern that places a significant financial cost on both people and nations [1].

The long-term disabilities that TBI induces are mostly imperceptible, which is why it is frequently referred to as a "hidden epidemic." Permanent impairments that impact their capacity to learn, work, and care for their families may be an outcome of severe brain injuries. Prolonged periods of debilitation and the loss of productive years can result from these impairments. Additionally, people, their families, and society as a whole endure a significant financial burden through TBI. Through enhanced prevention initiatives, the burden of disability could be significantly diminished, and numerous lives could be saved [2].

A higher risk of death and morbidity is associated with elevated intracranial pressure (ICP) in traumatic brain injury (TBI) patients. Decompressive craniectomy (DC) is an option for patients whose intracranial pressure is uncontrolled should be considered, despite the implementation of aggressive medical management [3].

Described in the early 1900s, DC was used to treat intracranial hypertension and prevent brain herniation. Subsequently, it became often utilized as a potentially life-saving procedure for cases involving severe traumatic brain injury. Nevertheless, it is still unclear whether DC improves outcomes following TBI [4].

However, the results are conflicting and have sparked a significant debate, despite the fact that the available studies in the literature are numerous and varied. Conversely, the ICP is expected to return to its pre-traumatic level within four weeks. Consequently, decompressive craniectomy, which reduces the ICP, may alter the pathogenesis and reduce the mortality rate during the initial four weeks of trauma [5].

In accordance with the schedule and rationale for the procedure, DC can be classified as primary or secondary. Primary DC is implemented during the surgical decompression of mass lesions, including hematomas, to mitigate postoperatively elevated ICP. The persistent refractory ICP is treated through secondary DC [6].

Early bifrontal DC dramatically decreased mean intracranial pressure (ICP) in traumatic brain injury (TBI) patients, according to the DECRA experiment. At six months, though, there had been no discernible improvement in the clinical prognosis [7].

The purpose of this study was to evaluate the predictors of clinical outcome and survival of DC following TBI patients.

Patients and Methods

This retrospective study was performed at a tertiary care university hospital in the Republic of Korea. We gathered all of the medical and radiological records of patients who had DC for TBI. from January 2019 to December 2022. We looked back through the medical records of 113 TBI patients to find out things like their demographics, clinical presentation, comorbidities, vital signs, neurological status at the beginning of the process, time of operation, results from radiologic, and any other relevant information.

Patients or their legal guardians gave their written, informed consent. The study was done after approval from the Ethical Committee of Benha University Hospitals .

The inclusion criteria being at least 18 years old, having a head injury severity index (AIS) of 3 or higher, another area of the body with an AIS of 2 or higher, an ISS of 15 or higher upon arrival, suffering from a traumatic brain injury with less than a 24-hour delay between injury and hospital admission, and so on.

For DC to be performed at our institution, the following were the requirements: conditions that occupy space on one side of the body, such as a confirmed contusion, subdural or epidural hemorrhage, or MLS; moderate to severe traumatic brain injury (TBI) (Glasgow Coma Scale [GCS] score 3-12); and persistent intracranial pressure (ICP) that has not responded to standard treatment.

Bilateral decompressive hemi-rhinectomy, suboccipital craniectomy, and bifrontal craniectomy were procedures that were not included in this study. Complex comminuted depressed skull fractures were treated with DC. A postoperative CT scan was not possible because patients experienced a contralateral side hematoma following surgery.

The data that was extracted from the electronic health records at Tongji Hospital includes the following: age, gender, injury type, length of time since injury until admission, vital signs (blood pressure, heart rate, pupil size, pupillary reflex), admission GCS score, ISS score, head AIS score, injury position, tracheal intubation or tracheotomy implemented, and hospital complications.

It took one month after patients were discharged from the hospital to evaluate them and track their GOSE scores [8]. In order to diagnose traumatic brain injury (TBI), patients were hospitalized with cranial computed tomography (CT). Using CT scans, we looked for signs of acute brain lesions including cerebral hemorrhage, subarachnoid hemorrhage (SAH), subdural hematoma (SDH), epidural hematoma (EDH), and skull fracture.

The widely accepted head abbreviation injury score (AIS) uses classifications for nine distinct regions: the head and face, neck and torso, belly, spine, upper and lower limbs, entire body, and other. Mild AIS was rated as 1 point, moderate as 2 points, severe as 4 points, not life-threatening as 3 points, severe as 4 points, critical as 5 points, and deadly as 6 points along a scale from 1 to 6. [9]. Hence, an AIS score of 3 or above was considered a moderate traumatic brain injury. The intensity of the maximum AIS in a maximum of three different anatomical regions was used to calculate the ISS score. An ISS value of 15 or higher was used to define severe multiple traumata because it has the ability to predict a 10% mortality rate in trauma patients.

The Global Comorbidity Scale (GCS) classified symptoms as mild (13–15 points), moderate (9–12 points), or severe (3–8 points) [10]. Success or failure was defined by a positive GOSE score (ranging from full recovery to moderate disability; GOSE 5-8) or a negative GOSE score (ranging from full disability to death; GOSE 1-4) [8]. The protocols established by the Brain Trauma Foundation were followed in the treatment of patients [11]. The frontotemporoparietal area was the site of a question mark-shaped cutaneous incision that was closed around 1 cm in front of the tragus. An extensive bony incision was made by elevating a piece of bone in the area of the frontotemporoparietal joint.

By exposing the base of the temporal fossa to an adequate degree, decompression of the brainstem and temporal lobe was accomplished. After the hematoma was evacuated, extensive duraplasty was performed utilizing artificial dura mater. Two seasoned neurosurgeons carried out each procedure. Hypothermia, analgesia, osmotherapy with hypertonic saline or mannitol, mechanical ventilation, head elevation to 30°, and anesthesia were the postoperative medical interventions for intracranial pressure management. As a sedative, barbiturates were given to patients whose cerebral edema refused to go away after DC.

Clinical outcome:

The initial GCS score was assessed. The GOSE score was employed to evaluate the long-term outcomes at six months postoperatively. The patients were categorized into two groups: the adverse group (1–4 score) and the favorable group (5–8 score).

Statistical analysis

Used SPSS v26, which is developed by IBM and located in Armonk, NY, USA, for my statistical analysis. Quantitative variables were compared between the two treatment groups using an unpaired Student's t-test. These variables were presented as means and standard deviations (SD). The paired sample t-test is a statistical tool for comparing the means of two populations when there are two correlated samples. Analysis was performed using Fisher's exact test or Chi-square test, if applicable, and the frequency and percentage (%) of qualitative variables were shown thereafter. At least one tailed P value less than 0.05 was deemed statistically significant. You can use multivariate logistic regression to have a solid picture of how one variable influence another.

Results

Among the studied patients, 82 showed favourable outcome and 31 patients showed unfavourable outcome. The age and HR were significantly lower in the favourable outcome group compared to the unfavourable outcome group (P<0.001, <0.001). The eye pupil was significantly different between both groups (P<0.001), There was an insignificant difference between both groups regarding sex, SBP and DBP. **Table 1**

Table 1: Patient characteristics and vital signs of the groups

		Total (N=113)	Favorable outcome (n=82)	Unfavorable outcome (n=31)	P value
Age (years)		45.97± 8.6	41.87± 4.5	56.83± 7.42	**<0.001***
Sex	Male	83(73.45%)	58(70.73%)	25(80.65%)	0.287
	Female	30(26.55%)	24(29.27%)	6(19.35%)	
Pupil	Dilated pupils	56 (49.56%)	51 (62.2%)	5 (16.13%)	**<0.001***
	Constricted pupils	57 (50.44%)	31 (37.8%)	26 (83.87%)	
HR (beats / min)		84.15± 10.99	81.17± 7.1	92.03± 15.05	**<0.001***
SBP (mmHg)		129.78± 11.88	130.11± 11.63	128.9± 12.67	0.632
DBP (mmHg)		74.81± 8.42	74.02± 8.28	76.9± 8.57	0.105

Data are presented as mean ± SD or frequency (%), HR: heart rate, SBP: systolic blood pressure DBP: diastolic blood pressure, *: statistically significant P value <0.05.

Hb concentration, platelet count and albumin were significantly higher in the favourable outcome group compared to the unfavourable outcome group (P<0.05). The sodium level and high PT were significantly lower in the favourable outcome group compared to unfavourable outcome group (P<0.001, <0.001). There was an insignificant difference between both groups regarding the WBCS, urea, creatinine, potassium and INR. **Table 2**

Table 2: Laboratory data of the studied groups

	Total (N=113)	Favorable outcome (n=82)	Unfavorable outcome (n=31)	P value
Hb (gm/dL)	11.82± 1.04	12.19± 0.81	10.83± 0.93	**<0.001***
Platelets (*10^9/L)	174.37± 50.45	204.24± 13.91	95.35± 9.35	**<0.001***
WBCS (*10^9/L)	13.56± 1.48	13.65± 1.44	13.35± 1.59	0.351
Albumin (g/dL)	3.93± 0.59	4.17± 0.45	3.31± 0.44	**<0.001***
Urea (mg/dL)	34.98± 8.63	34.21± 8.32	37.03± 9.25	0.121
Creatinine (mg/dL)	1.06± 0.18	1.06± 0.18	1.07± 0.18	0.711
K (mEq/L)	4.55± 0.6	4.52± 0.63	4.65± 0.52	0.276
Na (mEq/L)	139.76± 5.35	137.27± 1.66	146.35± 6.13	**<0.001***
INR	1.09± 0.13	1.09± 0.13	1.08± 0.14	0.560
High PT	18 (15.93%)	7 (8.54%)	11 (35.48%)	**<0.001***

Data are presented as mean ± SD or frequency (%). Hb: hemoglobin, WBCS: white blood cells, K: potassium, Na: sodium, INR: international normalized ratio, PT: Prothrombin time, *: statistically significant P value <0.05.

There was an insignificant difference between both groups regarding the interval time between injury and operation, DC type and operation time. The intraoperative blood loss was significantly lower in the favourable outcome group compared to unfavourable outcome group (P<0.001). **Table 3**

Table 3: Clinical and operative data of the studied groups

		Total (N=113)	Favorable outcome (n=82)	Unfavorable outcome (n=31)	P value
Interval time between injury and operation (hrs.)		9.85± 3.22	9.93± 3.27	9.65± 3.13	0.680
DC type	**Unilateral**	32 (28.32%)	24(29.27%)	8(25.81%)	0.526
	Bifrontal	53 (46.9%)	40(48.78%)	13(41.94%)	
	Bilateral	28 (24.78%)	18(21.95%)	10(32.26%)	
Operation time (min)		206.73± 89.99	207.38± 82.94	205.03± 107.96	0.902
Intraoperative blood loss (ml)		1034.75± 174.9	982.61± 143.98	1172.68± 176.47	**<0.001***

Data are presented as mean ± SD or frequency (%). DC: Decompressive craniectomy, *: statistically significant P value <0.05.

The hospital length of stay and ICU length of stay were significantly shorter in the favourable outcome group compared to unfavourable outcome group (P<0.001, <0.001). The patients with favourable outcome showed significant improvement in GCS after rest compared to GCS on admission (P<0.001), whereas in patients with unfavourable outcome GCS was insignificantly different compared to GCS on admission. The GCS on admission and after rest was significantly higher in the favourable outcome group compared to the unfavourable outcome group (P<0.001, <0.001). The ISS score was significantly lower in the favourable outcome group compared to unfavourable outcome group (P=0.002). **Table 4**

Table 4: Hospital length of stay and clinical scores of the studied groups

		Total (N=113)	Favorable outcome(n=82)	Unfavorable outcome (n=31)	P value
Hospital length of stay		16.09± 7.45	14.06± 7.29	21.45± 4.75	**<0.001***
ICU length of stay		10.52± 4.78	7.99± 2.56	17.23± 1.96	**<0.001***
GCS	**On admission**	8.42± 2.19	9.32± 1.73	6.03± 1.3	**<0.001***
	After rest	8.77± 2.49	9.88± 1.76	5.84± 1.61	**<0.001***
	P value		**<0.001***	0.351	
ISS score		27.39± 4.72	26.55± 4.06	29.61± 5.63	**0.002***

Data are presented as frequency (%), ICU: intensive care unit. GCS: Glasgow Coma Scale, ISS: Injury Severity Score, *: statistically significant P value <0.05.

The incidence of complications were significantly lower in the favourable outcome group compared to unfavourable outcome group (P<0.001). **Table 5**

Table 5: Complications of the studied groups

		Total (N=113)	Favorable outcome (n=82)	Unfavorable outcome (n=31)	P value
Complications	**Meningitis**	21(18.58%)	3(3.66%)	10(32.26%)	**<0.001***
	Subdural hygroma	4(3.54%)	2(2.44%)	2(6.45%)	
	Hydrocephalus	4(3.54%)	1(1.22%)	3(9.68%)	
	Reoperation	7(6.19%)	0(0%)	4(12.9%)	

Data are presented as mean ± SD or frequency (%), *: statistically significant P value <0.05.

The multivariate logistic regression showed that age, HR, HB, platelet, albumin, Na, high PT, intraoperative blood loss, GCS on admission and ISS score were the significant predictors of the outcome. **Table 6**

Table 6: Multivariate logistic regression analysis for prediction of the outcome

	OR	95 % CI	P value
Age (years)	0.5655	0.4202 to 0.7611	**<0.001***
Sex	10.5752	0.4968 to 225.1166	0.131
Pupil	0.5457	0.0952 to 3.1269	0496
HR (beats / min)	0.9001	0.8555 to 0.9470	**<0.001***
SBP (mmHg)	1.0105	0.9719 to 1.0506	0.600
DBP (mmHg)	0.9451	0.8899 to 1.0038	0.066
Hb (gm/dL)	6.3473	2.9467 to 13.6721	**<0.001***
Platelets (*10^9/L)	1.0718	1.0459 to 1.0983	**<0.001***
WBCS (*10^9/L)	2.0067	0.6658 to 6.0474	0.216
Albumin (g/dL)	275.5612	22.1098 to 3434.39	**<0.001***
Urea (mg/dL)	0.9726	0.8451 to 1.1193	0.698
Creatinine (mg/dL)	0.6488	0.0673 to 6.2548	0.708
K (mEq/L)	0.0179	0.0003 to 1.2003	0.061
Na (mEq/L)	0.1408	0.0243 to 0.8146	**0.029***
INR	2.5693	0.1111 to 59.4421	0.556
High PT	5.8929	2.0247 to 17.1513	**0.011***
Interval time between injury and operation (hrs.)	1.0704	0.9180 to 1.2482	0.385
DC type	0.7339	0.3748 to 1.4368	0.367
Operation time (min)	0.9992	0.9936 to 1.0047	0.770
Intraoperative blood loss (ml)	0.9921	0.9887 to 0.9956	**<0.001***
GCS On admission	6.0770	2.6253 to 14.0669	**<0.001***
ISS score	0.8651	0.7505 to 0.9971	**0.045***

HR: heart rate, SBP: systolic blood pressure DBP: diastolic blood pressure, Hb: hemoglobin, WBCS: white blood cells, K: potassium, Na: sodium, INR: international normalized ratio, PT: Prothrombin time, DC: Decompressive craniectomy, *: statistically significant P value <0.05.

Discussion

For patients with intractable intracranial hypertension, DC has been widely used as a treatment option due to MCA infarction or TBI. When compared to other medical treatments, DC has not demonstrated any benefits in people with severe TBI, despite numerous randomized controlled trials demonstrating its usefulness in myocardial infarction (MCA) [12].

Primary DC is a possibility for patients with high-density lesions of significant volume, who may suffer from cerebral edema and clinical exacerbation. In addition, patient outcomes may be enhanced by a shorter interval between surgery and TBI, a younger age, and a higher GCS score [13].

We compared pre- and post-operative CT images with 6-month results for 113 patients who underwent primary DC for moderate to severe TBI.

With respect to age and HR, the two groups were significantly different, with the good outcome group exhibiting lower values (P<0.001, <0.001). Students' performance differed significantly (P0.001) between the two sets. When looking at the groups with favorable and unfavorable outcomes, there was a significant decrease in intraoperative blood loss (P<0.001). In the present investigation, the multivariate logistic regression revealed that the outcome was significantly predicted by age, HR, HB, platelet, albumin, Na, elevated PT, intraoperative blood loss, GCS on admission, and ISS score.

In a previous study, Moein et al., [14] according to the report, 60% of patients who underwent DC experienced a favorable outcome, while the mortality rate was 10%. Tommasino and Grille [15] Characteristics like age, GCS, and craniectomy type were found to have little impact on the result in their series of 64 TBI patients who underwent DC. The result was significantly worsened by post-decompression intracranial hypertension.

Recently Kapapa et al., [16] Results from a number of disorders were reported utilizing DC. After the final pathophysiological phase of resistant intracranial hypertension, hypoxia, compression of the basal cisterns, and/or midline shift has passed, their research demonstrates that the prognosis following DC is not significantly different between illnesses.

Hukkelhoven et al., [17] we also determined that older patients with traumatic brain injuries had a worse prognosis. They found that the longer one lives after a traumatic brain injury, the more likely it is that their condition will worsen. Dhandapani et al., [18] It was also shown that in cases of severe traumatic brain injury, age is a significant predictor of prognosis. This could be because most of the TBI patients in our series are young men, and there isn't a lot of significant variation or range in their ages or genders.

Consequently, because of the small variation, age would not be a good predictor of the result. Other series, similar to the ones mentioned earlier, included a diverse group of TBI patients spanning a broad age range. Notwithstanding, our results are consistent with those of a few other studies. [19].

Pompucci et al. [20] found that patients above the age of 65 had unsatisfactory results. In addition, Huang et al. [21] found that after DC, older patients had a higher chance of dying in the short term. Tang et al. [22] Age is a known predictor of mortality within 30 days. In this study, as in others before it, age and initial GCS scores were found to be significant predictors of outcome.

The levels of hemoglobin, platelets, and albumin were considerably greater in the positive outcome group than in the bad outcome group ($P<0.05$). In comparison to the unfavorable outcome group, the favorable outcome group had a significantly lower salt level and higher PT ($P<0.001$, <0.001).

In an earlier study, a multivariate logistic regression model found that platelet count to be the only significant blood parameter. Acute coagulopathy of trauma (ACT) occurs as a result of tissue injury and tissue perfusion. When the INR is high, the APTT is long, or the platelet count is low, it is known as coagulopathy. Traumatic brain injury (TBI) patients had worse results when their platelet count was low, their platelet distribution width (PDW) was high, and their platelets were dysfunctional. Reducing platelet dysfunction and improving survival rates after multiple traumas, fresh frozen plasma (FFP) resuscitation was administered to animals [23].

Furthermore, ACT's importance in TBI patients is being more and more recognized. INR and APTT were found to independently correlate with the in-hospital mortality of a significant number of TBI patients. Additionally, it was found that trauma patients with a high PT were more likely to die from their injuries. The results of this study do not support the idea that PT and INR are independent variables. A poor prognosis was linked to hypernatremia and hyperglycemia following severe traumatic brain injury [24].

The main point is that when we're under stress, our sympathetic nervous system and hypothalamic-pituitary-adrenal axis get activated, which leads to higher levels of neurohormones and insulin resistance. There has been prior research into the efficacy of intensive insulin therapy in alleviating cerebral metabolic distress. Still, trying to avoid hypoglycemia by controlling blood sugar levels too strictly was not a good idea. Hyperglycemia, elevated BUN, or high Na+ concentration were not identified as independent outcomes predictors, on the other hand. Additionally, when patients with traumatic brain injuries were anemic, their prognosis was worse [25].

The current study found that the favourable outcome group had a significantly lower incidence of complications than the unfavourable outcome group (P<0.001).

Multiple factors linked to abnormalities in CSF absorption and circulation dynamics can lead to postoperative hydrocephalus and the development of subdural hygromas. This could appear in the first week after DC and worsen until the fourth week; however, most cases would clear up without surgery [26].

Ki et al., [27] and De Bonis et al., [28] shown that subdural hygroma formation and postoperative hydrocephalus are associated with craniotomies that pass the midline. Jeon et al., [29] Subdural hygroma occurred in 19 out of 85 patients who had DC compared to 0 in the control group. Researchers found that subdural hygroma increased the likelihood of problems including midline shifts bigger than 5 mm, subarachnoid hemorrhage, delayed hydrocephalus, compression of the basal cistern, and rupture of the arachnoid membrane.

The scope of this investigation was severely limited. Due to the fact that this was originally a retrospective study, selection bias is possible. Secondly, this study only included a small number of patients, so it might not be a significant representation of the overall population of people with traumatic brain injuries who have multiple severe injuries.

Conclusions:

DC is linked to a positive outcome in the majority of TBI patients. Significant outcome predictors for TBI patients undergoing DC include age, HR, HB, platelets, albumin, Na, high PT, intraoperative blood loss, GCS upon admission, and ISS score.

To strengthen the evidence for predicting patient outcomes, additional randomized studies with large populations and appropriate follow-up times are required.

Financial support and sponsorship: Nil

Conflict of Interest: Nil

References

1. Capizzi A, Woo J, Verduzco-Gutierrez M. Traumatic Brain Injury: An Overview of Epidemiology, Pathophysiology, and Medical Management. Med Clin North Am. 2020;104:213-38.

2. Iderdar Y, Arraji M, Wachami NA, Guennouni M, Boumendil K, Mourajid Y, et al. Predictors of outcomes 3 to 12 months after traumatic brain injury: a systematic review and meta-analysis. Osong Public Health Res Perspect. 2024;15:3-17.

3. Zhang D, Sheng Y, Wang C, Chen W, Shi X. Global traumatic brain injury intracranial pressure: from monitoring to surgical decision. Front Neurol. 2024;15:11-22.

4. Abouhashem S, Albakry A, El-Atawy S, Fawzy F, Elgammal S, Khattab O. Prediction of early mortality after primary decompressive craniectomy in patients with severe traumatic brain injury. Egypt J Neurosurg. 2021;36:11-22.

5. Maas AIR, Menon DK, Manley GT, Abrams M, Åkerlund C, Andelic N, et al. Traumatic brain injury: progress and challenges in prevention, clinical care, and research. Lancet Neurol. 2022;21:1004-60.

6. Vitali M, Marasco S, Romenskaya T, Elia A, Longhitano Y, Zanza C, et al. Decompressive Craniectomy in Severe Traumatic Brain Injury: The Intensivist's Point of View. Diseases. 2023;11:11-22.

7. Sahuquillo J, Dennis JA. Decompressive craniectomy for the treatment of high intracranial pressure in closed traumatic brain injury. Cochrane Database Syst Rev. 2019;12:22-33.

8. Wilson L, Boase K, Nelson LD, Temkin NR, Giacino JT, Markowitz AJ, et al. A manual for the glasgow outcome scale-extended interview. J Neurotrauma. 2021;38:2435-46.

9. Loftis KL, Price J, Gillich PJ. Evolution of the Abbreviated Injury Scale: 1990-2015. Traffic Inj Prev. 2018;19:109-13.

10. Bodien YG, Barra A, Temkin NR, Barber J, Foreman B, Vassar M, et al. Diagnosing Level of Consciousness: The Limits of the Glasgow Coma Scale Total Score. J Neurotrauma. 2021;38:3295-305.

11. Hawryluk GWJ, Rubiano AM, Totten AM, O'Reilly C, Ullman JS, Bratton SL, et al. Guidelines for the Management of Severe Traumatic Brain Injury: 2020 Update of the Decompressive Craniectomy Recommendations. Neurosurgery. 2020;87:427-34.

12. Liu C, Xie J, Xiao X, Li T, Li H, Bai X, et al. Clinical predictors of prognosis in patients with traumatic brain injury combined with extracranial trauma. Int J Med Sci. 2021;18:1639-47.

13. Lenell S, Nyholm L, Lewén A, Enblad P. Clinical outcome and prognostic factors in elderly traumatic brain injury patients receiving neurointensive care. Acta Neurochir (Wien). 2019;161:1243-54.

14. Moein H, Sanati MA, Fard SA, Moein P, Hasheminasab SM. Outcome of decompressive craniectomy in patients with severe head injury: a pilot randomized clinical trial. Neurosurg Q. 2012;22:149-52.

15. Grille P, Tommasino N. Decompressive craniectomy in severe traumatic brain injury: prognostic factors and complications. Rev Bras Ter Intensiva. 2015;27:113-8.

16. Kapapa T, Brand C, Wirtz CR, Woischneck D. Outcome After Decompressive Craniectomy in Different Pathologies. World Neurosurg. 2016;93:389-97.

17. Hukkelhoven CW, Steyerberg EW, Rampen AJ, Farace E, Habbema JD, Marshall LF, et al. Patient age and outcome following severe traumatic brain injury: an analysis of 5600 patients. J Neurosurg. 2003;99:666-73.

18. Dhandapani S, Manju D, Sharma B, Mahapatra A. Prognostic significance of age in traumatic brain injury. J Neurosci Rural Pract. 2012;3:131-5.

19. Khalili H, Niakan A, Ghaffarpasand F, Kiani A, Behjat R. Outcome Determinants of Decompressive Craniectomy in Patients with Traumatic Brain Injury; A Single Center Experience from Southern Iran. Bull Emerg Trauma. 2017;5:190-6.

20. Pompucci A, De Bonis P, Pettorini B, Petrella G, Di Chirico A, Anile C. Decompressive craniectomy for traumatic brain injury: patient age and outcome. J Neurotrauma. 2007;24:1182-8.

21. Huang YH, Lee TC, Lee TH, Liao CC, Sheehan J, Kwan AL. Thirty-day mortality in traumatically brain-injured patients undergoing decompressive craniectomy. J Neurosurg. 2013;118:1329-35.

22. Tang Z, Yang K, Zhong M, Yang R, Zhang J, Jiang Q, et al. Predictors of 30-Day Mortality in Traumatic Brain-Injured Patients after Primary Decompressive Craniectomy. World Neurosurg. 2020;134:298-305.

23. Furay E, Daley M, Teixeira PG, Coopwood TB, Aydelotte JD, Malesa N, et al. Goal-directed platelet transfusions correct platelet dysfunction and may improve survival in patients with severe traumatic brain injury. J Trauma Acute Care Surg. 2018;85:881-7.

24. Svedung Wettervik T, Howells T, Ronne-Engström E, Hillered L, Lewén A, Enblad P, et al. High Arterial Glucose is Associated with Poor Pressure Autoregulation, High Cerebral Lactate/Pyruvate Ratio and Poor Outcome Following Traumatic Brain Injury. Neurocrit Care. 2019;31:526-33.

25. de Oliveira DV, Amorim RL, de Cássia Almeida Vieira R, Paiva WS. Traumatic brain injury and hyperglycemia. Oncotarget. 2017;8:11-22.

26. Papaioannou V, Czosnyka Z, Czosnyka M. Hydrocephalus and the neuro-intensivist: CSF hydrodynamics at the bedside. Intensive Care Med Exp. 2022;10:20-33.

27. Ki HJ, Lee HJ, Lee HJ, Yi JS, Yang JH, Lee IW. The Risk Factors for Hydrocephalus and Subdural Hygroma after Decompressive Craniectomy in Head Injured Patients. J Korean Neurosurg Soc. 2015;58:254-61.

28. De Bonis P, Pompucci A, Mangiola A, Rigante L, Anile C. Post-traumatic hydrocephalus after decompressive craniectomy: an underestimated risk factor. J Neurotrauma. 2010;27:1965-70.

29. Jeon SW, Choi JH, Jang TW, Moon SM, Hwang HS, Jeong JH. Risk factors associated with subdural hygroma after decompressive craniectomy in patients with traumatic brain injury : a comparative study. J Korean Neurosurg Soc. 2011;49:355-8.