Journal of Advanced Zoology

*ISSN: 0253-7214*

*Volume **44** Issue **S-1 Year 2023** Page **562:569***

# Incidence and Considerations of Decompressive Craniectomy in Traumatic Brain Injury: An Updated Analysis

**Piedad Elizabeth Acurio Padilla[1], Jamilex Veronica Aucapiña Garnica[2], Angie Karina Naranjo Borja[3]**

[1,2,3,4]*Universidad Regional Autónoma de Los Andes Ambato. Ecuador.*

*Email: ua.piedadacurio@uniandes.edu.ec[1], ma.jamilexvag58@uniandes.edu.ec[2], ma.angieknb27@uniandes.edu.ec*

*ORCID ID: 0000-0003-2274-5444[1], 0009-0007-4629-7005[2], 0009-0006-7428-7632[3]*

**Corresponding author's E-mail: ua.piedadacurio@uniandes.edu.ec*

***Article History***

Received: 06 June 2023
Revised: 05 Sept 2023
Accepted:11Sept 2023



***Abstract***

*The article addresses the issue of Traumatic Brain Injury (TCE) and its incidence in different contexts. It is reported that TBI has an incidence rate of 579 per 100,000 person/year, with traffic accidents being the main cause, followed by falls. It is considered the main cause of disability in people from 15 to 44 years old, with a predominance in males in relation to sports practice, driving means of transport, and the use of neurostimulant substances or work causes. An updated bibliographic review of the descriptive nature of decompressive craniectomy in traumatic brain injury was conducted during the months of July and August 2022. Scientific articles in databases such as Medline, PubMed, Google Scholar, Web of Science, and Clinical Key were reviewed, complementing the information with high-impact journals such as Scielo, Scopus, reviews of randomized controlled clinical trials, systematic reviews, and approaches. meta-analysis, where keywords were investigated. It was found that Third World countries, especially in Latin America, have higher incidence rates due to poor road culture and education, along with a high range of injuries caused by traffic accidents and violence, and deficient care in health services.*

**Keywords:** *Traumatic Brain Injury (TBI), Incidence, Decompressive craniectomy*

## 1. Introduction

Traumatic brain injury (TBI) is one of the leading causes of mortality and disability worldwide. The average age of the population in developed countries increases at a great pace, although in this range the economically and economically active population remains affected, which has generated that many of the concepts and management strategies used until today become obsolete, new treatment options are reconsidered and others are resumed, as is the case of decompressive craniectomy. In addition, we are facing a multi-pathological population aging, which should make us change the approach. The World Health Organization estimates that, by 2030, TBI will be the third leading cause of morbidity and mortality worldwide. (1)

Intracranial hypertension syndrome (ICH) is manifested by an increase in the value of intracranial pressure (ICP) from the normal range, which, depending on the stage in which it is determined, causes different signs and symptoms in the patient, usually produces headaches, vomiting, papilledema, Cushing's triad and focal neurological symptoms; If not treated in time, it can lead to cephalocaudal degeneration, resulting in coma and death. According to the Monroe-Kelly law, ICP is determined by brain volume, cerebrospinal fluid (CSF), blood volume, and brain parenchyma. In this review we limit ourselves to the consideration of the traumatic etiology of this syndrome. (2)

Within the literature reviewed, there is a great variability of results. The most notorious has a temporal division of the studies, establishing a fictitious limit between those prior to 1991 and those carried out from 1997. Although those belonging to the first group combine worse results than the most recent, they are characterized by generally using retrospective studies, without a standardized methodology in their surgical technique or in conjunction with the rest of the measures applied before having resorted to CD, presenting strong heterogeneity in the groups of patients (mixing etiology, severity or even sometimes with inadequate randomization). which sometimes did not have a control group with which to establish a comparison, or resorting to CD only in very advanced stages of refractory ICH or in severely polytraumatized patients, which has made it difficult to reach conclusions and standardized protocols worldwide. (3)

The indications for performing CD have been involved in controversies, finding heterogeneity in the criteria for applying this surgery. While this is a technique that can save the lives of these patients, the high rates of disability and vegetative state reported should not be spared. Therefore, prior to the surgical resolution at the time of signing the informed consent, the type of craniotomy to be performed, its risks and complications, as well as disabling neurological sequelae and high mortality must be clearly and concisely detailed, a decision that the family will take and doubts are clarified regarding their expectations and the expected quality of life in the patient. (4)

The mortality and disability rates due to severe traumatic brain injury in Ecuador have increased exponentially over the last few years, which generates a direct and considerable increase in the health budget and in the economy of these families, which is why we developed this bibliographic review, with the aim of gathering criteria and reaching conclusions regarding the indications of decompressive craniectomy and based on Literature and professional experience in the field detail the complications of this procedure. (5)

This research has special significance since it responds to a training objective. The integration of substantive functions (training, research and linkage with society) is a necessity for the good performance of higher education institutions, as this contributes to the fulfilment of their social mission. Unquestionably, higher education institutions play an important role in the economic and social development of today's society. (6, 7)

## 2. Materials And Methods

This An updated, descriptive literature review on decompressive craniectomy in traumatic brain injury was conducted during the months of July and August 2022. Scientific articles were reviewed in databases such as Medline, PubMed, Google Scholar, Web of Science and Clinical Key, complementing the information with high-impact journals such as Scielo, Scopus, reviews of randomized controlled clinical studies, systematic reviews and meta-analysis approaches, where keywords such as: "decompressive craniectomy", "CD prevalence", "classification", "pathophysiology", "clinical manifestations", "indications", "complications", "diagnosis", "CD etiology", "prognosis", among others. These words were entered individually as combined for ease of searching. In addition, international and national journals, the World Health Organization database WHO and clinical guidelines were reviewed. Within the inclusion criteria, publications on the topic within the last 5 years were considered and case presentations were included.

## 3. Results and Discussion

The TCE reports an incidence rate of 579 per 100,000 person/year, the main cause reported are traffic accidents followed by falls, it is considered the main cause of disability in people between 15 and 44 years, with a predominance of the male sex in relation to sports practice, driving means of transport associated with the use of neurostimulant substances or for work reasons. (8)

Higher incidence rates are reported in third world countries, especially in Latin America; in low- and middle-income countries, in relation to poor road safety culture and education; With a high range of injuries caused by traffic accidents and violence, accompanied by poor care in health services, all these are direct factors that influence mortality from Traumatic Brain Injury. (9)

Ecuador is considered a third world country, on mortality, the National Institute of Statistics and Census (INEC) in 2014 reported 5768 deaths determined by severe trauma. The main causes listed

are: traffic accidents, falls, drowning, submersion, self-inflicted injuries and assaults in order of frequency (9). Traumatic brain injury is defined as all the external forces that generate a cranial injury and its contents: brain and adjacent tissues, by impact, penetration or forces of acceleration or deceleration. (8)

Currently, the clinical classification of TBI is based on the altered level of consciousness, based on the Glasgow Coma scale shown in Table 1. And the tomographic classification according to the Marshall CT scale reflected in Table 2. (10).

**Table 1.** Classification of the severity of Traumatic Brain Injury, according to the Glasgow Coma Scale

| TEC LEVE | MODERATE ECT | SEVERE ECT |
|---|---|---|
| -13-15<br>-Alert, aware of a brief period of unconsciousness (<1min)<br>-Headache, dizziness, fainting, nausea<br>-Just one episode of vomiting<br>-Difficulty concentrating<br>-Blurred vision | -9-12<br>-Coma, persistent confusion<br>-Behavioural changes<br>-Extreme dizziness<br>-Focal neurological signs such as hemiparesis<br>-Increased drowsiness<br>-Respiratory decrease<br>-Pupillary dilation | -8 or less<br>-Coma<br>-Babinski positive<br>-Affectations in pupillary size and reactivity<br>-Hemiparesis |

*Note: Classification of Traumatic Brain Injury, Glasgow scale. Source: "Risk factors associated with mortality in patients with acute traumatic brain injury." Cuban Journal of Anesthesiology and Reanimation 19.3 (2020).*

**Table 2.** Marshall classification of neurotraumatic injuries

| CATEGORY | DEFINITION |
|---|---|
| I. Diffuse lesion (without visible alteration) | No intracranial abnormalities visible on computerized axial tomography. Cisterns with midline deviation 0-5mm or dense lesions >25cm3 including bone fragments or foreign bodies. |
| II. Diffuse Injury II | Compression of tanks or absence, with deviation from the midline 0-5mm. Dense lesion of >25mm |
| III. Diffuse Lesion III (swelling) | Midline deviation >5mm Dense lesion >25mm. |
| IV. Diffuse Lesion IV<br>to. Drained mass lesions<br>b. Undrained mass lesions. | Surgically drained lesions. Dense lesions >25mm not surgically drained. |

*Note: Marshall classification of neurotraumatic injuries. Excerpted from Bejarano, L, Traumatic brain injury in children: relationship between tomographic findings and prognosis, Journal of Medical-Surgical Specialties, 2008*

Mild TBI is classified as an injured, conscious patient with 13 to 15 points on the Glasgow Coma Scale. They may present with a subgaleal wound or hematoma but not a fracture of the base or cranial vault, accompanied by headache, nausea and non-persistent vomiting. Most patients who suffer mild head trauma make a good recovery. (10)

Patients with a Glasgow Coma Scale score between 9 and 12 points, altered consciousness, focal neurological signs, progressive headache, dizziness, respiratory decline are included in moderate TBI. In the event that there is focusing neurological symptoms, the behavior will depend on the picture or the lesions found, ranging from observation and conservative treatment to surgical intervention. (11)

Severe TBI is seen in patients with a Glasgow Coma Scale score less than or equal to 8, decreased level of consciousness, neurological signs of focality, depressed fracture, or penetrating skull wound (12). Initial management includes prioritizing ABCDE. First the patient is stabilized, then a brain CT scan and radiological study of the cervical spine will be performed. If there are no injuries and the patient remains in a coma, he should be admitted to intensive care with measures to reduce ICP. (13). Where the nurse must be very attentive and prepared to identify any situation and act accordingly (13,14).

The clinical manifestations depend on the patient's condition and the severity of the traumatic brain injury according to the Glasgow Coma Scale having a wide range of presentations such as those cited below.

- Altered level of consciousness
- Peri- and post-traumatic amnesia
- Seizures
    - Immediate seizures: Appear in the first seconds or minutes after TBI
    - Early seizures: Appear between the first hour and 7 days post-trauma
    - Late seizures: They appear after the first week of TBI and define the existence of post-traumatic epilepsy from the second seizure (recurrence that defines the concept of epilepsy)
- Vomit
- Headache
- Difficulty concentrating
- Cephalocaudal degradation
- Comma (16)

Intracranial hypertension is the condition derived from the elevation of the pressure of the intracranial contents that exceeds the compensation mechanisms of the organism, and whose natural evolution without adequate and rapid treatment becomes irreversible brain damage and death. It is usually manifested by headache, altered level of consciousness and focal neurological deficits. Multiple situations can trigger this syndrome, and depending on the type of cerebral edema generated will require a certain therapy. ICP monitoring generally requires invasive instrumentation, and is performed in neurocritical units. In addition, in the management of these patients it is necessary to intervene in all concomitant systemic alterations, whose correct homeostasis will positively influence the prevention of complications. (4)

Monro's law - Kellie states that the intracranial content consists of 3 elements: the parenchyma, blood and cerebrospinal fluid (CSF). The parenchyma occupies a volume of 1,100 ml, and the CSF and blood, 150 ml each. The occurrence of intracranial hypertension is based on a continent/content problem. In adults, the skull and dura mater are rigid structures, which will prevent the necessary expansion of intracranial volumes in pathological conditions. However, in the newborn, the presence of fontanelles allows a greater distension of these. When these fontanelles are closed, the cranial cavity is formed, converted into a rigid case, which protects us from mild-moderate trauma, but which in turn becomes a propathological factor in case of need to increase the intracranial content, as occurs in severe or severe TBI. (17)

Stepwise measures for the treatment of ICP are detailed below, in favor of maintaining homeostasis, steroids, diuretics, hypertonic saline or mannitol, controlled hypothermia, hyperventilation, barbiturates and decompressive craniectomy (18). Decompressive craniectomy has been considered the last measure for the treatment of intracranial hypertension, although in recent years its early performance has decreased the incidence of neurological sequelae; CD can be divided into two types; primary and secondary, primary CD is described as a prophylactic intervention to prevent potential damage caused by cerebral edema. Secondary CD is generally performed as second-line treatment in cases refractory to medical treatment, however, it has also been used, although to a lesser extent early in patients with sustained ICH (17).

The surgical technique of decompressive craniectomy is considered a salvage technique in which an osteotomy is performed according to the intracranial lesion to be treated, followed by durotomy, evacuation of hemorrhagic lesions and duroplasty. In centers with availability of bone bank, the bone flap is preserved as long as there is no contaminated open wound or multifragmentary fracture, which if so, requires its elimination. In centers where there is no bone bank and no resources for subsequent cranioplasties, the bone flap is marsupialized with risk of osteolysis, infection and pain of the recipient site. To reduce the incidence of these complications, it is decided to wash the flap with hydrogen peroxide, absolute deperiostization and immersion in prontosan for 20 minutes, although the abdominal area generates less pain than the anterolateral aspect of the thigh the risk of osteolysis is greater. (18)

Cranioplasty can be early from the first postoperative month, it is performed by an autologous bone implant or by a titanium mesh implant, individualized implants with PEEK or other synthetic material. Currently, the indications for performing a decompressive craniectomy are related to neurosurgical lesions that evolve with cerebral edema, which produce an endocranial hypertension syndrome with neurological deterioration of the patient and signs of cerebral herniation. (18)

Depending on the clinic and the tomographic findings, different types of craniectomies will be performed for which their indications are specified. Bifrontal decompressive craniectomy is indicated in:

- Bilateral diffuse axonal lesions, with absence of subarachnoid space, presence of compressed cisterns and lateral ventricles in cleft (bilateral Marshall III, so there is no dislocation of the midline structures).
- Patients with unilateral or bilateral Marshall VI with focal lesions located in one or both frontal lobes.
- ICP greater than 25 mm Hg, refractory interventions of first level.
- Age under 65 years (19)

Bilateral fronto–temporo–parieto–occipital decompressive craniectomy shares indications of the preceding one and is added to patients with unilateral or bilateral Marshall VI with focal lesions extending beyond the frontal lobes of both hemispheres (19). Fronto–temporo–parieto–occipital decompressive hemicraniectomy is indicated when:

- Displacement of midline structures greater than 5 mm.
- No lesions of high or mixed density greater than 25 $cm^3$ (Marshall IV).
- Patients with high or mixed density lesion greater than 25 $cm^3$ not surgically evacuated (unilateral Marshall VI).
- ICP greater than 25 mmHg, refractory to first-line treatment
- Age less than 65 years. (19)

With regard to the patient's clinic and the application of the CD intervention, it is observed that complications manifest themselves later.

- Irreversible lesions located in the brainstem, or covering an area of both cerebral hemispheres and representing compatibility with life after clinical consideration.
- Hemodynamic instability of the patient associated with other complications of admission.
- Over 65 years (19)

The surgical procedure presents complications that are classified in relation to the time of onset in: Immediate and mediate complications

- Hypovolemic shock

It is an almost immediate and quite frequent complication, given the vascularity of the scalp, which tend to produce hemorrhages with significant blood losses that can lead to a very feared critical state in the patient and even death. (19)

- Increased cerebral edema

It is considered a rare complication, the risk of which should not be ruled out in the early postoperative period of CD. It can be found in hyperemic patients, as there is an increase in cerebral blood flow so it increases the probability of generating cerebral edema. This pathophysiological problem will be corrected with a therapy based on moderate or optimized hyperventilation depending on the results of the calculation of the arterio-jugular difference of oxygen or jugular oxygen saturation. On the other hand, we also consider in this classification the phenomena of necrosis by localized reperfusion and complicated hernias due to excessive or insufficient size of the flap. (4,20).

- Increase in ICP

The sudden decrease in ICP occurs in the first hours after surgical procedure with the CD technique. It is observed that in the range of the first 24 hours there are peaks of intracranial hypertension generally related to changes in brain blood flow and increased cerebral perfusion pressure (CPP) that are usually self-limiting. In these circumstances it is counterproductive to use adjusted capelins for the immediate postoperative period, since they have a direct impact by eliminating the physiological effect expected with CD, it is important to know that the high figures of the ICP are sustained for more than 24 hours, suspicions of errors when calibrating the system, insufficient diameter of the DC, elevation of the size of the contusions, appearance of other intraencephalic lesions, acute hydrocephalus should be raised. (4)

- CSF fistulas and subdural hygroma

They manifest themselves within the complications of CSF dynamics, are relatively frequent, appear on the same side in which the CD has been done. They usually resolve spontaneously, and intervention for their resolution is rare, which is done by means of lumbar punctures, individual or serial, lumboperitoneal or ventriculoperitoneal shunts and drains. Leakage of external cerebrospinal fluid poses an additional risk of surgical flap infection. The initial treatment consists of postural therapy, a compression for 48 to 72 hours covering the wound, a situation that can develop complications of burn or necrosis of the flap. (4)

Late complications

- Skin flap infections and more rarely intracranial infections

They are preventable complications through the use of prophylactic antibiotic procedures in all cases of admission, due to surgical time and secondary injuries associated with trauma. In addition, cranialization of the frontal sinus and ostium isolation are also used as fundamental maneuvers for the prevention of infections. Once the diagnosis is established, the dosage of antibiotics should be considered in relation to the antibiogram. These complications are also accompanied by dehiscences without infection, which appear mainly in older, female patients, with malnutrition, endocrine pathology, wounds with lacerated edges or abrasions. (4)

- Hydrocephalus

It is considered one of the most frequent complications after performing a CD. This procedure is an identifiable risk factor for post-trauma hydrocephalus. Although the cause is not clear, it has been proposed that an increase in CSF in the subdural or subgaleal space manifests alterations in its circulation, producing hydrocephalus. (4)

- Refining syndrome

It is a condition consisting in a clinic with headaches, paresis and paralysis, vertigo, behavioral alterations, vision problems, seizures, which tends to appear in patients undergoing a CD. (4)

- Bone flap resorption

It is one of the characteristic complications of this type of surgical intervention, with an incidence of 10% in patients once the flap has been repositioned. Situation for which, the use of a synthetic flap has been recommended. Some authors suggest that the complication is more frequent when the flap was stored in the abdomen or irradiated before its repositioning. (4)

Decompressive craniectomy is characterized by being a complex high-risk procedure, which, although it offers positive results in severe cases on the patient's survival, does not reduce the risk of sequelae and disability. Its implications and its execution place it as a second-level measure. According to the evidence, it is applicable even after an increase in sequelae in patients, in terms of disabilities to vegetative states, results that should be taken into account when performing a holistic analysis. (21)

The death during the first seven postoperative days of these patients will depend fundamentally on the initial neurological situation, so that the early action in the indication of CD before it deteriorates can play an important role. These results are plausible with greater aggressiveness in treatment in the most severe cases. On the other hand, we consider that they reflect the broad spectrum of variability of acute brain damage, a fact that hinders the development of studies and the generalization of the conclusions obtained. The trials carried out to date have included a small number of patients, which requires new lines of research that allow a better selection of patients for decompressive craniectomy in the different pathologies and identify useful information in clinical decision making (4)

The correct mechanics of neurotrauma is aimed at extending the decompression effect, dispensing with surgical complications, and thus facilitating its eventual resolution. The application of inappropriate decompression techniques can represent death for the patient (22). TBI is a public health problem, since it often represents disability in people who suffer from it due to the high morbidity and mortality that concerns it, due to the injuries it generates. Decompressive craniectomy is a practical neurosurgical strategy that allows reducing ICP when first-line measures to reduce it have failed, or when it is performed early for the evacuation of lesions in order to reduce cerebral edema (23)

In the RESCUE ICP and DECRA studies, it was found that CD was associated with high rates of vegetative states and high disability, which again underlines the importance of good patient selection. The work presents a detailed review of the indications and complications to take into account when selecting a patient for this surgical procedure (22).

## 4. Conclusion

TBI is a public health problem with high morbidity and mortality, mainly caused by traffic accidents and falls. Decompressive craniectomy (DC) is a surgical intervention used to reduce intracranial pressure in severe cases of TBI, it is an important part of the therapeutic measures applied in these cases. However, its execution must be carefully considered due to the associated complications and risks.

Better patient selection for CD and adequate assessment of risk factors and prognosis are required prior to intervention. It is important to know the type of CD performed, the normal findings after this surgery and recognize the main postoperative complications and their sequential presentation.

The indications of the types of decompressive craniotomy and their complications are important when selecting the patient prior to their individualized assessment. Younger age and better baseline neurological status, as measured by Glasgow Coma Scale scores, were associated with survival with fewer sequelae. Mortality was mainly concentrated in the first postoperative days. Decompressive craniectomy decreases mortality, prolongs survival, but is associated with high rates of vegetative state and significant functional neurological sequelae.

It is essential to improve road safety culture and education in low- and middle-income countries to reduce the incidence of TBI, especially in Latin America. In addition, health care services should be improved for more effective management of these cases.

## References:

1. Angulo Pastor, Y. M. (2020). Clinical-epidemiological characteristics of patients undergoing decompressive craniectomy for traumatic brain injury. National University of Cajamarca, Peru.
2. Carvajal Carpio, L., Vargas Mena, R., & Hidalgo Azofeifa, S. (2021). Pathophysiology of intracranial hypertension syndrome. *Medical Journal Synergy, 6*(10), 719.
3. Robayo, J. A. (2019). Comparative study of mortality in severe cranioencephalic trauma, in which decompressive craniotomy was performed versus conservative treatment in patients of the Teodoro Maldonado Carbo Hospital.
4. Barahona García, E. (2019). Results of decompressive craniectomy as therapy in neurocritical patients [Final degree project]. Open repository of the University of Cantabria.

5. Lamingo Soriano, G. I. (2017). Evaluation of primary lesions and their complications in cranioencephalic trauma at the Teodoro Maldonado Carbo Hospital period 2014-2016 [Field research thesis]. University of Guayaquil Repository.
6. Romero Fernández, A., Alfonso González, I., Álvarez Gómez, G., & Latorre Tapia, L. (2022). Research and its contribution to the development of Ecuadorian society: perspective of UNIANDES-Ecuador. *University and Society, 14*(6), 165-167.
7. Alfonso González, I., Alonso Camaraza, C., & Romero Fernández, A. J. (2022). The integration of university substantive processes from scientific research at UNIANDES. *University and Society, 14*(S6), 29-36.
8. Ordonez, A., & Ortiz, A. (2018). Epidemiology of cranial trauma in a national reference hospital of Quito-Ecuador in the period January 2017 to March 2018 in the city of Quito.
9. Martinez Herrera, G. (2019). Patients undergoing early decompressive craniectomy due to cranioencephalic trauma at Hospital México, in the period 2016-2019 [Research work]. University of Costa Rica.
10. Sangucho Villamarín, E. G. (2022). Relationship between the findings of the initial tomography with the Marshall Classification and the complications presented by patients under 18 years of age with Cranioencephalic Trauma at the Roberto Gilbert Elizalde Hospital, during the January period.
11. Acosta López, M. d. L. (2018). Moderate traumatic brain injury. [Bachelor's thesis, BABAHOYO, UTB].
12. Ortega Zufiría, J. M. (2018). Mild traumatic brain injury. *Surgical Neurology International, 21*(2), 21-25.
13. Cardona Pineda, S. M., Estrada, I., Anariba, R., & Pineda, L. (2019). Clinical-epidemiological characterization of pediatric severe traumatic brain injury at Mario Catarino Rivas National Hospital 2016-2018. *Acta Pediátrica Hondureña, 10*(1), 978-995.
14. Rodríguez Plasencia, A., Donoso Noroña, R. F., Hernández Zambrano, Y. C., & Verano Gómez, N. C. (2021). Nursing care in neonates with anencephaly at Latacunga General Hospital. *University and Society Magazine, 13*(S3), 173-180.
15. Alvarado Chacón, R. E., Rodríguez Plasencia, A., & Alonzo Pico, O. M. (2022). Neutrosophic Analysis of the Nursing Care Process in the Teaching of Nursing. *Neutrosophic Sets & Systems, 52*(Special Issue: Neutrosophic in Latin America, progress and perspectives), 207-214.
16. Burgos Choque, E. R. (2020). Clinical-epidemiological characteristics of patients with traumatic brain injury. Manuel Núñez Butrón Regional Hospital 2019. *César Vallejo University Institutional Digital Repository.
17. Concha Enríquez, K. S. (2020). Epidemiological, clinical, and tomographic characteristics of patients with traumatic intracranial hypertension undergoing decompressive craniectomy at the Antonio Lorena Hospital, 2015-2019 [Undergraduate Thesis]. *Repository Andean University of Cusco.
18. Herrera Martínez, M. P., Ariza Hernández, A. G., Rodríguez Cantillo, J. J., & Pacheco Hernández, A. (2018). Epidemiology of cranioencephalic trauma. *Cuban Journal of Intensive Medicine and Emergencies, 17*(2), 3-6.
19. DeAquino Reyna, M. I. (2021). Neurological progression in patients with severe traumatic brain injury treated in the Intensive Care Unit of the Central Hospital of the Mexican Red Cross in the period from January 2017 to December 2020 [Bachelor's thesis]. *Benemérita Universidad Autónoma de Puebla, 67-69.
20. Soria Acosta, A. R., & Hernández Zambrano, Y. C. (2022). Nursing interventions in acute hypoxic ischemic encephalopathy due to neonatal asphyxia. *University and Society Magazine, 14*(S2), 230-236.
21. Hutchinson, P. J., Kolias, A. G., Tajsic, T., Adeleye, A., Aklilu, A. T., Apriawan, T., ... & Citerio, C. G. (2019). Consensus statement from the International Consensus Meeting on the Role of Decompressive Craniectomy in the Management of Traumatic Brain Injury. *PubMed Central, 7*(161), 1261-1274.
22. Escamilla Ocañas, C. E., & Albores Ibarra, N. (2020). Current status and future perspectives in the management of intracranial hypertension after traumatic brain injury: decompressive craniectomy, therapeutic hypothermia, and barbiturates. *ScienceDirect.
23. Cruz López, A. M., Contreras, L., Carnalia, M., & Parra, J. (2018). Approach to the patient with traumatic brain injury: an approach for the first contact physician. *Family Care, 26*(1), 28-33.