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EVALUATION OF POSTOPERATIVE OUTCOMES FOLLOWING DECOMPRESSIVE CRANIECTOMY IN PATIENTS WITH INTRACRANIAL HYPERTENSION DUE TO SEVERE TRAUMATIC BRAIN INJURY

Samuel Djilas Ferreira de Abreu, Beatriz Fogagnoli Araujo de Almeida, Victor Gabino de Macedo, Lara Nunes Gomes, Gustavo Furtado de Figueirêdo

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SYSTEMATIC REVIEW

ABSTRACT

Traumatic brain injury (TBI) is a major public health concern with significant neurological, social, and economic impacts. Decompressive craniectomy (DC) is a surgical intervention used to manage severe TBI with refractory intracranial hypertension (ICH), aiming to reduce mortality by alleviating intracranial pressure. Despite its life-saving potential, DC is associated with high rates of severe disability and long-term complications, including hydrocephalus and infections. This study aims to systematically analyze and compare the postoperative outcomes of decompressive craniectomy in patients with severe TBI, focusing on mortality, functional recovery, and complication rates. A systematic review was conducted using databases such as PubMed, MEDLINE, and SciELO, applying predefined inclusion and exclusion criteria. The search utilized keywords including "Decompressive Craniectomy," "Traumatic Brain Injury," "Intracranial Hypertension," and "Outcomes," combined with the Boolean operator "AND." The analysis revealed that decompressive craniectomy significantly reduces mortality compared to standard medical management but is associated with a higher incidence of vegetative states and severe disabilities. Early intervention appears to yield better neurological outcomes, while delayed surgery correlates with higher morbidity. The findings highlight the need for individualized treatment strategies and robust postoperative rehabilitation protocols to optimize patient recovery and quality of life. Decompressive craniectomy remains a critical intervention for severe TBI with ICH; however, careful patient selection and long-term follow-up are essential to balance survival benefits with quality of life considerations.

Keywords: Decompressive Craniectomy, Traumatic Brain Injury, Intracranial Hypertension, Postoperative Outcomes, Mortality, Functional Recovery.

AVALIAÇÃO DOS DESFECHOS PÓS-OPERATÓRIOS APÓS CRANIECTOMIA DESCOMPRESSIVA EM PACIENTES COM HIPERTENSÃO INTRACRANIANA DEVIDO AO TRAUMATISMO CRANIOENCEFÁLICO GRAVE

RESUMO

O traumatismo cranioencefálico (TCE) é um importante problema de saúde pública, com impactos neurológicos, sociais e econômicos significativos. A craniectomia descompressiva (CD) é uma intervenção cirúrgica utilizada para o manejo do TCE grave com hipertensão intracraniana (HIC) refratária, visando reduzir a mortalidade ao aliviar a pressão intracraniana. Apesar de seu potencial para salvar vidas, a CD está associada a altas taxas de incapacidade grave e complicações a longo prazo, incluindo hidrocefalia e infecções. Este estudo tem como objetivo analisar e comparar sistematicamente os desfechos pós-operatórios da craniectomia descompressiva em pacientes com TCE grave, com foco na mortalidade, recuperação funcional e taxas de complicações. Foi realizada uma revisão sistemática utilizando as bases de dados PubMed, MEDLINE e SciELO, aplicando critérios de inclusão e exclusão predefinidos. A busca utilizou palavras-chave como “Craniectomia Descompressiva”, “Traumatismo Cranioencefálico”, “Hipertensão Intracraniana” e “Desfechos”, combinadas com o operador booleano “AND”. A análise revelou que a craniectomia descompressiva reduz significativamente a mortalidade em comparação ao tratamento clínico padrão, porém está associada a uma maior incidência de estados vegetativos e incapacidades graves. A intervenção precoce demonstrou melhores desfechos neurológicos, enquanto a cirurgia tardia correlacionou-se com maior morbidade. Os achados destacam a necessidade de estratégias de tratamento individualizadas e protocolos robustos de reabilitação pós-operatória para otimizar a recuperação e a qualidade de vida dos pacientes. A craniectomia descompressiva continua sendo uma intervenção crítica para o TCE grave com HIC; no entanto, a seleção criteriosa dos pacientes e o acompanhamento a longo prazo são essenciais para equilibrar os benefícios de sobrevida com a qualidade de vida.

Palavras-chave: Craniectomia Descompressiva, Traumatismo Cranioencefálico, Hipertensão Intracraniana, Desfechos Pós-Operatórios, Mortalidade, Recuperação Funcional.

Instituição afiliada – Unifacisa, Famene

Autor correspondente: *Samuel Djilas Ferreira de Abreu samueldjilas@gmail.com*

INTRODUÇÃO

Traumatic brain injury (TBI) is a severe and prevalent neurological condition, representing one of the leading causes of morbidity and mortality worldwide (Hutchinson et al., 2016). It is characterized by brain injury resulting from external forces that lead to anatomical and functional alterations, ranging from mild to severe. Severe TBI, in particular, poses a significant challenge for healthcare systems due to its complications, such as intracranial hemorrhages, cerebral edema, and intracranial hypertension (ICH), which can result in unfavorable outcomes, including permanent disability or death (Kolias et al., 2022). Proper management of these complications is essential to improve patient prognosis and reduce the socioeconomic burden of the disease.

Intracranial hypertension is one of the most critical manifestations of severe TBI and is associated with a high risk of neurological deterioration and mortality. The increased intracranial pressure, often caused by cerebral edema or expanding hematomas, compromises cerebral perfusion, leading to ischemia and progressive neuronal injury (Minta et al., 2023). Initial management of ICH includes clinical measures such as sedation, controlled hyperventilation, and the use of osmotic agents. However, in cases refractory to these interventions, decompressive craniectomy (DC) has been employed as a last-resort therapeutic option to alleviate intracranial pressure and prevent secondary brain injury (Bor-Seng-Shu et al., 2012).

Decompressive craniectomy involves the removal of a portion of the skull, allowing the swollen brain tissue to expand and reducing intracranial pressure. Although DC has proven effective in reducing mortality in patients with severe TBI and refractory ICH, its use is not without challenges. Studies have shown that while the procedure can be life-saving, many patients experience severe neurological sequelae, such as persistent vegetative states or significant functional impairment (Hutchinson et al., 2016; Kolias et al., 2022). Additionally, postoperative complications such as infections, hydrocephalus, and sinking skin flap syndrome require careful monitoring and appropriate rehabilitation strategies (Grille & Tommasino, 2015).

The decision to perform decompressive craniectomy must consider several

factors, including patient age, severity of TBI, time elapsed since injury, and the presence of comorbidities. The timing of the intervention also plays a crucial role in clinical outcomes, with early procedures often associated with better functional recovery rates (Eldanasory & Farid, 2014). However, there is ongoing debate regarding the optimal criteria for DC indications and its long-term effectiveness in terms of quality of life.

This study aims to conduct a systematic review to compare the postoperative outcomes of decompressive craniectomy in patients with severe TBI, analyzing mortality rates, functional recovery, and complications associated with the procedure. The review seeks to provide a comprehensive perspective on the effectiveness and limitations of this surgical approach, contributing to evidence-based clinical decision-making and the development of more effective therapeutic protocols.

METODOLOGIA

This study is a systematic literature review aimed at analyzing the postoperative outcomes of decompressive craniectomy (DC) in patients with severe traumatic brain injury (TBI), focusing on mortality rates, functional recovery, and associated complications. The review was conducted using the electronic databases PubMed, MEDLINE, and SciELO. The following descriptors were applied: "Decompressive Craniectomy," "Traumatic Brain Injury," "Intracranial Hypertension," and "Outcomes," combined using the Boolean operator "AND" to refine search results and ensure relevant studies were retrieved.

The study timeframe was limited to articles published in the last 10 years (2014-2024) to capture the most recent data and clinical practices related to the management of severe TBI with DC. Studies included in the review were full-text articles available with open access, involving patients who underwent decompressive craniectomy as part of their treatment for severe TBI.

A total of 40 articles were initially reviewed, with 18 meeting the established inclusion and exclusion criteria and subsequently included in the final analysis. The inclusion criteria encompassed studies that provided relevant quantitative or

qualitative data on postoperative outcomes, including randomized clinical trials, cohort studies, and systematic reviews. The exclusion criteria applied to incomplete articles, studies not aligned with the selected descriptors, studies published outside the defined timeframe, and those not directly related to the research topic.

This systematic review aims to provide a comprehensive understanding of the effectiveness and limitations of decompressive craniectomy in severe TBI, contributing to evidence-based clinical decision-making and improving therapeutic strategies for affected patients.

RESULTADOS E DISCUSSÃO

Traumatic brain injury (TBI) is one of the most significant neurological conditions in terms of prevalence, social, and economic impact. The term TBI refers to any brain injury caused by external forces that result in anatomical or functional alterations. It can be categorized based on severity, which is commonly assessed using the Glasgow Coma Scale (GCS). This scale classifies TBI into three levels: mild (GCS 13-15), moderate (GCS 9-12), and severe (GCS ≤8). This classification is useful both for the initial evaluation of the patient and for predicting prognoses and defining therapeutic strategies (Hutchinson et al., 2016).
Mild TBI cases generally have a benign clinical course, although a portion of patients may experience long-term neuropsychological sequelae. Conversely, moderate and severe TBI are often associated with more extensive brain injuries and a higher risk of mortality or significant disability. Severe TBI, in particular, poses a considerable challenge, with high mortality rates even in well-equipped healthcare systems. Severe brain injuries are characterized by secondary complications such as intracranial hemorrhages, cerebral edema, and intracranial hypertension (ICH), which often determine patient outcomes (Kolias et al., 2022).

TBI is recognized as one of the leading causes of death and disability among young and adult individuals. Globally, it is estimated that more than 69 million cases of TBI occur annually, with a higher concentration in low- and middle-income countries. These regions report disproportionately high TBI rates due to limited implementation of preventive measures, such as helmet use, seat belts, and strict speed control on

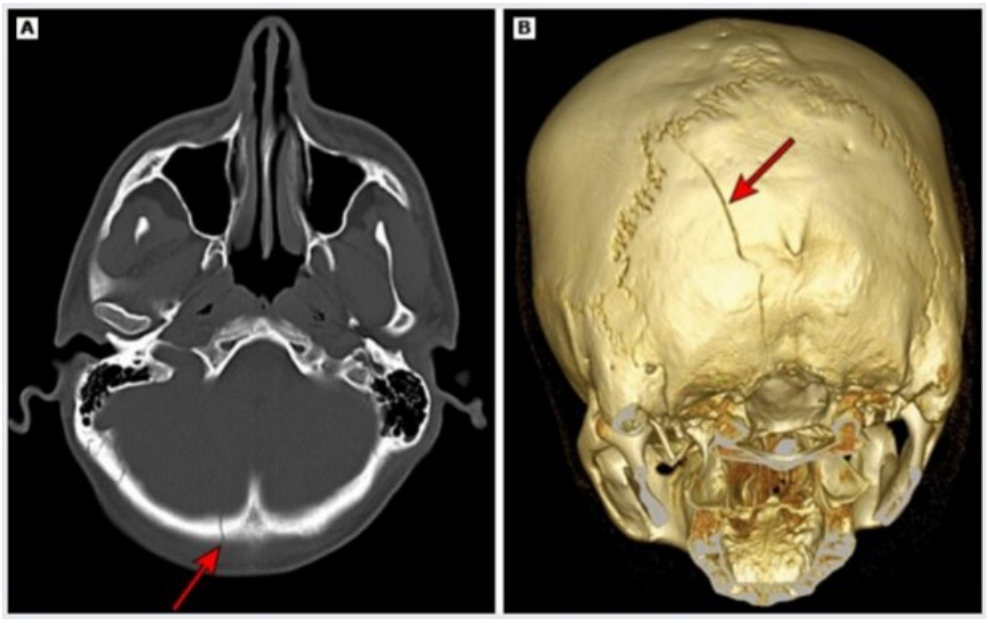
public roads (Minta et al., 2023). The primary cause of TBI in developed countries remains motor vehicle accidents, while in less developed nations, falls and interpersonal violence play a more significant role (Bor-Seng-Shu et al., 2012).

The economic burden of TBI is substantial, both in terms of direct costs associated with hospital care and indirect costs related to lost productivity. Severe TBI patients often require prolonged stays in intensive care units (ICUs) and extensive rehabilitation, resulting in significant expenses for healthcare systems and families. Additionally, the psychosocial impact of TBI profoundly affects the quality of life of survivors and caregivers, creating a considerable social burden (Kolias et al., 2022).

The pathophysiology of severe TBI involves two main phases: primary injury and secondary injury. The primary injury (Figure 1) occurs at the moment of impact and results from direct mechanical forces that cause structural damage to brain tissue. This damage may include contusions, hemorrhages, and axonal rupture, which are largely irreversible. In contrast, the secondary injury develops in the hours and days following the initial trauma and is driven by a cascade of biochemical and cellular events. This secondary phase involves hypoxia, ischemia, inflammation, mitochondrial dysfunction, and increased oxidative stress, which amplify the initial damage and can serve as targets for therapeutic interventions (Hutchinson et al., 2016).

Intracranial hypertension (ICH) is one of the most severe manifestations of TBI and plays a central role in the pathophysiology of secondary injury. ICH occurs due to increased pressure within the skull, which can result from cerebral edema, hematomas, or mass effect caused by expansive lesions. This rise in intracranial pressure reduces cerebral perfusion, leading to ischemia and worsening tissue hypoxia. Studies have shown that untreated ICH is associated with high rates of mortality and morbidity, underscoring the importance of effective management strategies (Bor-Seng-Shu et al., 2012; Minta et al., 2023).

Figure 1. Linear fracture in the right occipital bone.



Source: Redação Sanar, 2022.

Decompressive craniectomy has been established as a last-resort intervention for patients with severe TBI and intracranial hypertension (ICH) refractory to clinical treatment. This surgical technique involves the removal of a portion of the skull to allow the edematous brain to expand, thereby reducing intracranial pressure. Studies such as the RESCUEicp trial have demonstrated that decompressive craniectomy can significantly reduce mortality in cases of severe ICH, although it is associated with an increased proportion of patients with unfavorable functional outcomes, such as vegetative states or severe disabilities (Kolias et al., 2022).

The mechanism of action of decompressive craniectomy is based on the relationship between intracranial pressure and intracranial volume. By removing a portion of the skull, the procedure decreases intracranial pressure by allowing the brain to expand outward, alleviating the mass effect. Additionally, improved cerebral perfusion following the reduction in intracranial pressure is crucial to prevent the progression of secondary injury. However, complications such as infections, hydrocephalus, and sinking skin flap syndrome are relatively common and must be carefully monitored in the postoperative period (Bor-Seng-Shu et al., 2012; Minta et al., 2023).

The prognosis of patients undergoing decompressive craniectomy varies widely and depends on factors such as age, initial severity of TBI, timing of the intervention, and the presence of comorbidities. Younger patients generally have better outcomes

compared to older individuals, particularly when the intervention is performed early. Long-term studies suggest that although mortality is reduced, postoperative quality of life may be compromised due to persistent cognitive and functional deficits (Kolias et al., 2022). Intensive rehabilitation plays a crucial role in the recovery of these patients, helping to maximize residual functionality and improve social integration.

Postoperative Outcomes Following Decompressive Craniectomy

Author, Year	Study Title	Study Summary
Kolias et al., 2022	Evaluation of Outcomes Among Patients With Traumatic Intracranial Hypertension Treated With Decompressive Craniectomy vs Standard Medical Care at 24 Months	Comparison between decompressive craniectomy and standard care showed reduced mortality in the surgical group but with higher rates of vegetative states and severe disabilities.
Hutchinson et al., 2016	Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension	Study showed reduced mortality after decompressive craniectomy but increased vegetative and severe disability rates compared to medical management.
Chandankhede et al., 2023	Correlating Intracranial Pressure Following Decompressive Craniectomy With Neurological Outcomes in Severe Traumatic Brain Injury Patients	Postoperative intracranial pressure was strongly correlated with neurological outcomes. Road traffic accidents were the main cause of severe TBI.
Grille & Tommasino, 2015	Decompressive Craniectomy in Severe	A retrospective study identified post-surgical

	Traumatic Brain Injury: Prognostic Factors and Complications	intracranial hypertension as a negative prognostic factor.
Eldanasory & Farid, 2014	Early Decompressive Craniectomy after Severe Traumatic Brain Injury	Early craniectomy significantly reduced intracranial pressure and mortality compared to late interventions.
El-Sayed, 2018	Severe Traumatic Brain Injury: Clinical Outcome of 30 Cases Managed by Decompressive Craniectomy	Results indicated that decompressive craniectomy reduced mortality and improved functional outcomes in 60% of patients at 24 months.
Zhao et al., 2016	Prospective randomized evaluation of therapeutic decompressive craniectomy in severe traumatic brain injury with mass lesions (PRECIS)	A randomized study to evaluate therapeutic versus prophylactic decompressive craniectomy for mass lesions in severe TBI.
Gouello et al., 2014	Study of the Long-Term Results of Decompressive Craniectomy after Severe Traumatic Brain Injury	Retrospective analysis showed 50% of patients had favorable outcomes after craniectomy.
Kaushal et al., 2019	Long Term Outcome in Survivors of Decompressive Craniectomy following Severe Traumatic Brain Injury	Study showed 36% of patients achieved good functional recovery. Tracheostomy was associated with worse prognosis.
Saleh & Fetoh, 2022	Outcome of	Patients undergoing

	Decompressive Craniectomy for Severe Traumatic Brain Injury Patients with Persistently Elevated Intracranial Pressure	craniectomy demonstrated rapid control of intracranial hypertension with a 37.5% good recovery rate.

Source: The authors of the study

The studies analyzed provide a comprehensive view of postoperative outcomes of decompressive craniectomy in patients with intracranial hypertension caused by severe traumatic brain injury, addressing both the effectiveness and challenges associated with the procedure.

Kolias et al. (2022) and Hutchinson et al. (2016) converge in highlighting that decompressive craniectomy significantly reduces mortality compared to standard medical management. Kolias et al. (2022) reported a 20.5% reduction in mortality over two years, while Hutchinson et al. (2016) observed similar results, with mortality rates of 26.9% in the surgical group versus 48.9% in the medical group at six months. However, both studies underline an increase in rates of severe disability and vegetative states among survivors, emphasizing the challenges regarding postoperative quality of life.

Chandankhede et al. (2023) support these findings by demonstrating that postoperative intracranial pressure (ICP) levels are negatively correlated with neurological outcomes. Patients with lower ICP levels had better functional outcomes after two weeks and two months, reinforcing the importance of rigorous ICP monitoring to optimize surgical outcomes. These results align with those of Eldanasory and Farid (2014), who reported a reduction of 6 to 11 mmHg in ICP immediately after craniectomy, suggesting that early interventions can prevent subsequent complications.

Grille and Tommasino (2015) also identified persistent intracranial hypertension as the main negative prognostic factor following surgery, showing that patients with unresolved hypertension had significantly higher rates of complications and worse neurological recovery. Similarly, Saleh and Fetoh (2022) demonstrated that

early intervention based on ICP monitoring results in better pressure control and lower morbidity and mortality, with 37.5% of patients achieving good functional recovery.

El-Sayed (2018) expands the discussion by comparing immediate and delayed craniectomies. Patients who underwent early intervention showed better functional outcomes at three months (45% vs. 30%) and two years (60% vs. 30%). This pattern aligns with findings by Gouello et al. (2014), who reported a 50% favorable recovery rate after craniectomy, highlighting the importance of prompt intervention to mitigate secondary damage.

Zhao et al. (2016) introduce an additional dimension by evaluating prophylactic versus therapeutic craniectomies, indicating that the prophylactic approach can prevent the need for emergency interventions, although long-term benefits require further investigation. On the other hand, Kaushal et al. (2019) highlight independent factors associated with poorer outcomes, such as tracheostomy and low mean arterial pressure on admission, underscoring the need for a comprehensive assessment of patient conditions before surgery.

Studies such as those by Eldanasory and Farid (2014) and Saleh and Fetoh (2022) complement this perspective by emphasizing the effectiveness of craniectomy in reducing cerebral edema and improving cerebral perfusion. They suggest that strategies such as duraplasty can minimize secondary complications, aligning with Zhao et al. (2016) regarding ICP management.

The studies collectively demonstrate that while decompressive craniectomy offers clear benefits in reducing mortality, the impact on functional outcomes varies widely. Early intervention appears to be a key factor in improving results, but the high rates of complications and severe disabilities remain significant challenges. Integrating personalized approaches, based on rigorous monitoring of ICP and other clinical parameters, may represent a promising direction to optimize the management of these patients.

CONSIDERAÇÕES FINAIS

Decompressive craniectomy (DC) has proven to be an effective intervention for the management of severe traumatic brain injury (TBI) with refractory intracranial

hypertension (ICH), but it is not without significant challenges. DC is associated with a marked reduction in mortality compared to standard medical management, making it a crucial option for patients who fail to respond to conservative treatments. However, the procedure is accompanied by a high incidence of severe disability and long-term complications, such as hydrocephalus, infections, and persistent neurological deficits, necessitating a comprehensive rehabilitation strategy and long-term follow-up. These findings highlight the complex nature of DC as a life-saving yet functionally compromising intervention.

While DC offers a clear short-term survival advantage, the long-term functional outcomes remain highly variable, with many patients experiencing significant impairments in their quality of life. The timing of the intervention plays a crucial role, with early craniectomy often yielding better functional outcomes compared to delayed procedures. Nevertheless, the potential for postoperative complications and the need for secondary interventions underline the importance of careful patient selection and individualized treatment planning. DC should be considered within a multidisciplinary framework that takes into account patient-specific factors such as age, comorbidities, and the severity of brain injury.

The decision to perform decompressive craniectomy must be guided by a thorough discussion with patients' families and caregivers, weighing the trade-offs between potential survival benefits and the risk of severe disability. Shared decision-making is essential to ensure that the chosen management strategy aligns with the patient's prognosis, values, and long-term care goals. The implications of this review extend beyond clinical practice to emphasize the importance of optimizing perioperative care protocols and rehabilitation programs tailored to improve neurological outcomes.

Future research should focus on refining patient selection criteria and surgical techniques to maximize the benefits of DC while minimizing its adverse effects. Studies exploring the long-term quality of life, neurocognitive outcomes, and the economic burden associated with DC are crucial to guide healthcare policies and resource allocation. Additionally, advancements in neuroprotective strategies and postoperative monitoring protocols may help mitigate secondary brain injury and improve overall

patient prognosis.

Despite the strengths of this review, certain limitations should be acknowledged, including potential selection bias and heterogeneity across the included studies, which may affect the generalizability of the findings. Future systematic reviews should aim to include a broader spectrum of patient demographics and clinical settings to enhance the understanding of DC's role in TBI management. By addressing these gaps, ongoing research can contribute to evidence-based, patient-centered approaches that optimize outcomes and resource utilization in severe TBI management.

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