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Short Review

Indications And Outcomes Of Decompressive Craniectomy. Considerations From Clinical And Medical Ethics Perspectives.

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Abstract

Decompressive craniectomy (DC) is a neurosurgical intervention that entails removing a section of the skull to alleviate intracranial pressure (ICP) in patients with intracranial hypertension that does not respond to standard medical treatments. Although widely utilized in clinical practice, its indications, effectiveness, and functional outcomes continue to be topics of discussion in neurocritical care. This paper provides a review of the literature on the results of DC in various severe neurological conditions and explores the ethical challenges associated with its use. We analyze the indications for decompressive craniectomy in various neurosurgical conditions, assessing its outcomes in terms of survival and functional recovery. Additionally, we present considerations from a bioethical perspective, emphasizing a principlist and personalist approach. Our aim is to provide reflections that may assist healthcare professionals in the complex decision-making process inherent to these clinical scenarios.

Keywords: decompressive craniectomy, outcomes, clinical bioethics, neurosurgery.

INTRODUCTION

Decompressive craniectomy (DC) is a neurosurgical procedure involving the removal of a portion of the skull to reduce intracranial pressure (ICP) in patients with intracranial hypertension refractory to conventional medical therapies. Despite its established role in clinical practice, its indications, efficacy, and functional outcomes remain subjects of debate in various neurocritical care settings. This paper presents a literature review on the outcomes of DC in different critical neurological conditions, along with an analysis of the ethical dilemmas associated with its application.

CRITICAL ANALYSIS

Current Indications And Outcomes Of Decompressive Craniectomy

The indications for DC have evolved over time based on clinical studies and accumulated experience. Currently, the primary indications include:

Malignant Middle Cerebral Artery (MCA) Infarction

Malignant MCA infarction is a large ischemic event that can lead to significant cerebral edema and increased ICP. Studies such as DESTINY[2], DECIMAL[3], and HAMLET have demonstrated that DC, when performed within the first 48 hours after symptom onset, reduces mortality and improves functional prognosis in selected patients.

Several studies suggest that 60 years of age is a reasonable threshold to anticipate better outcomes. In patients older than this, DC may improve survival but often with poorer functional outcomes[4].

A recent Cochrane review[5] concluded that surgical decompression significantly improves outcomes in the treatment of malignant edema secondary to acute ischemic stroke. Key findings included a significant reduction in mortality or severe disability (modified Rankin Scale [mRS] >4) and a reduction in moderate mortality or disability (mRS > 3).

A recent meta-analysis[6], which included data from 488 patients across seven trials in six countries, concluded that surgical decompression is associated with a substantial increase in the likelihood of a favorable outcome. This benefit appears to be independent of factors such as the presence of aphasia, stroke severity, age, and involvement of vascular territories beyond the MCA. However, some authors have suggested that the definition of a favorable outcome should

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be restricted exclusively to an mRS score of ≤4.

Limited data are available on DC performed more than 48 hours after stroke onset, preventing definitive conclusions. Furthermore, variability in the proportion of elderly patients achieving a favorable outcome across studies complicates firm recommendations regarding the expansion of age and time criteria for surgical intervention.

Severe Traumatic Brain Injury (TBI)

The efficacy of decompressive craniectomy (DC) in the management of severe traumatic brain injury (TBI) remains a subject of debate. Studies such as DECRA[9] and RESCUEicp[10] have reported mixed results regarding its benefits, findings that have been reaffirmed in recent reviews[11,12]. However, individually or collectively, these studies have not provided a definitive recommendation for or against DC, complicating its interpretation in clinical practice.

In patients with TBI and diffuse cerebral edema with intracranial hypertension (ICH) refractory to conservative measures, a recent expert consensus conference[13] suggested that DC may be considered a therapeutic option. In particular, patients with initially preserved neurological function who experience deterioration secondary to sustained ICP elevation appear to be the most suitable candidates for this procedure. At 24 months of follow-up, patients with refractory post-traumatic ICH treated with DC have demonstrated a sustained reduction in mortality. However, this decrease is associated with a higher incidence of vegetative states, severe and moderate disability[14].

Long-term outcome data[15] remain limited, emphasizing the need for extended follow-up and comprehensive rehabilitation programs. Nevertheless, some studies have reported that up to 10 years after a traumatic brain injury, certain patients can achieve an acceptable quality of life, suggesting that the therapeutic potential of DC in this context may be underestimated.

Clinical guidelines for the management of severe traumatic brain injury include a Level IIA[16] recommendation stating that:

- "Bifrontal DC is not recommended to improve outcomes as measured by GOS-E score at 6 months post-injury in patients with severe TBI with diffuse injury (no mass lesions) and elevated ICP to values >20 mmHg for more than 15 minutes in a 1hour period who are refractory to first-tier therapies. However, this procedure has been shown to reduce ICP and minimize ICU days."
- "A large frontotemporoparietal DC (no less than 12 x 15 cm or 15 cm in diameter) is recommended instead of a small frontotemporoparietal DC to reduce mortality and improve neurological outcomes in patients with severe TBI".

Given the current uncertainty regarding long-term functional outcomes in patients undergoing decompressive craniectomy (DC), decision-making should involve family members or legal representatives, who must act based on the patient's previously expressed values and preferences—a principle known as "substituted judgment." To ensure an informed decision, it is essential to provide family members with the best available evidence, allow sufficient space for addressing concerns, and ensure that the process takes place within a framework of autonomy and voluntary decision-making.

In cases where the patient's values and preferences are unknown, the assessment should focus on determining the "best interest of the patient," considering their overall well-being and the proportionality of the intervention in relation to their expected functional prognosis and quality of life.

Spontaneous Intracerebral Hemorrhage (ICH)

Spontaneous intracerebral hemorrhage (ICH) remains associated with high mortality and morbidity, and the role of decompressive craniectomy (DC) in this context remains controversial. In patients with intraparenchymal hemorrhage associated with progressive neurological deterioration and signs of brain herniation, DC may be considered a therapeutic option to control intracranial pressure (ICP) and prevent secondary neurological damage. However, a recent review of the most relevant studies on the surgical management of supratentorial hemorrhages[17] noted that the role of open craniotomy for early hematoma evacuation remains highly debated. It has been postulated that this intervention may help prevent brain herniation, control intracranial hypertension, and minimize the neurotoxic effects of blood degradation products on healthy brain tissue due to their excitotoxic and proinflammatory properties.

A recent meta-analysis[18] demonstrated that DC was associated with a significant reduction in mortality in patients with ICH, with a possible functional benefit in selected populations, though these findings require further validation. Additionally, DC has not been shown to increase the risk of postoperative rebleeding or hydrocephalus. However, randomized clinical trials conducted to date have failed to provide conclusive evidence of reduced mortality or improved functional outcomes.

Currently, the American Heart Association/American Stroke Association (AHA/ASA) guidelines for the management of ICH, as well as recommendations from the European Stroke Organization (ESO), acknowledge that the benefit of surgical evacuation is not well established (Class IIb; Level of Evidence A)[19], and there is insufficient evidence to support its routine use (moderate quality of evidence, weak recommendation).

Cerebellar Edema with Brainstem Compression

In cases where cerebellar infarction or hemorrhage leads to brainstem compression and obstructive hydrocephalus, suboccipital decompressive craniectomy (SDC) may be

necessary to relieve intracranial pressure and prevent neurological deterioration. A recent meta-analysis[20], which included eleven studies with a total of 283 patients, analyzed the proportion of cases with moderate-to-severe disability, mortality, and adverse events following SDC. The findings reported a moderate-to-severe disability rate of 28% and a mortality rate of 20%, with a lower mortality rate in patients with a mean age under 60 years. The incidence of adverse events associated with SDC was 23%. Additionally, SDC in cerebellar infarction has been associated with better functional outcomes compared to decompressive surgery for hemispheric infarcts. However, uncertainties remain regarding the optimal indications for decompression and the ideal timing to prevent irreversible neurological deterioration. Some authors have proposed neuroimaging-based scoring systems (CT or MRI) to quantify the volume of the posterior fossa and hematoma[21], aiming to identify patients who may benefit from early surgical decompression.

ETHICAL AND CLINICAL CONSIDERATIONS

The findings discussed in the previous sections underscore the need for individualized assessment and thorough discussions with family members regarding potential clinical outcomes. While decompressive craniectomy (DC) may reduce mortality, it is crucial to recognize that some patients survive with severe disabilities that significantly impact their quality of life. This raises important ethical dilemmas regarding the appropriateness of the intervention in certain cases.

Determining the optimal timing for DC is critical. While early intervention may mitigate secondary damage, it also carries the risk of subjecting patients to surgery who might have recovered with conservative management. Conversely, delayed intervention may fail to provide the same benefits. DC is a valuable neurosurgical tool in the management of critically ill patients; however, its application must be carefully considered, balancing the potential survival benefits against the risks and long-term sequelae.

The appropriate timing for reconstructive cranioplasty, a procedure required to replace the bone flap or insert an artificial substitute, must also be carefully analyzed. The syndrome of the trephined, characterized by focal neurological deficits, hydrocephalus, and extraaxial hygromas, has been reported as a consequence of cerebrospinal fluid dynamics alterations, which can also affect the final clinical outcome.

Ethical Framework for Decision-Making

From a principlist ethical perspective

decision-making should be individualized, grounded in the best available evidence, and facilitated through open communication with the patient and their family regarding potential outcomes and expectations. To uphold the principle of autonomy, it is essential to consult the patient's advance directives, ideally documented within the healthcare system and accessible to medical professionals. In the absence of formal directives, decisions should be guided by interviews with the patient's designated representatives to understand their values and apply substituted judgment. If neither prior directives nor representatives are available, decisions should be based on the "best interests of the patient."

From the principle of beneficence, ethical deliberation must balance risks and benefits. Surgery aims to preserve life and minimize brain damage; in well-selected cases, it can improve survival and functional outcomes. However, sociocultural and geographic factors influencing decision-making must be considered. Medical literature highlights that the acute clinical environment in which these decisions are made is inadequate and emotionally overwhelming[22], which may impair the autonomy and decision-making capacity of both family members and healthcare professionals. Furthermore, performing DC in cases with a poor prognosis or as a heroic measure without a realistic chance of survival is considered maleficent, as it prolongs life support without meaningful prospects of recovery. In surviving patients, this can result in coma, a vegetative state, or minimal consciousness, leading to extreme dependency.

Regarding the principle of justice, given that DC is a high-cost procedure and healthcare resources are limited in many systems, concerns arise about its fairness and opportunity cost in relation to patients with a better prognosis. However, studies indicate that up to 78.9% of relatives would opt for surgical intervention to preserve the patient's survival[23]. Additionally, research among healthcare professionals[24] has shown that acceptance of DC varies depending on the information provided regarding the expected functional outcome and the affected brain hemisphere.

In clinical practice, the appropriateness of therapeutic intervention is often reconsidered after several days of intensive care, once an unfavorable prognosis becomes evident. In such cases, decision-making becomes complex, and occasionally, measures exceeding widely accepted ethical boundaries are proposed, further complicating ethical dilemmas[25].

From the perspective of ontological personalism

decisions must be guided by the intrinsic and unique dignity of the human being. In accordance with the principle of the primacy of the person, DC should not merely be considered a means of prolonging life but should also be evaluated in terms of its impact on the patient's overall integrity. The goal should not be life extension at all costs but rather ensuring that the individual can maintain a dignified existence. In line with the principle of totality, it is essential to assess whether the intervention will allow the patient to regain acceptable

functionality or condemn them to a state of extreme dependence and suffering.

The principle of freedom and responsibility emphasizes that patient autonomy must be considered within a framework of shared responsibility. Family members and healthcare professionals must act in the patient's best interest, taking into account their life history and values. Additionally, the principle of solidarity and subsidiarity calls for the involvement of the family, community, and healthcare system in decision-making, ensuring that both patient neglect and therapeutic obstinacy are avoided.

CONCLUSIONS

Decompressive craniectomy is a fundamental therapeutic strategy in the neurosurgical management of critically ill patients. However, its application must be rigorously evaluated, balancing the benefits in terms of survival and quality of life against its risks and potential sequelae. Decision-making should be evidence-based and supported by transparent communication with the patient and their family. DC is a reasonable intervention when it preserves life with dignity, but it becomes ethically questionable when its only outcome is the prolongation of a state of suffering with no meaningful prospect of recovery.

Both a principlist and a personalist approach can reasonably consider the ethical aspects related to this surgical technique.

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