Review Article

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Decompressive craniectomy in children and adolescents with severe traumatic brain injury: a systematic review.

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Introduction/Background: Decompressive craniectomy (DC) is a neurosurgical technique employed in pediatric patients with severe traumatic brain injury (sTBI). However, consensus remains lacking regarding the specific criteria for its indication. The objective of this study is to synthesize data concerning the clinical and CT scan criteria for performing DC in children and adolescents with sTBI.

Methods: This systematic review analyzed scientific studies indexed in the MEDLINE database via the PubMed platform. The search included studies published between 2015 and 2025 that involved children and adolescents (under 18 years of age) with sTBI treated with DC. This review is registered in the International Prospective Register of Systematic Reviews (PROSPERO: CRD420251159406).

Results: Eighteen manuscripts describing the clinical and tomographic criteria for DC indication were included. In a combined sample of 916 children, pupillary abnormalities (162/343; 47.2%) were identified as a primary clinical factor guiding surgical decisions in nine articles. CT imaging revealed post-traumatic intracranial mass lesions associated with midline shift (MLS), further justifying the procedure. Invasive intracranial pressure monitoring (ICPm) was utilized in 48.6% (386/794) of cases, and the overall mortality rate was 24% (220/916).

Conclusions: In children and adolescents victims of sTBI, pupillary abnormalities coupled with CT evidence of acute intracranial lesions, mass effect, and MLS are key indicators for DC, whether or not invasive ICPm is employed.

Keywords: decompressive craniectomy, children, traumatic brain injury, mortality, prognosis.

INTRODUCTION

Severe traumatic brain injury (sTBI), defined by a Glasgow Coma Scale (GCS) score of 8 or less, is a leading cause of permanent disability and mortality among polytraumatized children and adolescents [1,2]. Among the surgical and non-surgical interventions recommended for these critically ill patients, decompressive craniectomy (DC) has been the subject of significant attention and debate [3-5]. Currently, there is no consensus regarding the clinical criteria or the optimal timing (early vs. late) for surgical decompression. Furthermore, it remains unclear whether invasive intracranial pressure monitoring (ICPm) should precede DC, particularly as ICPm is not routinely performed in all pediatric sTBI cases [3,6,7].

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The definitive benefits of DC also remain uncertain, given the associated risk of post-surgical complications, severe neurological impairment, and high in-hospital mortality rates [3,6]. This study presents a systematic review of scientific literature published between 2015 and 2025 and indexed in the MEDLINE database via the PubMed/NCBI (National Library of Medicine; National Center for Biotechnology Information) search platform. We aimed to identify scientific articles to compile information on clinical indications and the specific radiological features identified in head computed tomography (CT) scans that support the decision to perform DC in children and adolescents with sTBI. The primary outcome assessed in this systematic review was in-hospital mortality.

MATERIALS AND METHODS

Study design, information sources, and ethical considerations

This is a systematic review of scientific articles published between January 2015 and October 2025, retrieved from the PubMed/NIH (MEDLINE) platform. The search strategy employed the following terms: "children" AND "decompressive craniectomy" AND "traumatic brain injury". The study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [8]. The research question and eligibility criteria were structured using the PICo framework (P = Population: children and adolescents < 18 years of age; I = Phenomenon of Interest: decompressive craniectomy; Co = Context: traumatic brain injury) [9]. Risk of bias was assessed using the ROBIS (Risk of Bias in Systematic Reviews) tool [10]. This review included only peer-reviewed articles from scientific journals that reported prior approval by a research ethics committee. As this study is exclusively a systematic review of previously published literature and did not involve retrospective medical record analysis or the recruitment of human participants, institutional research ethics committee approval was not required.

Eligibility (inclusion and exclusion) criteria

In the first stage of the study (first-level screening), the authors screened the titles of all retrieved articles. At this point, duplicate publications were eliminated, along with articles unrelated to the main theme or written in a language other than English. The second stage (second-level screening) consisted of reading the abstracts of the selected articles. The full text was also reviewed whenever an abstract was deemed suitable. This stage aimed to select articles providing specific information regarding clinical and CT-scan findings for DC indications within the pediatric population. Studies were included if their samples consisted of children and adolescents (under 18 years of age) with sTBI who underwent DC. In the third stage (third-level screening), the selected articles were read in full. All bibliographic references within these articles were checked to identify any additional studies that met the inclusion criteria but had not been captured in previous stages. This systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO CRD420251159406) [11].

Regarding the type of publication, the study included original research (retrospective or prospective cohorts, matched case-control studies, and cross-sectional studies) and case series (≥ 5 cases) published in peer-reviewed journals. To be eligible, the study samples had to include children and adolescents (under 18 years of age) with sTBI who underwent DC as neurosurgical treatment. The exclusion criteria consisted of articles published in journals not indexed in the selected platforms (PubMed/NIH/MEDLINE), letters, editorial comments, unpublished manuscripts, dissertations, government citations, or references not published in scientific journals. Books and book chapters were also excluded. Considering study designs, we excluded case reports with fewer than five cases, qualitative studies, and research without a structured methodology. Furthermore, studies were excluded if they:

- Failed to differentiate the pediatric population from the adult population in the analyses;
- Did not establish specific criteria for DC indication;
- Did not distinguish DC cases due to sTBI from non-traumatic cases (i.e. cerebrovascular diseases or intracranial infections);
- Did not assess mortality in children treated with DC due to sTBI.

The summary flowchart of this systematic review is shown in Figure 1.

Data collection instrument, variables, outcomes, and statistical analysis

To minimize selection and observation bias, the research group underwent a one-month calibration period prior to the official data collection, during which they practiced completing the collection instrument. Once all queries were resolved and the group was calibrated, the formal data collection began. Selected articles were discussed as a group whenever doubts emerged. The following variables were extracted and recorded: study identification (first author's name and publication year), sample size, and the clinical and CT-scan criteria used for DC indication. Additionally, data on ICPm (whether it was used, and if so, before or at the time of DC) and in-hospital mortality among children and adolescents (under 18 years of age) undergoing DC for sTBI were collected. Statistical analyses were performed using the open-source software PSPP (GNU General Public License). Continuous variables with a normal distribution are expressed as means ± standard deviation (SD); otherwise, they are presented as medians and interquartile ranges (IQR). The Chi-square test with Yates' correction was used to investigate associations between categorical variables, and Odds Ratios (OR) were calculated where applicable.

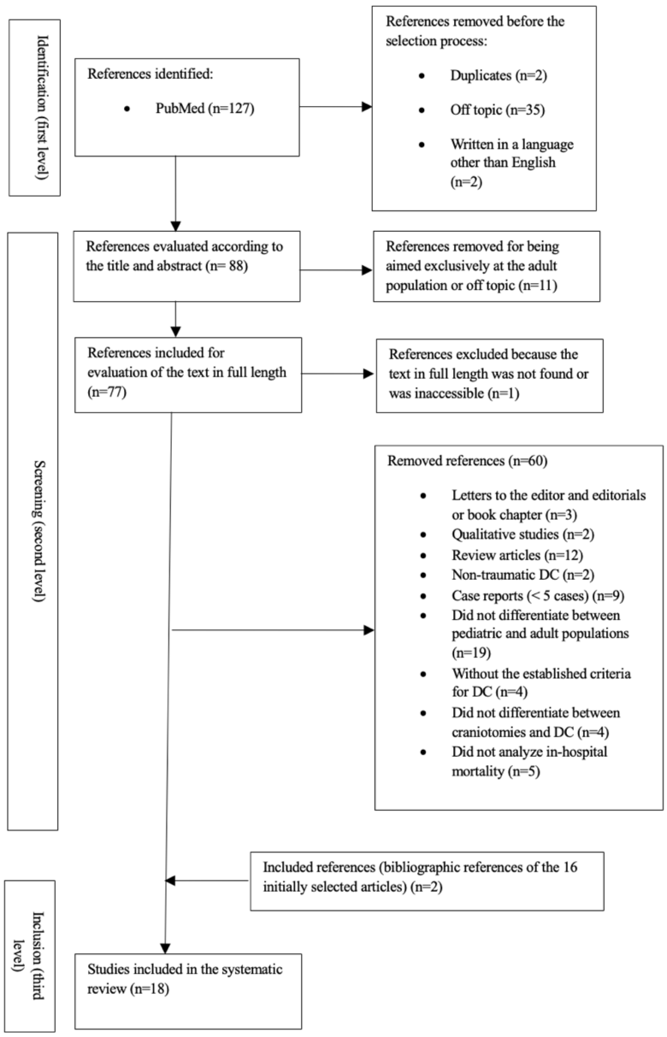

Figure 1. Flowchart following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria for selection of bibliographic references to be included in the present systematic review on decompressive craniectomy (DC) in children and adolescents < 18 years of age due to severe traumatic brain injury (sTBI), published between January 2015 and October 2025.

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Table 1. Clinical and tomographic criteria* for indication of decompressive craniectomy (DC) with or without invasive intracranial pressure monitoring (ICPm) in children and adolescents < 18 years of age victims of severe traumatic brain injury (sTBI) (2015 to 2025).

Main author and year of publication of the article	Sample (n)	Clinical criteria highlighted in the body of the text	Pupillary abnormalities	Invasive ICPm	In-hospital mortality
Mhanna 2015 [21]	17	sTBI; PRISM	-	17/17 (100%)	5/17 (29.4%)
Prasad 2015 [32]	36	sTBI + Refractory ICH	-	33/36 (91.6%)	18/36 (50%)
Hockel 2017 [24]	9	sTBI + Refractory ICH	-	9/9 (100%)	2/9 (22.2%)
Rallis 2018 [12]	14	sTBI + Refractory ICH; PRISM III; ISS	14/14 (100%)	14/14 (100%)	4/14 (28.6%)
Tang 2018 [13]	36	sTBI; ISS	24/36 (66.7%)	-	14/36 (38.9%)
Ballestero 2019 [14]	16	sTBI	12/16 (75%)	**	5/16 (31.2%)
Manfiotto 2019 [5]	150	sTBI	47/150 (31.3 %)	70/150 (46.6%)	23/150 (15.3%)
Beez 2019 [15]	12	sTBI + Refractory ICH	6/12 (50%)	5/12 (41.7%)	4/12 (33.3%)
Goker 2020 [16]	12	sTBI + Refractory ICH	6/12 (50%)	-	3/12 (25%)
Hubertus 2022 [17]	11	sTBI + Refractory ICH	3/11 (27.3%)	11/11 (100%)	3/11 (27.3%)
Korhonen 2022 [22]	20	sTBI + Refractory ICH	-	7/20 (35%)	3/20 (15%)
Bruns 2022 [20]	402	sTBI; AIS; ISS	-	161/402 (40%)	83/402 (20.6%)
Falconi 2023 [34]	13	sTBI + Refractory ICH	-	11/12*** (91.7%)	6/13 (46.2%)
Nagy 2023 [18]	47	sTBI; 2019 TBI guidelines	25/47 (53.2%)	24/47 (51%)	15/47 (31.9%)
Du Plooy 2024 [33]	17	sTBI; 2019 TBI guidelines	-	**	6/17 (35%)

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Melo 2024 [3]	19	sTBI + Refractory ICH	-	8/19 (42.1%)	4/19 (21%)
Morgan 2025 [23]	40	sTBI	-	**	11/40 (27.5%)
Jaradat 2025 [19]	45	sTBI + clinical signs of brain herniation	25/45 (55.5%)	16/45 (35.5%)	11/45 (24.4%)
Total	916	-	162/343 (47.2%)	386/794 (48.6%)	220/916 (24%)

* Brain CT scan: the following tomographic criteria were mentioned in the articles: acute traumatic lesions with compressive effect, diffuse brain lesions or brain swelling with mass effect, acute or hemorrhagic space-occupying lesions and/or lesions with mass effect and/or with midline shift and/or with obliteration of cerebral cisterns. ** Not possible to identify the proportion of those who underwent invasive ICPm. *** In Table 3 of the aforementioned article, Falconi et al. (2023) report that 11 out of 12 children who underwent DC underwent ICPm.

AIS: Abbreviated Injury Score. ICH: intracranial hypertension. ISS: Injury Severity Score. PRISM: Pediatric Risk of Mortality.

Table 2. Prevalence of in-hospital mortality considering reference centers that did not systematically perform invasive intracranial pressure monitoring (ICPm) in all children and those that systematically did it in all cases.

Reference centers	Death - yes	Death - no
No systematic invasive ICPm	167	576
Systematic invasive ICPm	14	37

Mortality rate in reference centers where ICPm was not systematically implemented in all cases: 167/743 (22.5%). Mortality rate in reference centers where ICPm was implemented in all cases: 14/51 (27.4%). Chi-square with Yates correction 0.418 with 1 degree of freedom; OR 0.7662; 95% CI 0.4046 – 1.4512; z statistic 0.817; p = 0.4.

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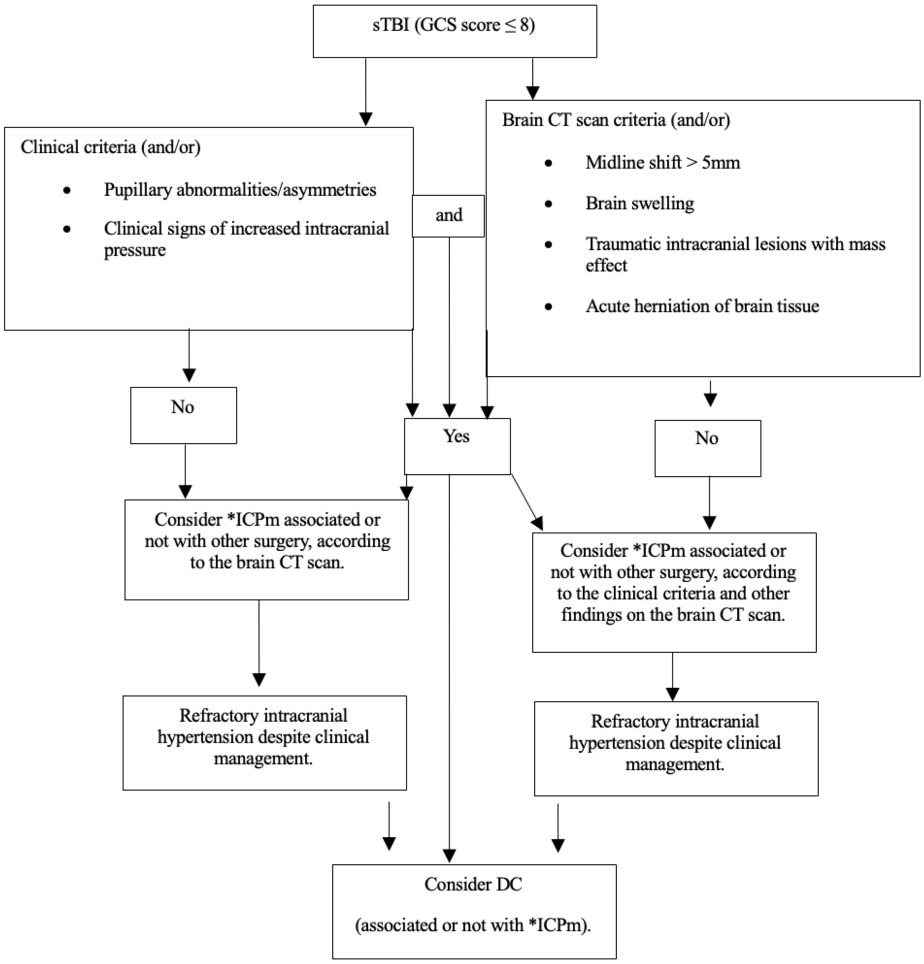

Figure 2. Flowchart with the recommendations proposed in the current systematic review for indication of primary decompressive craniectomy (DC) in children and adolescents < 18 years of age with severe traumatic brain injury (sTBI):

*Intracranial Pressure monitoring (ICPm)

RESULTS

Our bibliographic search identified 127 references published between January 2015 and October 2025. Following the PRISMA guidelines, we excluded two duplicates, 35 articles that did not meet the inclusion criteria, and two texts written in languages other than English during the first-level screening. Of the 88 articles that proceeded to second-level screening, 77 were selected for full-text review. Ultimately, 18 articles were included in the final analysis (Fig. 1). The 18 selected studies provided a combined sample of 916 children and adolescents (under 18 years of age) with sTBI. A GCS score of ≤ 8 was a primary selection criterion across all included manuscripts. Furthermore, clinical signs of increased Intracranial Pressure (ICP) and/or refractory Intracranial Hypertension (ICH) were confirmed in all articles as parameters for DC indication. Regarding clinical criteria, pupillary abnormalities were analyzed in nine articles (Rallis 2018 [12], Tang 2018 [13], Ballestero 2019 [14], Manfiotto 2019 [5], Beez 2019 [15], Goker 2020 [16], Hubertus 2022 [17], Nagy 2023 [18], Jaradat 2025 [19]) and were identified in 47.2% of the total evaluated cases (162/343). These abnormalities included pupillary asymmetry (anisocoria) or bilateral changes in diameter (mydriasis or miosis) (Table 1). Additionally, scales such as the Abbreviated Injury Score (AIS) (Bruns 2022 [20]), Injury Severity Score (ISS) (Tang 2018 [13], Bruns2022 [20]), and Pediatric Risk of Mortality (PRISM) (Mhanna 2015 [21], Rallis 2018 [12]) were utilized in several studies to characterize trauma severity and the risk of unfavorable prognosis when considering DC.

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Regarding brain CT scans, all 18 articles identified the following findings as indications for DC: acute traumatic lesions with compressive effects, diffuse brain injury or swelling with mass effect, and acute hemorrhagic space-occupying lesions associated with Midline Shift (MLS) or obliteration of the basal cisterns. Three manuscripts highlighted the Marshall classification (Ballestero 2019 [14], Hubertus 2022 [17], Nagy 2023 [18]), while six emphasized the Rotterdam score (Rallis 2018 [12], Manfiotto 2019 [5], Beez 2019 [15], Korhonen 2022 [22], Nagy 2023 [18], Morgan 2025 [23]) as supportive diagnostic tools for DC indication. ICPm via ventricular, parenchymal, or subdural catheters—was performed in 48.6% of cases (386/794) and was analyzed in 16 studies. Among the reference centers, four reported systematic ICPm for their entire samples (Mhanna 2015 [21], Hockel2017 [24], Rallis 2018 [12], Hubertus 2022 [17]). The overall in-hospital mortality rate was 24% (220/916) (Table 1). No statistically significant difference in mortality was found between centers that did not implement universal invasive ICPm (22.5%; 167/743) and those that performed it in all patients (27.4%; 14/51) (OR 0.7662; 95% CI 0.4046 – 1.4512; z statistic 0.817; p = 0.4) (Table 2). Based on the analysis of these 18 articles, a flowchart was developed to assist in the clinical indication of DC for children and adolescents under 18 years of age with sTBI (Fig. 2).

DISCUSSION

Even in specialized trauma centers, the indication for DC in children with sTBI is usually an individual decision made by the neurosurgeon on duty in the pediatric emergency department. This highlights the ongoing difficulty in standardizing recommendations for this surgical procedure [3,4,25]. Consequently, the topic remains highly debated and controversial in the literature. Although scoring systems, such as the Surgical Intervention for Traumatic Injury (SITI) score, have been developed to assist neurosurgical teams in decision-making [25,26], universally accepted criteria have yet to be established. DC is commonly described as a unilateral fronto-temporo-parietal decompression (hemicraniectomy), but it may also be performed through the removal of bilateral frontal bones (bifrontal craniectomy) or via bifrontal-biparietal approaches [4,27,28,29,30,31]. The challenges in establishing standardized guidelines are evident in the current systematic review, which synthesizes various clinical and tomographic criteria in an effort to guide this surgical indication.

Among the clinical criteria, TBI severity (specifically GCS scores of ≤ 8) stands out in most studies as the starting point for discussions regarding DC indication. It is frequently emphasized as the primary parameter for decisions in favor of the procedure [3,20,21,28,32,33], often combined with other criteria and scales for a more accurate assessment of trauma severity [12,20]. For instance, the presence of pupillary abnormalities strengthens the suspicion of post-traumatic intracranial injury with compressive effects on brain structures [12,13,14,15,18,19], supporting the need for neurosurgical decompression. Other clinical signs of elevated ICP—such as bradycardia, systemic arterial hypertension, respiratory rhythm abnormalities, and focal motor neurological deficits—along with criteria established through invasive ICP monitoring when performed— are also essential for the indication of DC in children with sTBI [3,4,12,15,16,17,22,23,24,30,31,32,34].

Following the clinical assessment, a brain CT scan is mandatory and remains the gold standard for diagnosing acute post-traumatic lesions, playing a decisive role in confirming the indication for DC. Tomographic criteria—such as the diagnosis of intracranial hemorrhagic lesions, MLS, and the status of the basal cisterns—led to the development of the Marshall and Rotterdam classifications. These CT-based systems are the most frequently used scales to assist in DC indications [35], a finding further supported by this systematic review. The Marshall classification stratifies CT findings into six categories, accounting for MLS (measured in millimeters), the appearance of the basal cisterns, and the presence of hemorrhagic lesions (measured in milliliters or cm^3) [35,36]. Conversely, the Rotterdam classification assigns scores ranging from 1 to 6. In this system, a score of 1 represents a normal CT scan, while specific scores are assigned to identified abnormalities. This scale evaluates the compression of basal cisterns, the degree of MLS, the presence of epidural lesions with mass effect, and the occurrence of intraventricular or subarachnoid hemorrhage [35,37].

Invasive ICPm stands out as a critical criterion for defining refractory ICH during initial medical treatment, helping to determine the optimal timing for DC [4,31]. However, the universal use of invasive

ICPm in all children and adolescents with sTBI has been questioned, even in reference centers. The primary reasons include:

1. The initial severity identified in polytraumatized children often necessitates immediate DC;

2. Disposable materials are not always available for all pediatric sTBI cases;

3. The procedure involves high costs and is not consistently accessible across healthcare centers and public health systems worldwide [3,13,14,15,22].

Regarding mortality rates in children with sTBI, major specialized reference centers report rates between 22% and 30% [3,38,39], which is consistent with the findings of the present systematic review. Notably, mortality rates showed no statistically significant differences when comparing reference centers that performed systematic invasive ICPm in all children to those that did not. We acknowledge that, despite the result presented here, there is an imbalance in the number of participants across the comparison groups, and this imbalance may limit the statistical power of the analyses in this regard.

Flowchart, and Limitations

Our results enabled the development of a flowchart designed to guide the decision-making process for DC, specifically considering the Brazilian context—a country of continental dimensions with significant socioeconomic disparities. It is particularly challenging to rigidly adopt management strategies established in high-income countries without critical reflection or flexibility, given that even in those nations, universal invasive ICPm is not always feasible. DC occupies a unique position among neurosurgical interventions because it is frequently indicated in scenarios of refractory ICH, where clinical urgency coexists with high prognostic uncertainty. However, a consensus is still lacking regarding objective criteria for the indication and ideal timing of this procedure, as well as the specific ICP thresholds that justify its use. This gap highlights that the decision to perform DC is more than a technical act; it is a complex deliberative process. Therapeutic proportionality must be analyzed, considering not only the potential for survival but also the risks of severe neurological sequelae, prolonged suffering, and long-term functional impact. It was beyond the scope of this study to establish the superior surgical technique, define specific ICP thresholds, determine the optimal timing for DC (early vs. late), or identify medium- and long-term functional outcomes (such as neurological recovery, quality of life, or long-term disability). The absence of longitudinal follow-up limits our understanding of the true long-term benefit of this intervention. We reinforce that the decision to perform DC should not be based solely on immediate survival but must also weigh long-term functional outcomes and therapeutic proportionality against the expected neurological prognosis.

CONCLUSION

The compilation of clinical and brain CT scan criteria for DC indication in pediatric sTBI patients (under 18 years of age) demonstrates a clear consensus. A GCS score of ≤ 8, associated with pupillary abnormalities or clinical signs of increased intracranial pressure, combined with space-occupying post-traumatic lesions identified on CT scans—specifically those producing a compressive effect and midline shift—constitute indications for performing DC, regardless of whether ICPm is utilized.

DISCLOSURES

Ethical approval

This systematic review included only articles published in scientific journals that have been analyzed and authorized by a research ethics committee. Since the design of the present study is exclusively a systematic review (previously published literature) without need for retrospective analysis of medical records or inclusion of new cases (no new human participant recruitment), no consent from a research ethics committee was needed.

Consent to participate

Since the design of the present study is exclusively a systematic review (previously published literature) without need for retrospective analysis of medical records or inclusion of new cases (no new human participant recruitment), no consent from a research ethics committee was needed.

Conflict of interest

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper

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Artificial intelligence

The authors affirm that no artificial intelligence tools were used in the writing, editing, or content generation of this manuscript.

CONTRIBUTIONS

José Roberto Tude Melo: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Visualization, Writing - original draft, Writing - review & editing,
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Júlia Calviello Giordano: Data curation, Investigation, Methodology, Validation, Visualization, Writing - review & editing
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Paula de Almeida Azi: Data curation, Investigation, Methodology, Validation, Visualization, Writing - original draft, Writing - review & editing
Jean Gonçalves de Oliveira: Validation, Visualization, Writing - review & editing.
José Carlos Esteves Veiga: Project administration, Supervision, Validation, Visualization, Writing - review & editing

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