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Review Article

Can early cranioplasty reduce the incidence of hydrocephalus after decompressive craniectomy? A meta-analysis

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Received : 23 March 2020
Accepted : 08 April 2020
Published : 02 May 2020

DOI
10.25259/SNI_120_2020

Quick Response Code:

ABSTRACT

Background: Do alterations of cerebrospinal fluid dynamics secondary to decompressive craniectomy (DC) lead to hydrocephalus, and can this effect be mitigated by early cranioplasty (CP)? In this meta-analysis, we evaluated whether the timing of CP decreased the incidence of postoperative hydrocephalus.

Methods: We performed a systematic search of PubMed/MEDLINE, Scopus, and the Cochrane databases using Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for English language articles (1990–2020). We included case series, case–control, and cohort studies, and clinical trials assessing the incidence of hydrocephalus in adult patients undergoing early CP (within 3 months) versus late CP (after 3 months) after DC.

Results: Eleven studies matched the inclusion criteria. The rate of postoperative hydrocephalus was not significantly different between the early (=96/1063; 9.03%) and late CP (=65/966; 6.72%) group ($P = 0.09$). Only in the three studies specifically reporting on the rate of hydrocephalus after DC performed to address traumatic brain injury (TBI) alone was there a significantly lower incidence of hydrocephalus with early CP ($P = 0.01$).

Conclusion: Early CP (within 90 days) after DC performed in TBI patients alone was associated with a lower incidence of hydrocephalus. However, this finding was not corroborated in the remaining eight studies involving CP for pathology exclusive of TBI.

Keywords: Cranioplasty, Decompressive craniectomy, Hydrocephalus, Ventriculoperitoneal shunt

INTRODUCTION

Hydrocephalus is one of the main complications of decompressive craniectomy (DC).[9] In the literature, the rate of hydrocephalus after DC ranged from 11.9% to 36% in adults, with most cases requiring ventriculoperitoneal shunt placement (VPS).[8] Early cranioplasty (CP) was typically defined as those performed within ≤3 months after DC.[6] In this meta-analysis, we evaluated whether early versus late CP resulted in a lower rate of hydrocephalus following DC.

MATERIALS AND METHODS

Search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed utilizing the PubMed/Medline, Scopus, and Cochrane databases from 1999 to 2020.

Keywords included "Cranioplasty, early" or "cranioplasty, timing."

Study selection and outcome

In 11 studies (comparative case control or cohort), we asked whether early CP (i.e., CP ≤3 months) versus later CP differently impacted the rate of hydrocephalus following DC [Table 1].[1-5,7,9,10-12,14]

Statistical method for meta-analysis

The meta-analysis was performed using STATA/IC 13.1 statistical package (StataCorp LP, College Station, TX, USA). The log odds ratios (LORs) and 95% confidence intervals for each outcome were then reckoned as by "early" and "late" time points. LORs were pooled using the Mantel–Haenszel method with fixed effects model. The I^2 metric was reported to further quantify heterogeneity (0% = no heterogeneity, 100% = maximal heterogeneity). $P < 0.05$ was considered statistically significant.

RESULTS

Inclusion of eleven studies

Eleven studies met the inclusion criteria for this meta-analysis [Figure 1]. Ten studies were retrospective, and one study involved a prospective cohort.[1-5,7,9,10-12,14]

All papers were classified as level of evidence "IIIB."

Indications for DC

Indications for initial DC included; arteriovenous malformations, ischemic or hemorrhagic stroke, infection, ruptured aneurysm, trauma (i.e., traumatic brain injury [TBI] alone – 3 studies),[3,8,11] or tumors. Nine of 11 studies defined early CP as CP as those performed within equal to/or <3 postoperative months versus late CP, occurring after 3 postoperative months. All studies reported the development of hydrocephalus as a complication following DC; in 8 of 11 studies, hydrocephalus required a VPS [Table 1].

Pooled rate of hydrocephalus

The pooled rate of hydrocephalus for these 11 studies averaged 7.93% (n = 161/2029, with a range of 0.7–28.4%). The rate of postoperative hydrocephalus was not significantly different between the early (=96/1063; 9.03%) and late CP (=65/966; 6.72%) groups [Figure 2].

However, in three studies solely involving patients undergoing DC for TBI, there was a significantly lower incidence of hydrocephalus in the early CP patients (=11/152; 7,23%) versus late CP (=36/171; 21.05%) [Figure 3].[3,8,11]

DISCUSSION

We utilized this meta-analysis to determine whether early CP decreased the rate of hydrocephalus following DC. Notably, we did not find any prospective, randomized, comparative studies to clearly answer this question.

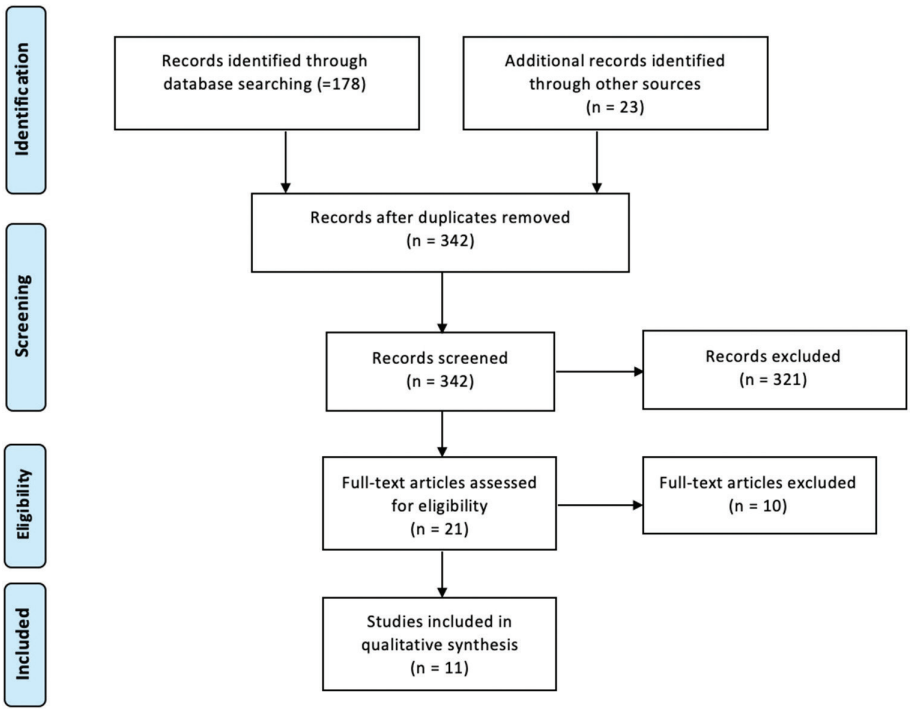

Figure 1: Flowchart of search mechanism according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Table 1: Characteristics of included studies reporting hydrocephalus rate related to cranioplasty timing.

References	Type of study	Indication for DC	Type of DC	Type of CP	Early CP cutoff (months)	Definition of hydrocephalus	Number of patients with hydrocephalus in early CP group	Total number of patients in early CP group	Number of patients with hydrocephalus in late CP group	Total number of patients in late CP group
Cho, 2011	Retrospective	TBI	NR	Autologous, synthetic	1,5*	Enlarged ventricles on CT scan without neurological deterioration or lack of improvement.	2	15	1	21
Piedra, 2013	Retrospective	Stroke	Unilateral	Autologous, synthetic	3	Need to VP shunt	1	37	0	37
Walcott, 2013	Retrospective	Stroke, TBI	Unilateral, bifrontal	Autologous	3	Need to VP shunt	6	71	6	168
Bender, 2013	Retrospective	TBI, intracerebral hematoma, SAH, ischemic stroke	Unilateral, bifrontal	NR	3	Enlarged ventricles on CT scan with neurological deterioration or lack of improvement.	12	75	6	72
Piedra, 2014	Retrospective	TBI	NR	Autologous, synthetic	3	Need to VP shunt	6	78	1	79
Hng, 2015	Retrospective	TBI, intracerebral hematoma, SAH, ischemic stroke, infection	Unilateral, bifrontal	Autologous, synthetic	3	Need to VP shunt	4	121	2	66
Quah, 2016	Prospective	Trauma, ischemic stroke, SAH, tumor	NR	Autologous, synthetic	3	Need to VP shunt	0	25	1	45
Morton, 2017	Retrospective	TBI, intracerebral hematoma, SAH, ischemic stroke, infection, tumor	NR	Autologous, synthetic	NA*	NR	59	521	9	233
Nasi, 2018	Retrospective	TBI	Unilateral, bifrontal	NR	3	Need to VP shunt	3	59	34	71
Bjorson, 2019	Retrospective	TBI, intracerebral hematoma, SAH, ischemic stroke, infection	Unilateral, bifrontal	Synthetic	3	Need to VP shunt	2	24	5	66
Goedemans, 2020	Retrospective	TBI, intracerebral hematoma, SAH, ischemic stroke, infection	NR	Autologous, synthetic	3	Need to VP shunt	1	37	0	108

NR: Not reported, NA: Not available, TBI: Traumatic brain injury, SAH: Subarachnoid hemorrhage, VP: Ventriculoperitoneal, *Article reports individual case data or data at various time intervals. Patients were divided at a 90-day cutoff

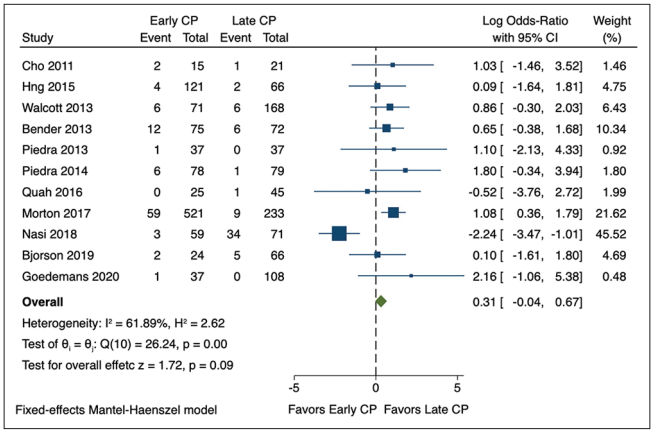

Figure 2: Meta-analysis of hydrocephalus rate in the 11 included studies.

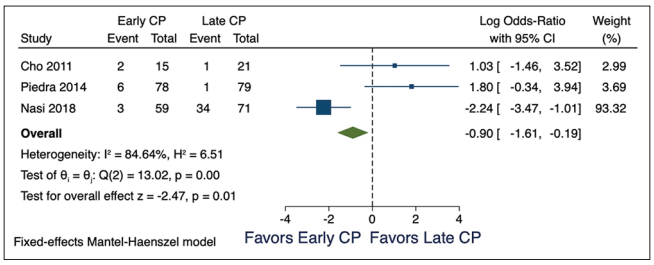

Figure 3: Meta-analysis of hydrocephalus rate in the three studies focused on trauma patients.

Studies favoring early CP for DC to reduce incidence of hydrocephalus

In Xu *et al.* study in 2015, they reviewed three studies involving 312 patients that showed early CP following DC increased the risk of hydrocephalus.[15] When Tasiou *et al.* reviewed 10 studies evaluating the timing of CP after DC for TBI, four of which were included in our own meta-analysis, they reported a general trend for early CP to improve cerebrospinal fluid (CSF) dynamics and perfusion.[13]

Rate of hydrocephalus requiring VP shunt after DC

In 2016, Malcom *et al.* observed in four studies their following DC that the pooled rate of hydrocephalus requiring a VP shunt was slightly lower (5.6%) than the rate in our study (7.93%).[6]

Why would early CP decrease rates of hydrocephalus?

Early CP may restore normal intracranial CSF pressure dynamics resulting in the spontaneous resolution of hydrocephalus and other CSF disturbances. On the contrary, delayed cranial reconstruction, by prolonging this disruption, may result in permanent dysfunction of the arachnoid granulations resulting in permanent hydrocephalus (e.g., such as the one seen in hydrocephalus induced by long-term CSF drainage).[8,9]

CONCLUSION

Early CP (within or equal to 90 days) after DC performed in TBI patients was associated with a lower incidence of hydrocephalus. However, this finding was not corroborated in other studies for patients undergoing DC attributed to other etiologies.

Ethical approval

All procedures performed in studies involving human participants were in accordance with in ethical standards.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Nasi D, Dobran M. Can early cranioplasty reduce the incidence of hydrocephalus after decompressive craniectomy? A meta-analysis. Surg Neurol Int 2020;11:94.