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

Davide Nasi, Mauro Dobran

Department of Neurosurgery, Marche Polytechnic University Faculty of Medicine, Ancona, Marche, Italy.

E-mail: *Davide Nasi - davidenasi83@gmail.com; Mauro Dobran - dobran@libero.it

INTRODUCTION

Hydrocephalus is one of the main complications of decompressive craniectomy (DC). 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). Early cranioplasty (CP) was typically defined as those performed within ≤3 months after DC. 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].

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. 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), 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].

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. Need to VP shunt | 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, synthetic | 3 | Need to VP shunt | 6 | 71 | 6 | 168 |
| Bender, 2013 | Retrospective | TBI, intracerebral hematoma, SAH, ischemic stroke | NR | Unilateral, bifrontal | 3 | Need to VP shunt | 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* | 9 | 233 |
| Nasi, 2018  | Retrospective | TBI               | Unilateral, bifrontal | NR | 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.
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. 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.

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%).

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).

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 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.

REFERENCES

1. Bender A, Heulin S, Röhrer S, Mehrkens JH, Heidecke V, Straube A, et al. Early cranioplasty may improve outcome in neurological patients with decompressive craniectomy. Brain Inj 2013;27:1073-9.
2. Bjornson A, Tajsic T, Kolias AG, Wells A, Naushahi MJ, Anwar F, et al. A case series of early and late cranioplasty-comparison of surgical outcomes. Acta Neurochir (Wien) 2019;161:467-72.
3. Cho K, Park S. Safety and efficacy of early cranioplasty after decompressive craniectomy in traumatic brain injury patients. J Korean Neurotraumatol Soc 2011;7:74-7.
4. Goedemans T, Verbaan D, van der Veer O, Bot M, Post R, Hoogmoed J, et al. Complications in cranioplasty after decompressive craniectomy: Timing of the intervention. J Neurol 2020; [Epub ahead of print]. DOI: 10.1007/s00415-020-09695-6.
5. Hng D, Bhaskar MI, Khan FM, Budgeon C, Damodaran O, Knuckey N, et al. Delayed cranioplasty: Outcomes using frozen autologous bone flaps. Craniomaxillofac Trauma Reconstr 2015;1:190-7.
6. Malcolm JG, Rindler RS, Chu JK, Grossberg JA, Pradilla G, Ahmad FU. Complications following cranioplasty and relationship to timing: A systematic review and meta-analysis. J Clin Neurosci 2016;33:39-51.
7. Morton RP, Abecassis IJ, Hanson JF, Barber JK, Chen M, Kelly CM, et al. Timing of cranioplasty: A 10.75-year single-center analysis of 754 patients. J Neurosurg 2018;128:1648-52.
8. Nasi D, Dobran M, Iacoangi M, Di Somma L, Gladi M, et al. Early cranioplasty and hydrocephalus. Surgical Neurology International 2020;11(94):4.
Scerrati M. Paradoxical brain herniation after decompressive craniectomy provoked by drainage of subdural hygroma. World Neurosurg 2016;91:673.e1-4.

9. Nasi D, Gladi M, Di Rienzo A, di Somma L, Moriconi E, Iacoangeli M, et al. Risk factors for post-traumatic hydrocephalus following decompressive craniectomy. Acta Neurochir (Wien) 2018;160:1691-8.

10. Piedra MP, Ragel BT, Dogan A, Coppa ND, Delashaw JB. Timing of cranioplasty after decompressive craniectomy for ischemic or hemorrhagic stroke. J Neurosurg 2013;118:109-14.

11. Piedra MP, Ragel BT, Dogan A, Coppa ND, Delashaw JB. Timing of cranioplasty after decompressive craniectomy for trauma. Surg Neurol Int 2014;25:25.

12. Quah BL, Low HL, Wilson MH, Bimpis A, Nga VD, Lwin S, et al. Is there an optimal time for performing cranioplasties? Results from a prospective multinational study. World Neurosurg 2016;94:13-7.

13. Tasiou A, Vagkopoulos K, Georgiadis I, Brotis AG, Gatos H, Fountas KN. Cranioplasty optimal timing in cases of decompressive craniectomy after severe head injury: A systematic literature review. Interdiscip Neurosurg 2014;1:107-11.

14. Walcott BP, Kwon CS, Sheth SA, Fehnel CR, Koffie RM, Asaad WF, et al. Predictors of cranioplasty complications in stroke and trauma patients. J Neurosurg 2013;118:757-62.

15. Xu H, Niu C, Fu X, Ding W, Ling S, Jiang X, et al. Early cranioplasty vs. Late cranioplasty for the treatment of cranial defect: A systematic review. Clin Neurol Neurosurg 2015;136:33-40.

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.