Article published online: 2024-12-24

A Transdiploic Cerebrospinal Fluid Diversion Device: Potential Use in Intracranial Hypertension Associated with Traumatic Brain Injury

Luis Rafael Moscote-Salazar[1] Amit Agrawal[2] William A. Florez-Perdomo[1] Ariana Chacon[1]

[1] Department of Research, Colombian Clinical Research Group in Neurocritical Care, Bogota, Colombia
[2] Department of Neurosurgery, All India Institute of Medical Sciences, Saket Nagar, Bhopal, Madhya Pradesh, India

Address for correspondence Luis Rafael Moscote-Salazar, MD, Colombian Clinical Research Group in Neurocritical Care, Bogota 110110, Colombia (e-mail: rafaelmoscote21@gmail.com).

Indian J Neurotrauma

Abstract

Intracranial hypertension (IH) is a critical condition in neurocritical care and needs effective management to avoid severe outcomes like brain herniation and cerebral ischemia. External ventricular drains, although effective in reducing intracranial pressure, pose risks of infection, hemorrhage, and malfunction. This technical note present the transdiploic cerebrospinal fluid (CSF) diversion device, an alternative technique for CSF diversion utilizing the parietal diploic venous system.

Keywords

- cerebrospinal fluid diversion
- neurotrauma
- ventriculostomy
- diploic venous system
- intracranial hypertension

Introduction

Intracranial hypertension (IH) is considered a severe condition in the neurocritical care field. Appropriate and adequate management of IH to control elevated intracranial pressure (ICP) is essential to prevent brain herniation, cerebral ischemia, and neurological damage and to improve outcomes.[1] An appropriate management of IH is, therefore, paramount to improving patient outcomes.[2,3] External ventricular drains (EVDs) are used as a strategy to reduce ICP; however, they can be associated with an increased risk of infection, bleeding, and malfunction, delaying patient recovery and increasing morbidity. In this technical note, we elaborate on an alternative method, that is, transdiploic cerebrospinal fluid diversion device (TCFDD), to reduce ICP that can be used in neurotrauma patients who are admitted to neurocritical care settings (see ►**Fig. 1**).

Pathophysiology of Intracranial Hypertension

It is well known that an imbalance between the production and absorption of cerebrospinal fluid (CSF) or from increased intracranial blood volume, brain edema, or space-occupying lesions can lead to raised ICP/IH. Acute neurological alterations like traumatic brain injury, hydrocephalus, intracerebral hemorrhage, subarachnoid hemorrhage, and malignant stroke can be associated with IH. When ICP rises, IH can increase, and adequate management is relevant to avoid changes in cerebral perfusion that can lead to severe neurological deficits. Traditional ICP management techniques, such as ventriculostomy, are highly invasive, involving the placement of catheters into the brain's ventricular system to drain CSF. Performing ventriculostomy could be associated with complications such as catheter misplacement, brain tissue damage, hemorrhage, and ventriculitis.

DOI https://doi.org/10.1055/s-0044-1801325.
ISSN 0973-0508.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

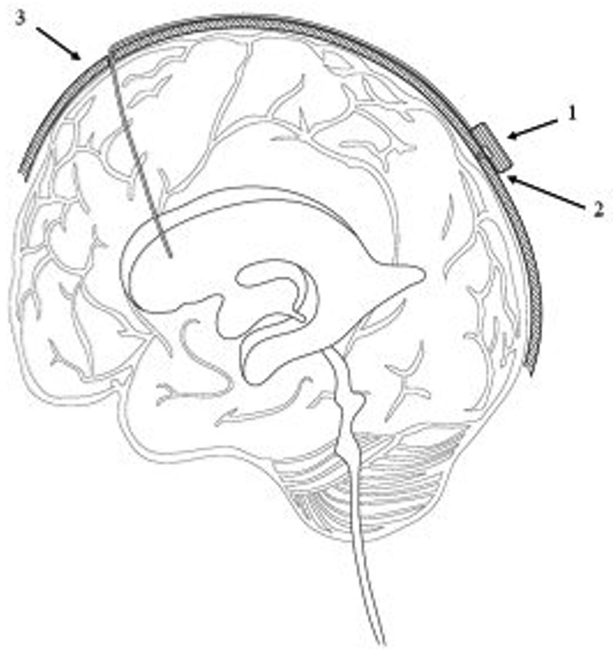

Fig. 1 Transdiploic cerebrospinal fluid diversion device. 1. Intraventricular catheter. 2. Extracranial device 3. Intradiploic screw.

The Diploic Venous System

In recent years, the diploic venous system has become a potential alternative route for CSF drainage.[4–6] The venous channels of Breschet provide a physiological link between the scalp and intracranial circulation, suggesting that they offer a less invasive option for CSF diversion. Preclinical studies have shown that the diploic system can absorb CSF in animal models of hydrocephalus.[7,8] Some researchers have proposed the use of the diploe for alternative fluid diversion strategies in both chronic and acute settings, although clinical applications remain limited.[7–10] Based on this anatomical and physiological background, we hypothesize that the diploic system could be effectively leveraged for temporary CSF diversion in the acute management of IH using a device-type screw.

Diploic System and the Proposed

The proposed device is designed to divert CSF through the parietal diploic venous system, providing a safe and temporary means of reducing ICP without requiring direct access to the brain's ventricles. The parietal diploe is a vascularized cancellous bone located between the inner and outer layers of the skull. The diploe (i.e., the spaces of Breschet) are a network of venous channels that connect the superficial veins of the scalp to the intracranial venous system, including the dural venous sinuses. These diploic veins are well developed in the parietal region and present a unique opportunity for CSF drainage, serving as a natural pathway for diverting fluid from the intracranial compartment.

Design and Mechanism of the TCFDD

The TCFDD is focused on physiological foundations well recognized during a ventriculostomy but explicitly designed to engage with the parietal diploe rather than the brain's ventricles. The device consists of a screw-like mechanism that is anchored into the parietal bone, allowing CSF to drain into the diploic venous system and leading to reduced ICP. The device has a hollow central channel through which CSF flows, and a valve mechanism regulates the drainage rate, preventing excessive fluid diversion and maintaining safe ICP levels. The proposed device is intended for short-term use in acute neurocritical conditions where temporary ICP management is necessary. The device can be removable. One advantage of this device is a reduced infection risk in contrast with the primary risks of ventriculostomy, which can have complications like ventriculitis, which can lead to severe complications and prolonged hospital stays. This device offers a prolonged functional duration, which could reduce the need for repeated invasive procedures. This device can be easily removed and converted to conventional shunting.

Conclusion

The diploic venous system can be explored as a temporary solution to address increased ICP and thus as a CSF diversion mechanism, reducing the risk of infection, which improves patient outcomes in the neurocritical care setting. In summary, the proposed TCFDD shall serve as a novel approach to managing IH that will offer a safe and less invasive alternative to conventional ventriculostomy.

Funding
None.

Conflict of Interest
None declared.

References

1 Sharma S, Hashmi MF, Davidson CL, Kumar A. Intracranial Hypertension. Treasure Island, FL: StatPearls Publishing; 2024
2 Zhang X, Medow JE, Iskandar BJ, et al. Invasive and noninvasive means of measuring intracranial pressure: a review. Physiol Meas 2017;38(08):R143–R182
3 Robba C, Bacigaluppi S, Cardim D, Donnelly J, Bertuccio A, Czosnyka M. Non-invasive assessment of intracranial pressure. Acta Neurol Scand 2016;134(01):4–21
4 Lachkar S, Dols MM, Ishak B, Iwanaga J, Tubbs RS. The diploic veins: a comprehensive review with clinical applications. Cureus 2019;11(04):e4422
5 Tsutsumi S, Ogino I, Miyajima M, Ito M, Arai H, Yasumoto Y. Cerebrospinal fluid drainage through the diploic and spinal epidural veins. J Anat 2015;227(03):297–301
6 Skrzat J, Zarzecki M. Cranial diploic channels and their veins: a review of literature. Folia Med Cracov 2022;62(04):77–90
7 Johnston KD, Walji AH, Fox RJ, Pugh JA, Aronyk KE. Access to cerebrospinal fluid absorption sites by infusion into vascular channels of the skull diploë. J Neurosurg 2007;107(04):841–843

8 Yağmurlu K, Sokolowski J, Soldozy S, et al. A subset of arachnoid granulations in humans drain to the venous circulation via intradural lymphatic vascular channels. J Neurosurg 2021;136(03):917–926
9 Fox RJ, Walji AH, Mielke B, Petruk KC, Aronyk KE. Anatomic details of intradural channels in the parasagittal dura: a possible pathway for flow of cerebrospinal fluid. Neurosurgery 1996;39 (01):84–90, discussion 90–91
10 García-González U, Cavalcanti DD, Agrawal A, et al. The diploic venous system: surgical anatomy and neurosurgical implications. Neurosurg Focus 2009;27(05):E2

