Interhemispheric Endoscopic Fenestration of the Lamina Terminalis through a Single Frontal Burr Hole

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Abstract

Objective We evaluate the feasibility and safety of performing a novel interhemispheric endoscopic fenestration of the lamina terminalis (IEFLT) through a single frontal burr hole immediately lateral to the superior sagittal sinus.

Methods Five cadaveric heads underwent IEFLT. Sequential burr holes were made beginning above the glabella and progressed cranially to caudally until the frontal sinus. An endoscope was inserted, and interhemispheric dissection of the arachnoid membranes was completed with endoscopic instruments in a straight direction from the point of entry to the lamina terminalis (LT). Angled optics (0 and 30 degrees) were used to study the neurovascular structures and surgical landmarks.

Results The IEFLTs were successfully completed in all specimens and allowed for good visualization of the inferior portion of the LT. The arachnoid dissections were achieved uneventfully. The endoscope provided good surface control of the LT and excellent stereoscopic visualization of the neurovascular complexes. Improved circumferential visualization of the superior part of the anterior portion of the third ventricle was attained.

Conclusion IEFLT is a potential alternative to the classic endoscopic third ventriculostomy and a simpler alternative to the subfrontal EFLT, although surgical maneuverability is still limited due to the size of the probe in relation to the narrow surgical corridor.

Keywords

- lamina terminalis
- endoscopic
- fenestration
- burr hole
- third ventriculostomy

Introduction

In the past few decades, endoscopic third ventriculostomy (ETV) performed at the floor of the third ventricle through a precoronal burr hole has become a well-established surgical technique. ETV is the treatment of choice for many forms of obstructive hydrocephalus.^{1–3} However, anatomical variations of the basilar artery, clivus, and their relation to the floor of the third ventricle may hinder the standard EVT in a small subpopulation of patients.

Despite exhaustive descriptions of the different microscopic and endoscopic techniques and locations for ventriculostomy, each strategy has its limitations and disadvantages.^{4–10}

The lamina terminalis (LT) is a known route to the third ventricle and has been used as a target in the treatment of noncommunicating hydrocephalus. We propose an interhemispheric endoscopic fenestration of the lamina terminalis (IEFLT) through a single frontal burr hole immediately lateral to the superior sagittal sinus, in an attempt to find an alternative that is as simple, safe, and minimally invasive as

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the classic ETV. We evaluate the feasibility of this technique and study the anatomical landmarks used in this approach.

Methods

Five preserved cadaveric heads injected with colored latex (red for arteries and blue for veins), underwent IEFLT. Three-point fixation was achieved with a Mayfield head holder, and the head was positioned with 5 to 10 degrees of extension and 10 degrees of lateralization to the right side. Gravity was used to aid retraction of the right hemisphere.

Exposure of the bilateral frontal bone and orbital rim was achieved with a bicoronal skin incision and subperiosteal dissection. Sequential burr holes, ~ 15 mm in diameter and placed immediately lateral to the superior sagittal sinus, were performed beginning at 80 mm above the glabella and progressed in a cranial to caudal direction until the frontal sinus was opened (► Fig. 1). The burr holes were enumerated in a cranial to caudal direction toward the base of the anterior cranial fossa.

The number of burr holes placed depended on the size of the each specimen's frontal sinus. The dissection was attempted sequentially through each burr hole, beginning at burr hole I, to evaluate the most suitable location for approaching the LT. The maximum distance above the glabella was defined as the distance from the glabella to the inferior border of the first burr hole through which the IEFLT was technically feasible. Dissection was not attempted through the last, most anteroinferior, burr hole due to the obstruction of the frontal sinus.

Fig. 1 Sequence of placed burr holes, numbered (I–V) in a cranial to caudal direction. Gla, glabella; FB, frontal bone.

All specimens underwent IEFLT through a single right frontal burr hole (15-mm diameter). Dissections were performed using 0- and 30-degree rigid endoscopes (4 mm diameter, 18 cm length; Karl Storz; Tuttlingen, Germany). The arachnoid membrane was dissected using endoscopic instruments, brain retraction was achieved with a 12F Foley catheter filled with water, and LT fenestration was performed at the midline avascular region with a blunt dissector. The images were recorded and stored by the Karl Storz Aida system.

Approach

The right frontal burr hole was performed using a high-speed drill, immediately lateral to the superior sagittal sinus. The dura mater was opened in an arch shape with the base toward the superior sagittal sinus, and the frontal lobe, interhemispheric fissure, and cerebral falx were identified. The initial arachnoid dissection was completed without the endoscope to gain space at the interhemispheric corridor. The position of the head favored right frontal lobe retraction with the aid of gravity.

Once sufficient space was achieved between the cerebral falx and the frontal lobe, a rigid endoscope was inserted to improve illumination and dissection of deep-sited structures (► Fig. 2A). Orientation was confirmed by observing the anterior cranial base at the superior part of the monitor. Brain retraction was achieved with a 12F Foley catheter filled with water to facilitate arachnoid dissection. As the dissection progressed, the Foley catheter was relocated deeper into the interhemispheric fissure (► Fig. 2B). The cerebral falx was followed anteriorly and inferiorly to the crista galli and the olfactory groove. The olfactory bulb and the cribriform plate were used as important anatomical landmarks (► Fig. 2C).

From this point, sufficient dissection of the arachnoid was required to advance the endoscope without risking injury to the interhemispheric vessels. The endoscope was advanced posteriorly along the midline of the anterior cranial fossa. The optic nerves were identified as they traveled laterally to the optic canal from the optic chiasm. The LT was identified as a thin sheet of gray matter and pia mater that attached to the upper surface of the chiasm and stretched upward to fill the interval between the optic chiasm and the rostrum of the corpus callosum. Anterior to the LT, both anterior cerebral arteries and the anterior communicating artery (ACoA) were observed. Beneath the chiasm, the pituitary stalk was directed anteriorly and caudally to the sellar diaphragm. Above the chiasm, the LT was identified with the chiasmatic and hypothalamic branches of the ACoA contouring to its central avascular region where the fenestration was performed (► Fig. 2D, 2E). Blunt dissection and fenestration of the LT was performed under endoscopic guidance, with excellent anatomical visualization (► Fig. 3).

Results

Dissection and IEFLT through a single burr hole were feasible and more easily performed when closer to the anterior cranial base. The burr holes located high above the glabella limited

Fig. 2 Right frontal burr hole. (A) Arachnoid dissection at the interhemispheric fissure. (B) Improved brain retraction with a Foley catheter. (C) Identification of anatomical landmarks at the anterior cranial base. (D) Anatomical control of the region around the lamina terminalis. (E) Completed fenestration of the lamina terminalis. CF, cerebral falx; *crib*, cribriform plate; FL, frontal lobe; LT, lamina terminalis; OB, olfactory bulb; ON, optic nerve; PS, pituitary stalk.

the final surgical step where posterior advancement of the endoscope was required to visualize the optic nerve and LT. In all specimens, dissection along the cerebral falx and identification of the olfactory bulb and cribriform plate improved the safety of the procedure.

Location of Burr Hole

The number of burr holes performed for evaluation on each specimen, from 80 mm above the glabella until the frontal sinus, varied from four (one specimen) to five (four speci-

mens). Excluding the last, most basal burr hole due to the presence of the frontal sinus, IEFLT was not possible through the first (I) or second (II) burr holes in all specimens due to the difficulty of progressing the endoscope posteriorly along the anterior cranial base. IEFLT was feasible through the third (III) burr hole in one specimen, the third (III) and fourth (IV) burr holes in two specimens, and the fourth (IV) burr hole in two specimens. The maximum distance or height above the glabella from which IEFLT was possible was 3.6 cm (►Table 1).

Fig. 3 Regional endoscopic anatomy and position of the endoscope. A1, A1 segment of the anterior cerebral artery; A2, A2 segment of the anterior cerebral artery; AComm, anterior communicating artery.

Discussion

Despite the high success rate of standard ETVs in treating noncommunicating hydrocephalus, some patients may not benefit from this procedure due to the close relationship between the floor of the third ventricle, the basilar artery, and the clivus—a potential anatomical limitation. The alternative in such cases is the ventriculoperitoneal shunt, which is associated with many complications related to shunt dependency (shunt infections, mechanical difficulties, and late malfunction).^{11–13} For this reason we evaluated an alternative strategy that avoids implantation of a prosthesis.

The exhaustive descriptions in the literature of many different techniques and locations for both microscopic and

endoscopic ventriculostomies indicate the imperfection of the technique and open the door for an alternative that is as simple, safe, and minimally invasive as the classic ETV.^{3–10}

The LT is a known route to the third ventricle that has been used in the management of suprasellar and ventricular pathologies, and it may be approached through anterior, antero-lateral, lateral, and transsphenoidal surgical corridors.¹⁴ Microsurgical fenestration of the LT, well described for use in ruptured aneurysm surgery, remains controversial in the literature. Although obstructive hydrocephalus secondary to subarachnoid hemorrhage involves a complex hydrodynamic pathophysiology, different from other forms of noncommunicating hydrocephalus, numerous studies support opening of the LT as a sufficient alternative to shunting.^{15–21}

Only a few studies addressing endoscopic fenestration of the LT through either a transcranial subfrontal or transventricular approach exist in the literature.^{4,5,9} Although promising, such endoscopic techniques also have their own limitations.

We propose a novel approach through a single frontal burr hole immediately lateral to the superior sagittal sinus that provides a simple and direct route to the LT. In our cadaveric study, the procedure demonstrated to be feasible through a 15-mm burr hole, and it was most easily performed when closest to the anterior cranial base without violation of the frontal sinus.

When using this transcranial endoscopic approach to the LT, crossing of the brain parenchyma is not required. This is of

Table 1 Dissection characteristics by specimen

Specimen	No. of burr holes	Feasibility (burr hole no.)	Maximum distance above glabella, cm
1	5	III	3.6
2	4	III	3.2
3	5	IV	2.2
4	5	III	3.5
5	5	IV	2.4

particular importance when considering that the ideal entry point to perform the transventricular LT fenestration is located in close proximity to the premotor area. Moreover, the transcranial approach also avoided several highly functional structures including the fornix, hypothalamus, and thalamus that may be injured when transventricular fenestration of the LT is attempted with a rigid endoscope.

The transcranial trans-LT ventriculostomy has the advantage of providing optimal control of the vasculature around the stoma site, something not attainable in transventricular approaches. Additionally, in the transcranial approach, the arachnoid membranes and adhesions that are dissected to reach the LT have the potential to reduce the potential for the failure of cerebrospinal fluid outflow from the third ventricle.

Spena et al described a subfrontal endoscopic fenestration of the LT (SEFLT) in cadaveric specimens, and they proposed a potential ETV alternative that provided complete control of the site of fenestration and its surrounding structures.⁵ Aside from the advantages of the transcranial approach, the interhemispheric approach through a single frontal burr hole provides a shorter, less invasive, and direct trajectory to the LT when compared with anterolateral approaches. The limited amount of bone resection is possible because bimanual dissection is not required to reach the LT.

The potential drawback of the endoscopic interhemispheric approach, similar to other transcranial endoscopic approaches, is the risk of vascular injury along the trajectory of the endoscope. This is minimized with arachnoid dissection and cerebral retraction from a Foley catheter, however. The use of an endoscope sheath could improve safety, especially during the insertion and removal of instruments. Additionally, the skin incision presents a cosmetic disadvantage, although this could be overcome with a glabellar or a forehead crease incision. Clinical studies are necessary to determine the effectiveness of the proposed approach in the treatment of hydrocephalus.

Conclusion

IEFLT is a feasible alternative to the classic ETV for the management of obstructive hydrocephalus that can be performed through a single burr hole placed immediately lateral to the superior sagittal sinus with a bone opening placed as high as 3.6 cm above the glabella. Clinical studies are required to evaluate the therapeutic efficacy of this approach.

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