

Microsurgical anatomy of the ventricular system, in particular
of the lateral aperture and the septum pellucidum

Doctoral thesis

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1. Introduction

The anatomical knowledge of the liquor spaces is essential for neurosurgeons, as they serve as natural corridors during intracranial operations. Moreover, pathological changes in the circulation of the cerebrospinal fluid are common indications of neurosurgical operations.

The present dissertation aims to describe the microsurgical anatomy of two regions: the lateral aperture of the fourth ventricle and the septum pellucidum.

The pontocerebellar cistern (cerebellopontine angle, CPA) is the most challenging region of the posterior scala due to the anatomical complexity of its neurovascular structures. The normal and pathological anatomy of the vessels and nerves of the CPA is well described in the neurosurgical literature. However, the available information is limited about the Bochdalek's flower basket (Bfb) and the closed variant of the lateral aperture. The relation of the latter to different cystic structures of the CPA is also controversial.

The primary closed variant of the lateral aperture is associated with the arachnoid cysts of the CPA and the diverticular enlargement of the lateral aperture, with or without simultaneous closure of the other apertures of the fourth ventricle (fourth ventricle outlet obstruction).

The septum pellucidum is a thin, sheat-like neural structure that forms the medial wall of the frontal horn and pars centralis of the lateral ventricles. The clinical significance of the septum pellucidum is related to its localization: this structure represents the only border between the two lateral ventricles. Its endoscopic fenestration (endoscopic septum pellucidotomy, ESP) is a well-described and accepted method of treating monoventricular hydrocephalus. The indications and the technical aspects of this operation are clarified, but the ideal position of the fenestration is controversial.

According to the majority of the authors, the septal veins should be preserved during the operation by using the avascular areas of the septum pellucidum.

It is generally accepted, that the septum pellucidum contains neural elements. However, there is a lack of their surgical topographic description in the literature as well as

the identification of the ideal perforation site considering their anatomy.

2. Aims

The aims of the present study can be summarized as follows.

- Describing the microsurgical anatomy and morphometry of the Bfb.
- Examining the macro-and microscopic anatomy and morphometry of the primary closed variant of the lateral aperture.
- Describing of the relation between the primary closed lateral aperture and the cystic structures of the CPA.
- Examining of the pathomechanism of the diverticular enlargement of the lateral aperture.
- Describing of the topographic anatomy of the neural elements of the septum pellucidum.
- Identifying of the ideal site for perforation during ESP from the aspect of the venous and neural anatomy.

3. Methods

The examinations presented in this dissertation were carried out on formalin fixed human cadavers. The cadavers were donated for education and research purposes to the Semmelweis University, Department of Anatomy, Histology and Embryology.

The examination of the Bochdalek's flower basket

42 human brains (84 CPA) were involved in this part of the dissertation. After removing the outer arachnoid, the extent of the Bfb was measured, and the relations between the choroid plexus and the neurovascular structures of the CPA as well as between the choroid plexus and the lateral aperture were registered. Finally, the choroid plexus was removed, and the extent of the lateral aperture was measured.

The examination of the primary closed form of the lateral aperture.

61 human brains (122 lateral apertures) were involved in this part. 42 of them were previously used at the examination of the Bfb. After removing the outer

arachnoid, the primary closed lateral apertures were identified, measured, and their relations with the surrounding neurovascular structures recorded. The specimens were then prepared for histological examination with hematoxylin and eosin, AZAN and Luxol-fast blue combined with cresyl violet and impregnated with silver according to the Gallyas method.

Clinical examinations

The documentation of patients operated with unilateral, symptomatic cystic structure located in the CPA was retrospectively analyzed. Ethical approval was not necessary due to the retrospective nature of this study.

The examination of the septum pellucidum

9 human brains (18 septa pellucida) were involved in this part of the dissertation. 7 of them were prepared for fiber dissection according to the method of Klingler. To validate the results of the dissections, two brains were prepared for histologic examination. The slides were stained with hematoxylin and eosin, Luxol fast blue

combined with crezyl violett and Luxol fast blue combined with picrosirius red.

Documentation of the dissections

Photo documentation with a millimeter scale was carried out in every step of the dissections using a Canon EOS 5D Mark I or Mark II body with 50 mm or 100 mm macro objectives.

The method of the morphometry

The morphometrical measurements were carried out with surgical rulers during the examination of the Bfb and with the Fiji open-source image manipulating software (version 1.51d) during the examination of the primary obstructed lateral apertures and the septum pellucidum.

4. Results

The Bochdalek's flower basket

The Bfb is located between the upper and middle neurovascular complexes of the CPA. It is composed of two structures: the cisternal segment of the choroid plexus of the fourth ventricle and the rhomboid lip.

The most common morphological variation of the choroid plexus was the spherical form. It was not identifiable in the CPA in one case. The lateral aperture and the Bfb was covered by a membrane in 6 cases. The morphology of the rhomboid lip showed triangular and rectangular variants. This structure covered only the proximal part of the choroid plexus in most cases, but on some specimens, it reached the distal pole of the plexus and therefore narrowed the lateral aperture.

The choroid plexus of the Bfb was directly in contact with the inferior anterior cerebellar artery in 20, with the inferior posterior cerebellar artery in 6, with the vertebral artery in 0 cases and with the vestibulocochlear nerve in 39 cases. The glossopharyngeal, vagal and accessorial nerves were attached to the Bfb in 57 cases. In 6 of these

cases this connection was so strong, that the nerves were unseparable from the Bfb without injuring the rhomboid lip.

The primary obstructed lateral aperture

Primary obstructed lateral aperture was found in 11 cases, all of them was unilateral. In one case, there was a significantly enlarged, thick walled cystic structure in the CPA. Its cavity was continuous with the fourth ventricle through the widened lateral recess and contained choroid plexus.

The histological structure of the primary closed lateral aperture was composed of three layers in all cases: an inner layer of ependymal cells, a middle layer of glial cells and an outer layer of connective tissue of the pia mater. The inner and middle layers were continuous with the identical layers of the lateral recess.

The histological features of the rhomboid lip, independently of its extent, corresponded to the histology of the primary obstructed lateral aperture.

Clinical examinations

5 patients with Luschka diverticulum underwent surgery between 2014 and 2017 in the Department of Neurosurgery, Katharinenhospital, Stuttgart, Germany. The preoperative MRI images showed a cystic structure in the CPA filled with cerebrospinal fluid, that communicated with the fourth ventricle through the widened lateral recess and contained choroid plexus. The glossopharyngeal, vagal and accessorial nerves were dislocated medially due to the compression caused by the cystic structure.

The postoperative MRI images provided indirect signs of a successfully performed decompression: the widening of the lateral recess was decreased; the wall of the diverticulum was separable from the temporal bone and the medial dislocation of the lower cranial nerves was reduced.

Septum pellucidum

The medial wall of the frontal horn and pars centralis of the lateral ventricles is composed of the dorsally located, thin septum pellucidum and of the subjacent and wider septum verum.

Gray matter corresponding to the septal nuclei was identifiable on the septum verum just anterior to the column of the fornix.

Three tracts were described on the septum pellucidum and septum verum using fiber dissection technique: 1) the superior fascicle of the septum pellucidum (between the genu of the corpus callosum and the fornix); 2) the inferior tract of the septum pellucidum (between the septal nuclei and the genu of the corpus callosum); and 3) the precommissural fibers of the fornix (between the postcommissural portion of the fornix and the septal nuclei).

The histological examinations validated the results of the fiber dissections concerning the location and the direction of the fibers.

The veins of the septum pellucidum and the septum verum were very variable, however, an avascular area located over the foramen interventriculare was identifiable in all cases.

A new anatomical variation of the anterior septal vein, that perforates the fornix and reaches the velum interpositum between its fibers, was described.

5. Conclusions

The Bfb of the two sides are symmetrical in case of a normal anatomical variation. The relation between the structures composing the Bfb and the vestibulocochlear, glossopharyngeal, vagal and accessorial nerves emphasize the importance of cautious placement of the retractor during operations through the retrosigmoid approach.

The identical histological structure of the primary closed lateral apertures and the rhomboid lip refers to a common embryological origin. The apertures of the fourth ventricle develop by perforation of the thinned ventricular wall. The failure of this process results in the primary obstructed form. The size of the rhomboid lip correlates with the extent of the perforation.

The histological structure of the Blake's pouch (originated from the imperforation of the median aperture of the fourth ventricle) and the diverticula of the CPA found in fourth ventricle outlet obstruction are identical with the histological features of the rhomboid lip and the primary obstructed lateral aperture.

According to the results of the present dissertation, the pathomechanism of the unilateral Luschka diverticulum could be explained as follows. The combination of an extremely large choroid plexus and a primary obstructed lateral aperture results in the diverticular enlargement of this pouch through local hypersecretion and decreased outflow of cerebrospinal fluid, leading to symptoms.

Considering the neural and the vascular architecture of the septum pellucidum, the optimal site of the fenestration of the septum during endoscopic septum pellucidotomy is localized over the interventricular foramen, where the superior tract of the septum pellucidum runs.

In order to avoid the injury of the pre- and postcommissural fibers of the fornix, a distance of few millimeters superiorly and minimum 5 millimeters rostrally should be kept during the fenestration.

The results of the present dissertation does not suggest using the anterior avascular area because of the vicinity of the septal nuclei. The anatomy of the septal veins had a great variability, however, an avascular area over the foramen interventriculare was identifiable in all cases.

6. Publications

Related to the present dissertation

- [1] **Barany L**, Baksa G, Patonay L, Ganslandt O, Buchfelder M, Kurucz P. (2017) Morphometry and microsurgical anatomy of Bochdalek's flower basket and the related structures of the cerebellopontine angle. *Acta Neurochir (Wien)*, 159: 1539-1545. **IF: 1,929**
- [2] **Barany L**, Baksa G, Patonay L, Racz G, Ganslandt O, Buchfelder M, Kurucz P. (2018) Primary Obstruction of the Foramen of Luschka: Anatomy, Histology, and Clinical Significance. *World Neurosurg*, 112: 288-297. **IF: 1,723**
- [3] **Barany L**, Meszaros C, Ganslandt O, Buchfelder M, Kurucz P. (2019) Neural and vascular architecture of the septum pellucidum: an anatomical study and considerations for safe endoscopic septum pellucidotomy. *J Neurosurg*, 1-10. **IF: 4,130**

Not related to the present dissertation

- [1] Ruttkay T, **Bárány L**, Grimm A, Patonay L, Petneházy Ö, Rácz G, Baksa G, Galajda Z. (2019) A different technique for sutureless coronary bypass grafting. *Interventional Medicine and Applied Science*, 1-6. **IF: 0,000**
- [2] Kurucz P, Meszaros C, Ganslandt O, Buchfelder M, **Barany L**. (2019) The "Valva Cerebri": Morphometry, Topographic Anatomy and Histology of the Rhomboid Membrane at the Craniocervical Junction. *Clin Anat*, 33: 56-65. **IF: 1,813**
- [3] Kurucz P, **Barany L**, Buchfelder M, Ganslandt O. (2019) Endoscope-Assisted Minimally Invasive Microsurgical Removal of a Medium-Sized Acoustic Neuroma (T3a) through a Retrosigmoid Mini-Craniotomy with Preservation of Hearing. *J Neurol Surg B Skull Base*, 80: 276-278. **IF: 1,216**
- [4] Kurucz P, Ganslandt O, Buchfelder M, **Barany L**. (2019) Arachnoid Membranes Around the Cisternal Segment of the Trigeminal Nerve: A Cadaveric Anatomic Study and Intraoperative Observations During Minimally Invasive Microvascular

Decompression Surgery. *World Neurosurg*, 125: 262-272. **IF: 1,723**

- [5] Kurucz P, **Barany L**, Buchfelder M, Ganslandt O. (2018) The Clival Line as an Important Arachnoid Landmark During Endoscopic Third Ventriculostomy: An Anatomic Study. *World Neurosurg*, 120: 877-888. **IF: 1,723**
- [6] Vitanovics D, **Barany L**, Papp Z, Padanyi C, Balogh A, Banczerowski P. (2015) Role of modified open-door laminoplasty in the treatment of multilevel cervical spinal stenosis: a retrospective analysis of 43 cases. *Ideggyogy Sz*, 68: 15-21. **IF: 0,376**