Microsurgical anatomy of the interpeduncular cistern and related arachnoid membranes

JIAN LÜ, M.D., PH.D., AND XIANLI ZHU, M.D.

Department of Neurosurgery, Second Hospital, Xi'an Jiaotong University, Shaanxi; and Department of Neurosurgery, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China

Object. The goal of this study was to investigate the microsurgical anatomy of the interpeduncular cistern and related arachnoid membranes.

Methods. The interpeduncular cistern and related arachnoid membranes were studied in eight Han Chinese adult human cadaveric brains with the aid of an operating microscope.

The interpeduncular cistern is one area in the cranial cavity in which the arachnoid membranes and trabeculae are extremely luxuriant and complicated. The Liliequist membrane, the medial pontomesencephalic membrane, and the lateral pontomesencephalic membranes form the walls of the interpeduncular cisterns. The basilar artery (BA) bifurcation membrane, posterior perforated membrane, and arachnoid trabeculae fill the cistern. These arachnoid membranes and trabeculae adhere to the hypothalamus, brainstem, and oculomotor nerves, and bind the bifurcation of the BA, posterior cerebral arteries, superior cerebellar arteries, posterior communicating arteries, and their perforating branches.

Conclusions. Arachnoid membranes and trabeculae complicate the exposure and dissection of lesions within the interpeduncular cistern. All arachnoid membranes and trabeculae should be dissected and incised sharply during surgical procedures. The BA bifurcation membrane and the posterior perforated membrane must be incised after opening the Liliequist membrane for sufficient exposure of deep structures within the interpeduncular cistern.

Key Words • interpeduncular cistern • arachnoid membrane • anatomy • microsurgery • subarachnoid space

Since 1976 when Yasargil stressed the concept of performing intracranial operations by moving from one cistern to another, it has become the principle of microsurgery to incise the arachnoid membranes and to open the subarachnoid cisterns in an orderly manner to gain a natural pathway through which most operations can be performed noninvasively. An understanding of the microanatomy of the arachnoid membranes and trabeculae is of vital importance in modern neurosurgery, especially in minimally invasive neurosurgery.

The interpeduncular cistern is one of the most difficult regions to approach, even with the aid of the operating microscope, making it difficult to expose lesions in the interpeduncular cistern such as aneurysms of the BA bifurcation, craniopharyngiomas with superoposterior extension, chordomas, and so on. With the development of skull base surgery, several surgical approaches have been developed to reach the interpeduncular cistern, but the topography of the interpeduncular cistern has not been studied in detail.

The goal of the present study is to provide a good description of the microsurgical anatomy of the interpeduncular cistern.

Materials and Methods

The interpeduncular cistern was identified and studied in eight Han Chinese adult human cadaveric brains, which had been obtained from persons ranging in age from 22 to 65 years at the time of death. Each brain had an intact dura mater and had been fixated with 10% formalin before removal from the cranial cavity. None of the specimens displayed signs of cerebral diseases on macroscopic examination. The microsurgical dissections were performed with microscopic instruments and techniques with the aid of an operating microscope (10 ×) made in China. An Olympus OM-10 camera (Olympus Corp., Tokyo, Japan) was used for photographic documentation.

Results

Interpeduncular Cistern

Location and Limit of the Cistern. The interpeduncular cistern is an unpaired cone-shaped cistern that is the confluent area of the supra- and infratentorial subarachnoid space. It occupies the interpeduncular fossa and is situated in the...
midline, across the anterior portion of the incisura of the tentorium. The cistern is surrounded by the cerebral peduncles, the posterior perforated substance, the pons, the diencephalons, and several arachnoid membranes (Figs. 1 and 2).

The roof of the interpeduncular cistern is formed by the inferior surface of the diencephalon from the anterior edge of the mammillary bodies to the junction of the diencephalon and mesencephalon. Its posterior wall is formed by the cerebral peduncles, the posterior perforated substance, and the ventral surface of the upper portion of the pons. The interpeduncular fossa lies at the innermost depth of the cistern. The posterior perforated substance is the most posterior border of the cistern. The anterosuperior wall of the interpeduncular cistern is the diencephalic leaf of the Liliequist membrane, which separates the cistern from the chiasmatic cistern, the posterior communicating cisterns, or the carotid and posterior communicating cisterns (Figs. 1 and 3). Its anteroinferior wall (Fig. 2) is the mesencephalic leaf of the Liliequist membrane, which separates the cistern from the dorsum sellae and clivus. Its lateral walls are formed by a pair of diencephalic–mesencephalic leaves of the Liliequist membrane, which separate the interpeduncular cistern from the oculomotor cisterns (Figs. 1 and 4).

The bottom of the interpeduncular cistern is situated at the midpoint or between the upper one third and lower two thirds of the BA. It is formed by the medial pontomesencephalic membrane and a pair of lateral pontomesencephalic membranes (Fig. 2). It separates the cistern from the pre-pontine cistern and the cerebellopontine cisterns.

Communication With Adjoining Cisterns. The interpeduncular cistern is encircled by the chiasmatic, posterior communicating, or carotid and posterior communicating cisterns, as well as by the oculomotor, crural, ambient, pre-pontine, and cerebellopontine cisterns. The interpeduncular cistern communicates with the ambient cistern via the narrow space between the cerebral peduncle and the posterior perforated substance, and the ventral surface of the upper portion of the pons. The interpeduncular fossa lies at the innermost depth of the cistern. The posterior perforated substance is the most posterior border of the cistern. The anterosuperior wall of the interpeduncular cistern is the diencephalic leaf of the Liliequist membrane, which separates the cistern from the chiasmatic cistern, the posterior communicating cisterns, or the carotid and posterior communicating cisterns (Figs. 1 and 3). Its anteroinferior wall (Fig. 2) is the mesencephalic leaf of the Liliequist membrane, which separates the cistern from the dorsum sellae and clivus. Its lateral walls are formed by a pair of diencephalic–mesencephalic leaves of the Liliequist membrane, which separate the interpeduncular cistern from the oculomotor cisterns (Figs. 1 and 4).

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Contents of the Interpeduncular Cistern. There are two distinct trabecular arachnoid membranes within the interpeduncular cistern: the BA bifurcation membrane (Figs. 1 and 3–5) and the posterior perforated membrane. The BA bifurcation membrane divides the cistern into two portions: deep and superficial. The superficial portion adjoins the oculomotor cisterns and the deep portion communicates with the
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ambient cisterns. With the exception of the upper portion of the BA, the superficial portion of the cistern is filled with arachnoid trabeculae. In the deep portion of the cistern, the bifurcation of the BA, the initial portions of the PCAs and the SCAs, the oculomotor nerves, the PCoAs, the perforating branches of the arteries, the posterior perforated substance, and the posterior perforated membrane are found (Figs. 1, 3, 4, and 6). The PCoAs join the PCAs in the deep portion of the interpeduncular cistern (Fig. 3). The deep portion of this cistern is subdivided by the posterior perforated membrane into two areas: one anterior and the other posterior. In the anterior area, there are only mammillary bodies and the perforating arteries that supply them.

Arachnoid Membranes Related to the Interpeduncular Cistern

The Walls of the Interpeduncular Cistern.

Liliequist Membrane. The Liliequist membrane is a com-
sum sellae. The superior margin of the diencephalic leaf attaches to the pia mater of the inferior surface of the diencephalon at the anterior edge of the mammillary bodies. It attaches laterally to the pia mater of the mesial surface of the temporal lobe. The PCoAs penetrate the diencephalic leaf to enter the interpeduncular cistern from the posterior communicating cistern or the carotid and posterior communicating cisterns.

There is a pair of diencephalic–mesencephalic leaves that join the diencephalic leaf and the mesencephalic leaf. They are located medially with respect to the oculomotor nerves. The pair attaches anterosuperiorly to the diencephalic leaf, superiorly to the lateral margins of the mammillary bodies, anteroinferiorly to the mesencephalic leaf, and caudally to the medial pontomesencephalic membrane or the lateral pontomesencephalic membranes. The posterior borders of the leaves are free. The diencephalic–mesencephalic leaves may be triangular or quadrilateral, intact, and dense membranes or they may constitute a sparse network.

Medial Pontomesencephalic Membrane. This unpaired arachnoid membrane (Fig. 2) is located in the midline and joins the BA and pons to the bottom of the mesencephalic leaf of the Liliequist membrane at the level of the midpoint of the BA or at the level between the upper one third and lower two thirds of this vessel. The lateral ends of the membrane are free or attach to the medial ends of the lateral pontomesencephalic membranes.

The medial pontomesencephalic membrane is reticular or palisade. It separates the interpeduncular cistern from the preopticine cistern incompletely. The BA is bound by this membrane and penetrates it to enter the interpeduncular cistern from the preopticine cistern.

Lateral Pontomesencephalic Membrane. This paired membrane (Fig. 2) is perpendicular to the ventral surface of the pons. It is located between the superior cerebral artery and the trigeminal nerve. Its medial end, which is located between 2.5 and 6.5 mm away from the lateral wall of the BA, is free or attaches to the lateral end of the medial pontomesencephalic membrane. Its lateral end is free or merges into the arachnoidal sheath of the trigeminal nerve. The lateral pontomesencephalic membrane separates the interpeduncular cistern and the ambient cistern from the cerebello-pontine cistern. It can be an intact membrane or a network.

Arachnoid Membranes Within the Interpeduncular Cistern.

Basilar Artery Bifurcation Membrane. This unpaired membrane attaches caudally to the anterior walls of the BA bifurcation and the proximal segments of the PCAs and/or SCAs. It spreads obliquely forward and upward to a point where it attaches to the anterior edge of the mammillary bodies and fuses with the diencephalic leaf of the Liliequist membrane. It attaches laterally or is joined by the arachnoid trabeculae to the mesencephalic–diencephalic leaf.

The BA bifurcation membrane is formed by interwoven tough arachnoid trabeculae. It binds and attaches directly to the BA bifurcation, the PCoAs, the proximal segments of the PCA and SCA, the perforating branches of the arteries, the oculomotor nerves, the hypothalamus, and the brainstem.

The configuration and appearance of this membrane vary greatly in different specimens. In our material, it was an intact membrane in two of the seven specimens, a porous and sparse network in three of the seven specimens, and a dense and porous network in the last two specimens (Figs. 1 and 3–5).

Posterior Perforated Membrane. This unpaired membrane was only seen in one of the eight specimens. It is located within the deep portion of the interpeduncular cistern behind the BA bifurcation membrane. It attaches caudally to the apex of the BA and the superior wall of the proximal segments of the PCAs. The posterior perforated membrane attaches rostrally to the posterosuperior margin of both mammillary bodies. It is joined bilaterally to the mesencephalic–diencephalic leaves of the Liliequist membrane by arachnoid trabeculae, and is a sparse network formed by thin arachnoid trabeculae. The membrane attaches to the BA bifurcation, the PCoAs, the proximal segments of the PCA and SCA, the perforating branches of the arteries, the oculomotor nerves, the hypothalamus, and the brainstem.

Discussion

The interpeduncular cistern is one area in the cranial cavity in which the arachnoid membranes and trabeculae are extremely luxuriant and complicated. The interpeduncular cistern was first described by Axel Key and Gustaf Retzius in 1875. In the early 1900s the radiographic appearance of the interpeduncular cistern were mentioned by Liliequist, Epstein, and others, but the attention of these papers was directed to the Liliequist membrane and not to the cistern. Since the introduction of the operating microscope by Yaşargil, the anatomy of the subarachnoid cisterns has been studied in detail by several neurosurgeons including Yaşargil, Rhoton, and Vinas, and their colleagues. A few reports of microsurgical anatomical studies of the interpeduncular cistern exist in the literature and descriptions of the interpeduncular cistern vary greatly among these papers.

The interpeduncular cistern is a deep-seated cistern surrounded and filled by luxuriant and complicated arachnoid membranes and trabeculae. The cistern is related to the majority of the arachnoid membranes and trabeculae in the skull base. Within the interpeduncular cistern, the arachnoid membranes and trabeculae crisscross in a dense network and adhere to the hypothalamus, brainstem, oculomotor nerves, BAs, PCoAs, PCAs, SCAs, and their perforating branches.

Among the arachnoidal walls of the interpeduncular cistern, the diencephalic leaf of the Liliequist membrane is the only safe entrance to the cistern during operations. It is an important anatomical landmark and interface during exposure of lesions in sellar and parasellar areas.

The arachnoid membranes that are located within the interpeduncular cistern have not been sufficiently described. Vinas and associates have described the perforated membrane that partitions the interpeduncular cistern into anterior and posterior compartments. In the material we investigated, within the interpeduncular cistern there were two distinct trabecular arachnoid membranes: the BA bifurcation membrane (that is, the perforated membrane mentioned by Vinas and associates) and the posterior perforated membrane. Only when the BA bifurcation membrane and the posterior perforated membrane are incised, after opening of the diencephalic leaf of the Liliequist membrane dur-
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ing surgical procedures, can structures within the interpe-
duncular cistern can be adequately exposed (Fig. 5).

All arachnoid membranes and trabeculae should be dis-
sected sharply during operations. The arachnoid mem-
branes and trabeculae complicate the exposure and dissec-
tion of lesions within the interpeduncular cistern. The
majority of arachnoid membranes and trabeculae in the
skull base are attached to the walls and contents of the cis-
tern; thus, all arachnoid membranes and trabeculae should
be dissected and incised sharply during surgical procedures,
especially during operations on intracranial aneurysms.
Sharp dissection of the arachnoid membranes and trabecu-
lae can help us avoid rupture of the aneurysm before clip
application. For example, during operations on aneurysms
of the BA bifurcation, the power of retraction or pulling of
any arachnoid membranes or trabeculae in the skull base
will be transmitted to the wall or dome of the aneurysm
by the arachnoidal membranes and trabeculae, especially
by the BA bifurcation membrane, the posterior perforated
membrane, and the Liliequist membrane. This will lead to
rupture of the aneurysm before the lesion can be clipped.

Opening the interpeduncular cistern can minimize the
occurrence of postoperative hydrocephalus. It has been
mentioned that the interpeduncular cistern is a common
site in which obstruction of CSF circulation occurs. Buxton
and colleagues\(^1\) have pointed out that failure to open the
Liliequist membrane to enter the interpeduncular cistern
could lead to failure of the neuroendoscopic management of
hydrocephalus. According to our observations, the region of
the subarachnoid space anterior and posterior to the dience-
phalic leaf can only communicate through the narrow
space between the free superior margin of the diencephalic
leaf, the optic tract, and the mesial surface of the temporal
lobe, and through the gap around the PCoA in cases in
which it penetrates the diencephalic leaf. In the setting of
subarachnoid hemorrhage or inflammation, the narrow space
or gap is easy to obstruct and, therefore, a disorder in CSF
circulation occurs. Thus, incising the diencephalic leaf of
the Liliequist membrane to create a total opening in the
interpeduncular cistern not only can release CSF, diminish-
ing retraction of the brain, but also prevent the occurrence
of postoperative hydrocephalus.

Conclusions

The interpeduncular cistern is one area in which arach-
noid membranes and trabeculae are extremely dense and
luxuriant. All arachnoid membranes and trabeculae should
be dissected sharply during surgical procedures.

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Address reprint requests to: Jian Lü, M.D., Ph.D., Department of
Neurosurgery, Second Hospital, Xi’an Jiaotong University, 157
Xiwu Road, Xi’an (710004), Shaanxi, People’s Republic of China.
email: lvjian70@hotmail.com or surgeonlv@yahoo.com.cn.