Reinvestigation of the ambient cistern and its related arachnoid membranes: an anatomical study

Laboratory investigation

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Object. A precise understanding of the ambient cistern and its associated arachnoid membranes is helpful for accessing perimesencephalic lesions. However, few studies of the arachnoid membranes related to the ambient cistern have been published, and, additionally, some aspects of the ambient cistern also require further examination. The goal of this study was to reinvestigate and expound on the anatomical features of the cistern and membranes.

Methods. The ambient cisterns and its associated arachnoid membranes were examined in 20 adult cadaveric brains using an operative microscope.

Results. The perimesencephalic membrane is a set of inner arachnoid membranes surrounding the midbrain at the level of the tentorial incisura. It arises from the outer arachnoidal membranes covering the tentorial edge and the dorsum sellae and can be subdivided into anterior and posterior portions. The anterior membrane is actually the mesencephalic leaf of Liliequist membrane, which is divided into medial and lateral parts by the oculomotor nerve. The posterior membrane can be divided into horizontal and ascending parts. The ambient cistern is located above the perimesencephalic membrane and contains the anterior choroidal arteries, the posterior cerebral arteries, the basal vein, and sometimes the segments of the superior cerebellar arteries. It communicates with the carotid cistern, the interpeduncular cistern, the oculomotor cistern, the cerebellopontine and cerebellomesencephalic cistern, and the quadrigeminal cistern.

Conclusions. This study updates some information about the ambient cistern and its arachnoid membranes. The perimesencephalic membrane was identified and described in detail. The ambient cistern was verified to be a supratentorial cistern above the perimesencephalic membrane. The borders and contents of this cistern, as well as its relationship with adjacent cisterns, were also redefined. (DOI: 10.3171/2011.2.JNS101365)

Key Words • arachnoid membrane • ambient cistern • subarachnoid • anatomy

SINCE Blasius first described and named the arachnoid membrane in 1664, many neuroscientists have tried to understand the microanatomy of the arachnoid membranes and subarachnoid cisterns that can provide a natural pathway to deep intracranial lesions, especially aneurysms and extraaxial tumors. The ambient cistern is a complex subarachnoid compartment lying deep within the brain and surrounding the midbrain, with some arachnoid membranes separating it from adjacent cisterns. Lesions in and around the ambient cistern present unique challenges to the neurosurgeon because of its deep location, narrow confines, and the density of vital structures. Successfully approaching these lesions requires a precise understanding of the anatomy of the cistern.

Various descriptions of the ambient cistern can be found in the literature, and the anatomy of neurovascular structures in this region has been ill-illustrated. However, only few microscopic studies of the arachnoid membranes related to the ambient cistern have been published, and in most studies the ambient cistern was considered to be a cistern extending across the tentorial incisura. Based on the literature we have reviewed, several questions need to be further investigated. Does the ambient cistern really extend across the tentorial incisura? What is the formation and distribution of the arachnoid membranes related to the ambient cistern? What is the relationship between these arachnoid membranes and the surrounding neurovascular structures? Focused on these questions, we reinvestigated the anatomy of the ambient cistern and its associated arachnoid membranes in an attempt to provide a more precise description.

Methods

Twenty adult cadaveric brains fixed in formaldehyde solution were carefully prepared for microsurgical dissection. On macroscopic examination, none of the brains showed signs of cerebral diseases. The supratentorial cerebral lobes were subpially removed, step by step, with
special attention not to stretch the relevant leptomeninges. The pia mater was then carefully dissected away from the surfaces of the arachnoid membranes surrounding the midbrain. All dissections and observations were performed under a surgical microscope (M651, Leica Co.), with a digital video camera (SCC-101BP, Samsung Co.) attached for photographic documentation. We examined in detail the ambient cisterns and their associated arachnoid membranes, configurations, borders, contents, and communications with adjacent cisterns.

**Results**

**Perimesencephalic Membrane**

The perimesencephalic membrane, found in all 20 specimens, is a set of inner arachnoid membranes surrounding the midbrain at the level of the tentorial incisura. It originates from the outer arachnoidal membrane covering the tentorial edge and the dorsum sellae. This membrane, as it extends toward the midbrain, usually changes in structure from an intact and thick membrane to a thinner trabeculated membrane with many perforations near its attachment to the midbrain. The perimesencephalic membrane is composed of 2 distinct membranes—antero-posterior—which are usually discontinuous and bordered by some trabeculae near the posterior edge of the peduncle (Fig. 1).

**Anterior Perimesencephalic Membrane.** The anterior perimesencephalic membrane is actually the mesencephalic leaf of Liliequist membrane, which is an unpaired membrane surrounding the cerebral peduncle. It extends between the dorsum sellae and bilateral tentorial edges. The oculomotor nerve courses along the upper surface of this membrane and divides it into medial and lateral parts (Figs. 1 and 2). The medial part arises anteriorly from the outer arachnoidal membrane covering the dorsum sellae and posterior clinoid processes. It extends posteriorly with a free edge attaching to the basilar bifurcation and the junction of the midbrain and pons by trabeculae, and it separates the interpeduncular cistern from the pre-pontine cistern (Fig. 2). Its free edge can be positioned at the level between the PCA and the superior cerebellar artery (15 [75%] of the 20 specimens), above the PCA (2 [10%] of 20), or below the superior cerebellar artery (3 [15%] of 20). The medial part presents as a structure of trabecular network with considerable variability. Some are dense and have small perforations, but most are thinner and incomplete with larger perforations. The lateral part arises laterally from the outer membrane covering the anterior tentorial incisura (Fig. 2). Its anterior edge passes below the oculomotor nerve to be continuous with the medial part (Fig. 2D), forming the floor of the oculomotor cistern. Its posterior edge is free and close to the lateral peduncle. As it extends backward, the lateral part becomes narrow, gradually, until it disappears. This part of the membrane is frequently intact without perforations, so that it acts as a separation between the anterior ambient and cerebellopontine cistern. The anterior and posterior perimesencephalic membranes are mostly discontinuous and connected by some sparse trabeculae (Fig. 3A). Although in 2 of 40 hemispheres, an intact membrane was found bridging the anterior and posterior membrane (Fig. 3B).

**Posterior Perimesencephalic Membrane.** The posterior perimesencephalic membrane is a paired membrane surrounding the midbrain tegmentum and part of the pulvinar. Posteromedially, it extends upward and ends at the arachnoid envelope surrounding the vein of Galen to form the lateral wall of the quadrigeminal cistern (the arachnoid envelope has been described in detail in our past study). Thus, we divided this membrane into horizontal and ascending parts according to the cisterns they separate. Arach. = arachnoid; Arach. Trab. = arachnoid trabeculae; Asc. = ascending; CN = cranial nerve; Hor. = horizontal; I.C.V. = internal cerebral vein; Lat. = lateral; Med. = medial; Memb. = membrane; M.P.Ch.A. = medial PChA; P.Co.A. = posterior communicating artery; Perimes. = perimesencephalic; Pit. = pituitary; Post. = posterior; S.C.A. = superior cerebellar artery; Tent. = tentorial; V. = vein.
Fig. 2. A–D: Anatomical dissections of the anterior perimesencephalic membrane: overall view (A); lateral view (B); superior view (C); and superior view after the oculomotor nerve has been retracted upward (D). The anterior perimesencephalic membrane is actually the mesencephalic leaf of Liliequist membrane positioned anteriorly to the peduncle. The oculomotor nerve courses above this membrane and divides it into medial and lateral parts. The medial part arises from the arachnoid membrane covering the dorsum sellae and posterior clinoid processes. Its posterior edge is attached to the basilar bifurcation and pontomesencephalic junction at the level between the PCA and superior cerebellar artery in most specimens. This part of the membrane is usually thin and incomplete with numerous large perforations, and it separates the interpeduncular cistern from the prepontine cistern. The lateral part arises from the outer arachnoidal membrane covering the tentorial edge. Its anterior edge extends below the oculomotor nerve to be continuous with the medial part, forming the floor of the oculomotor cistern. Its posterior edge is free and close to the lateral peduncle. This part of membrane is usually intact with few perforations, and it spans the interval of the PCA and superior cerebellar artery in most specimens. The anterior ambient cistern also borders the cerebellopontine cistern by this membrane. A. = artery; Bas. = basilar; Cist. = cistern; Clin. = clinoid; Dien. = diencephalic; Interped. = interpeduncular; P.Co.A. = posterior communicating artery; Ped. = peduncle.

Fig. 3. A and B: Anatomical dissections of the connection between the anterior and posterior perimesencephalic membrane. A: Lateral view. In most of the hemispheres, the anterior perimesencephalic membrane is connected with the posterior communicating artery by some sparse arachnoid trabeculae. B: Superior view. Infrequently, the anterior and posterior perimesencephalic membrane may be connected by a layer of intact arachnoid membrane. Trab. = trabeculae.
It is usually perforated by the medial PChA at its entrance to the quadrigeminal cistern (Figs. 1, 4D, and 5C) and separates the posterior ambient cistern from the quadrigeminal cistern (Fig. 5C). The posterior perimesencephalic membrane is mostly thinner and incomplete with multiple perforations near its attachment, especially in the ascending part, which causes a wide communication between the ambient and quadrigeminal cistern.

Configuration and Borders of the Ambient Cistern

The ambient cistern is a paired cistern situated above the level of the tentorial incisura and the perimesencephalic membrane, and it extends from the posterior edge of the oculomotor nerve anteriorly to the ascending part of the posterior mesencephalic membrane posteromedially. It is surrounded by the upper midbrain laterally in a semiring shape and is limited by the medial temporal lobe, the inferior occipital lobe, the midbrain, and the perimesencephalic membrane. The ambient cistern can be divided into anterior and posterior compartments.

Anterior Compartment. The anterior compartment is positioned anterolaterally to the cerebral peduncle and superiorly to the anterior perimesencephalic membrane. Its superior wall is formed by the pial layers covering the lateral surface of the upper peduncle, the optic tract, and the uncus, which merge and form a reflection before entering the choroid fissure. The inferior wall is formed by the lateral part of the anterior perimesencephalic membrane, the medial wall by the lateral surface of the peduncle, and the lateral wall by the medial surface of the temporal lobe (Fig. 5A). Occasionally, some discontinuous trabeculae below the AChA were found extending between the midbrain and the uncus.

Posterior Compartment. The posterior compartment is located posterolaterally to the midbrain tegmentum and superiorly to the posterior perimesencephalic membrane. Similar to the anterior compartment, its superior wall is formed by the pial layers covering the midbrain tegmentum, the lateral geniculate body, and the medial occipital lobe, which merge and form a reflection at the entrance.
to the choroid fissure. The inferior wall is formed by the horizontal part of the posterior perimesencephalic membrane, the medial wall by the midbrain tegmentum, the lateral wall by the medial occipital lobe, and the postero-medial wall by the ascending part of the posterior perimesencephalic membrane (Fig. 5B and C).

Contents of the Ambient Cistern

The ambient cistern contains the AChA, the P$_1$ and P$_3$ segments with their branches, the basal vein of Rosenthal, and, infrequently, a segment of the superior cerebellar artery.

The AChA originates from the ICA and enters the upper compartment of the anterior ambient cistern (Fig. 6A). It then runs along the roof of the cistern and enters the choroid fissure between the pial layers of the peduncle and the uncus, which fuse to form the tela choroidea.$^{6,13,14}$

According to the classification of Zeal and Rhoton,$^{23}$ the P$_3$ segment of the PCA can be subdivided into P$_{2a}$ and P$_{2p}$, which are bordered by the posterior edge of the peduncle. The P$_{2p}$ begins at the junction of the posterior communicating artery and courses through the anterior ambient cistern along the upper surface of the posterior perimesencephalic membrane (Fig. 2). The P$_{2p}$ commences at the posterior edge of the peduncle and enters the posterior ambient cistern. The P$_i$ segment proceeds posteriorly from the posterior edge of the ambient cistern to the ascending part of the posterior perimesencephalic membrane, which separates the quadrigeminal from the ambient cistern (Fig. 6B).$^{13,23}$ The medial PChA typically originates as a single trunk from the P$_i$ or P$_2$ and courses through the ambient cistern. It is the only branch of the PCA that perforates the ascending part of the perimesencephalic membrane and enters the quadrigeminal cistern (Figs. 1, 4D, and 5C).

The basal vein passes around the upper midbrain and drains the walls of the ambient cistern. It finally exits the ambient cistern and enters the arachnoid envelope over the pineal region to join the great vein or internal cerebral vein.$^{11}$

The superior cerebellar artery usually arises from the basilar artery near the apex and passes below the perimesencephalic membrane and the oculomotor nerve (Figs. 1 and 2). Its proximal portion mostly originates in the preoptic cistern and encircles the brainstem near the pontomesencephalic junction, passing between the trochlear and trigeminal nerve to enter the cerebellopontine cistern.$^{10}$ After leaving the cerebellopontine cistern, its distal portion enters the cerebellomesencephalic cistern and gives off numerous branches to the cerebellum (Fig. 6B). Sometimes, when the superior cerebellar artery runs above the medial part of the anterior perimesencephalic membrane, it may begin in the interpuduncular cistern, course through the anterior ambient cistern, and ultimately extend downward to enter the cerebellomesencephalic cistern.

Communications With Adjacent Cisterns

The anterior ambient cistern communicates with the carotid cistern anteriorly, the interpuduncular cistern medially, the cerebellopontine cistern inferiorly, and the oculomotor cistern inferomedially. The posterior ambient cistern communicates with the cerebellomesencephalic cistern inferiorly and the quadrigeminal cistern post-
hemispherially (Fig. 7). Respectively, the anterior ambient cistern borders the cerebellopontine cistern by the lateral part of the anterior perimesencephalic membrane, and the posterior ambient cistern borders the cerebellomesencephalic cistern by the horizontal part of the posterior perimesencephalic membrane, and the quadrigeminal cistern by the ascending part (Fig. 5). However, there is frequently a wide communication between the quadrigeminal and ambient cisterns due to big openings of the ascending part of the posterior perimesencephalic membrane. Other cisterns are usually separated by some sparse trabeculae.

Discussion

Perimesencephalic Membrane

According to Inoue et al., there are 2 types of arachnoid membranes: outer and inner. The perimesencephalic membrane described in the present study refers to a set of inner arachnoid membranes surrounding the midbrain at the level of tentorial incisura. To the best of our knowledge, few studies have provided a detailed description of the structure. Vinas et al. have identified a membrane, the “superior cerebellar membrane” that originates “...from the cerebellar precentral membrane and [runs] around the midbrain towards the oculomotor cistern.” We believe that this membrane represents the perimesencephalic membrane. However, our result was different with regard to the construction and distribution of the membrane. We found that the membrane arises from the outer arachnoid membranes covering the tentorial edge and the dorsum sellae. It looks like a ring-shaped membranous extension of the tentorial incisura surrounding the midbrain. Although the anterior part of the membrane was mostly discontinuous with the posterior part, the origination of both parts is the same. For this reason, we treated both parts as a whole membrane and named it the “perimesencephalic membrane,” which seems more precise than the “superior cerebellar membrane.” In addition, we found that different parts of the perimesencephalic membrane have various constructions. For example, the medial part of the anterior perimesencephalic membrane usually presents as a structure of trabecular network, whereas its lateral part is always intact without perforations. Vinas et al. also identified a “cerebellar precentral membrane” that was “the posterior limit of the ambient cistern and separated the quadrigeminal from the ambient cistern.” However, we found that this membrane was actually an upward part (the ascending part) of the posterior perimesencephalic membrane attached to the arachnoid envelope over the pineal region. There still exists another membrane in front of the vermis. It is connected to bilateral ascending parts and separates the quadrigeminal from the supracerebellar cistern. In our opinion, it is more reasonable to name this membrane the “cerebellar precentral membrane.” A detailed description of this membrane is beyond the scope of the present study and will be provided later.

As described in this study, the anterior perimesencephalic membrane originates from the arachnoid membranes covering the dorsum sellae and anterior tentorial edge, which actually act as the mesencephalic leaf of Liliequist membrane we have known before. There remain conflicting opinions regarding the lateral boundaries of this membrane. Yaşargil et al. described this membrane as stretched between bilateral medial surfaces of temporal lobe. Brasil and Schneider found that the lateral border was an arachnoid membrane covering the oculomotor trigone and tentorial edge and was attached to the medial surface of the uncus. According to Vinas et al., this membrane originated laterally from a “caudal oculomotor membrane” located below the oculomotor nerve. Matsuno et al. reported the membrane spreading the interval between the oculomotor nerves, with its lateral edge attaching to the arachnoid sheath surrounding the oculomotor nerves. Froelich et al. observed that the mesencephalic leaf attached to the pia of the parahippocampal gyrus and was continuous with the arachnoid membrane covering...
Reinvestigation of the ambient cistern

Fig. 7. Communications between the ambient cistern and adjacent cisterns (inferior view). The anterior ambient cistern (light blue) communicates with the carotid cistern (yellow) anteriorly, the interpeduncular cistern (dark blue) medially, the cerebellopontine cistern inferiorly, and the oculomotor cistern (green) inferomedially. The posterior ambient cistern (light blue) borders the cerebellomesencephalic cistern inferiorly and the quadrigeminal cistern (purple) posteromedially. Car. = carotid; Chiasm. = chiasmatic; Interped. = interpeduncular.

As a part of subarachnoid cisterns, the ambient cistern was first described in detail by Key and Retzius in 1875. In the literature, most authors have considered the ambient cistern to be a subarachnoid space extending across the tentorial incisura.3,6,7,18–20 Yaşargil et al.22 divided the ambient cistern into supra- and infratentorial compartments that contain the basal vein, the PCA, the superior cerebellary artery, and the trochlear nerve. Vinas et al.18–20 and Lü and Zhu7 described a “superior cerebellar membrane” that divides the ambient cistern into superior and inferior compartments. Our observations, however, showed that the perimesencephalic membrane, arising at the level of the tentorial incisura, created a relatively intact separation between the supra- and infratentorial compartments. Instead, no complete membrane was observed in the infratentorial compartment except some scattered trabeculae. As a result, we considered that the ambient cistern is a compartment extending above rather than across the level of the tentorial incisura or perimesencephalic membrane. The infratentorial compartment under this membrane was defined as the cerebellopontine cistern anteriorly and the cerebellomesencephalic cistern posteriorly. Accordingly, the contents of the ambient cistern in this study are also different from what the above-mentioned authors have described. The superior cerebellar artery and the trochlear nerve should be included into the scope of the cerebellopontine and cerebellomesencephalic cistern.

The crural cistern has also been described by many authors in the literature. Yaşargil22 noted that the crural cistern was positioned on top of the interpeduncular cistern and posterolateral to the ambient cistern, and it was clearly demarcated from the carotid and interpeduncular cisterns between the anterior choroidal and posterior communicating arteries. The cistern was considered to contain the anterior choroidal and medial posterior choroidal arteries as well as the basal vein. Inoue et al.6 observed that the cistern was situated between the peduncle and the posterior part of the uncus, and its inferior wall was formed by a “lateral pontomesencephalic membrane” that separated the crural cistern from the cerebellopontine cistern. They also identified an “intracrural membrane” extending from the posterior part of the uncus to the peduncle and adjacent part of the optic tract, dividing the crural cistern into upper and lower parts. Based on our results, only some sparse arachnoid trabeculae were infrequently found in the upper compartment of the anterior ambient cistern. No definite border or separation was observed between the crural and ambient cistern. Thus, the crural cistern was included within the anterior ambient cistern in this study. However, full verification requires further examinations in more specimens.

Clinical and Surgical Significance

The perimesencephalic membrane, involving the mesencephalic leaf of the Liliquist membrane, is a helpful landmark in various neurosurgical procedures. As an arachnoid extension of the tentorium surrounding the midbrain, it constitutes an important barrier between the supra- and infratentorial cisterns. In perimesencephalic lesions, such as diaphragma sellae meningiomas extending backward or petroclival meningiomas/ trigeminal neurinomas extending upward, this membrane is usually displaced but preserved, which may provide a clear and...
safe surgical plane for dissections and should be carefully followed. For example, when a supratentorial approach is used to access the posterior ambient cistern, preserving the perimesencephalic membrane may protect the superior cerebellar artery and the trochlear nerve below it from operative injury.

Yasargil et al. noted that aneurysms may become adherent to the arachnoidal walls of the cisterns and that tension on arachnoid membranes could be transmitted to the aneurysm even when dissection is performed at some distance. Therefore, it is helpful to know which membranes may be attached to the aneurysm before the surgery. As described in this study, an aneurysm arising at the P2 or P3 segment might be adherent to the posterior perimesencephalic membrane that originated from the arachnoid membranes covering the inferior occipital lobe and superior cerebellum. When the inferior occipital lobe needs to be retracted to access the aneurysms of the P2 or P3 segment, the retraction force may be transferred to the aneurysms and lead to their rupture. Thus, the inferior occipital arachnoid membrane should be first dissected and loosened before the retraction to minimize the risk of hemorrhage.

Conclusions

The anatomy of the ambient cistern and its related arachnoid membranes has been reinvestigated in this study. Compared with previously reported studies, some information was updated: 1) the perimesencephalic membrane was identified as a set of inner arachnoid membranes surrounding the midbrain at the level of the tentorial incisura, and its formation and distribution were been described in detail; 2) the ambient cistern was verified to be a supratentorial cistern located above the level of the tentorial edge and perimesencephalic membrane; and 3) the borders and contents of the ambient cistern, as well as its relationship with adjacent cisterns, have also been redefined. Hopefully, this study will provide a better understanding of the cistern and membrane, which may be helpful to more precisely manage lesions in this region.

Disclosure

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Author contributions to the study and manuscript preparation include the following. Conception and design: Song-ting. Acquisition of data: Fan, Zhang. Analysis and interpretation of data: Qi. Fan. Drafting the article: Fan. Critically revising the article: Qi. Reviewed final version of the manuscript and approved it for submission: Qi. Administrative/technical/material support: Qi. Study supervision: Qi.

References