The Arachnoid Sleeve Enveloping the Pituitary Stalk: Anatomical and Histologic Study

**BACKGROUND:** The arachnoid membrane in the suprasellar region may affect the growth pattern of sellar and suprasellar tumors however, the topographic relationships between the pituitary stalk and the surrounding arachnoid membranes remained unclear.

**OBJECTIVE:** The aim of this study was to evaluate the anatomical and histological characteristics of the arachnoid membranes.

**METHODS:** Microsurgical dissection and anatomical observation were performed in 16 formalin-fixed adult cadaver heads. In the other 5 adult cadaver heads, histologic sections of sellar-suprasellar specimens were studied under light microscopy.

**RESULTS:** An arachnoid sleeve enveloping the pituitary stalk of variable length presented in all specimens, which was formed by direct upward extension of the basal arachnoid membrane covering the diaphragma sellae. In the majority of specimens, the arachnoid sleeve was reinforced by the arachnoid trabeculae originating from the basal arachnoid membrane, the Liliquist membrane, and the medial carotid membrane.

**CONCLUSION:** The relationship between the pituitary stalk and the surrounding arachnoid membrane is important in evaluating the growth patterns of the sellar and suprasellar tumors, and their topographical relationships.

**KEY WORDS:** Anatomy, Arachnoid membrane, Histology, Pituitary stalk, Subarachnoid space

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Of 16 adult cadaveric formalin-fixed heads used for anatomical dissection, red latex was injected into arterial vessels in 10. The cranial vault and brain tissue 2 cm above the axial plane across the nasion and the inion were removed. Then, the brain tissue over and around the supratentorial basal cisterns was subpially removed in piecemeal fashion, with special attention to not stretch the underlying leptomeninges. By stepwise opening the pia mater covering the carotid cistern, chiasmatic cistern, and interpeduncular cistern, the play of tumors in sellar and suprasellar regions, the arachnoid membrane has long been considered an effective barrier limiting the cisternal extension of the tumors.1-5 Valuable information about the nomenclature, architecture, neurovascular relationships of the arachnoid membranes, and cisterns in suprasellar region has been provided by different authors based on intraoperative observation and anatomical study.2,4,6-13 However, authors who dealt with this issue seldom made detailed description of the topographic relationships between the pituitary stalk and the surrounding arachnoid membranes, which are fundamentally important for a better understanding of anatomical location and growth pattern of the tumors relative to the sellar and suprasellar critical neurovascular structures. Furthermore, we could not find answers in the literature to the following questions: (1) Does the pituitary stalk directly descend through a focal defect on the basal arachnoid membrane covering diaphragma sellae to reach the pituitary gland? (2) Is the inferior part of pituitary stalk enveloped in a downward arachnoid sleeve formed by basal arachnoid membrane covering diaphragma sellae as seen in other cranial nerves? And if so, where does the arachnoid sleeve terminate? (3) Is the pituitary stalk a structure in subarachnoid space, or with part in subarachnoid space and part in extrarachnoid space? We attempted to answer these questions by evaluating the anatomical and histologic characteristics of the arachnoid membrane related to the pituitary stalk.

**MATERIALS AND METHODS**

Of 16 adult cadaveric formalin-fixed heads used for anatomical dissection, red latex was injected into arterial vessels in 10. The cranial vault and brain tissue 2 cm above the axial plane across the nasion and the inion were removed. Then, the brain tissue over and around the supratentorial basal cisterns was subpially removed in piecemeal fashion, with special attention to not stretch the underlying leptomeninges. By stepwise opening the pia mater covering the carotid cistern, chiasmatic cistern, and interpeduncular cistern, the...
arachnoid membrane was investigated, with close relationship to the pituitary stalk. A Leica M651 surgical microscope (Samsung Co., Seoul, Korea) was used for microsurgical dissections, with a Samsung SCC-101BP digital video camera (Leica Co., Heerbrugg, Switzerland) attached for photographic documentation of relevant structures.

In another 5 adult cadaveric formalin-fixed heads used for histologic study, the sellar-suprasellar regions were removed from each head en bloc. The bone in each sample was decalcified. Serial histologic sections were obtained in sagittal and coronal directions at 5-μm intervals. All these sections were stained with Masson trichrome stains and immunohistochemically labeled for vimentin. Observation was made under the Olympus-DP71 light microscope (Olympus Co., Tokyo, Japan).

RESULTS

Cadaveric Dissection

Basal Arachnoid Membrane Covering Diaphragma Sellae

The basal arachnoid membrane covering the diaphragma sellae constituted the inferior wall of the chiasmatic cistern. It was continuous with the basal arachnoid membrane covering the tuberculum sellae, anterior clinoid processes, and limbus sphenoidale anteriorly; the superior wall of the cavernous sinus and temporal fossa laterally; and the dorsum sellae, posterior clinoid processes, and clivus posteriorly. The pituitary stalk penetrated the basal arachnoid membrane to reach the pituitary gland. At the penetrating site, the basal arachnoid membrane extended upward along the pituitary stalk, which formed an arachnoid sleeve enveloping the pituitary stalk (ASPS) in all specimens (Figure 1).

We observed 2 basic types of the relationships between the lower end of ASPS and the pituitary stalk. In 10 specimens, being supradiaphragmatic in 7 and protruding into the sella turcica in 3, the basal arachnoid membrane did not contact the superior surface of the pituitary gland at the opening of diaphragma sellae. There was an interval, no more than one-third the full length of the pituitary stalk, between the basal arachnoid membrane and the superior surface of the pituitary gland at the opening of diaphragma sellae. This made the lower part of the pituitary stalk, being free of arachnoid, envelop in variable length (type I; Figure 1, A-D). The distance between the lower end of the ASPS and the superior surface of the pituitary gland was nearly equal on the anterior and posterior surfaces of the pituitary stalk in 6 specimens (type IA; Figure 1, A and B), and longer on the posterior surface than that on the anterior surface of the pituitary stalk in 4 (type IB; Figure 1, C and D).

In the other 6 specimens, being supradiaphragmatic in 2 and protruding into the sella turcica in 4, the basal arachnoid membrane directly contacted the superior surface of the pituitary gland at the opening of diaphragma sellae, and the ASPS enveloped the pituitary stalk of nearly full length (type II; Figure 1, E and F).

In all specimens, stripping the ASPS upward could be accomplished at its lower part (Figure 1, B and F), but could not proceed beyond the middle part of the pituitary stalk without tearing the ASPS because of the tight adherence.

In 7 specimens, the basal arachnoid membrane between the posterior surface of the pituitary stalk and dorsum sellae sent out a few arachnoid trabeculae to attach to the posterior and lateral surfaces of the middle and lower parts of the ASPS (Figure 2, A and B), its presence being associated with the absence of the diencéphalic membrane of the Liliequist membrane, or the presence of higher protruding dorsum sellae.

Liliequist Membrane

The Liliequist membrane was situated posterior to the pituitary stalk. It arose from the basal arachnoid membrane covering
Cadaveric dissection showing the relationship between the pituitary stalk (PS) and the arachnoid trabeculae originating from the Liliequist membrane (LM), basal arachnoid membrane (BAM), and medial carotid membrane (MCM). A. In this specimen, only the BAM sent out arachnoid trabeculae (white arrowhead) to attach to the posterior and lateral surfaces of the lower and middle parts of the arachnoid sleeve enveloping the PS. B. In this specimen, arachnoid trabeculae originating both from the LM (black arrowhead) and the BAM (white arrowhead) could be seen attaching to the posterior, lateral, anterior surface of the arachnoid sleeve enveloping the PS along its entire course, and to the inferior lateral surface of the optic chiasma (OC). C. Anterior view of the attachments of MCM. D. Posterior view of the attachments of the MCM (black arrow). BA indicates basilar apex; CN III, cranial nerve III (oculomotor nerve); DS, dorsum sellae; ICA, internal carotid artery; ON, optic nerve; PCA, posterior cerebral artery; PCoA, posterior communicating artery; PG, pituitary gland.

Medial Carotid Membrane

The sagittally oriented medial carotid membrane, separating the chiasmatic cistern and the carotid cistern, varied greatly among different specimens and from side to side in individual specimens. In 5 specimens, the medial carotid membrane was absent unilaterally. The appearance of the medial carotid membrane varied from porous trabeculated wall to relatively intact membrane with small openings. The medial carotid membrane was originated from the basal arachnoid membrane interomedial to the supraclinoid internal carotid artery and posterior communicating artery, and paramedian superior surface of the Liliequist membrane. Extending superiorly and medially, the medial carotid membrane attached to the pia mater covering the inferior surface of the optic chiasma, adjacent optic nerve, lateral surface of the infundibulum, and upper part of ASPS (Figure 2, C and D). Perforating arteries originating from the internal carotid artery and posterior communicating artery traveled on or through the medial carotid membrane to supply the pituitary stalk, optic chiasma, optic tract, and hypothalamus.

Histologic Findings

The ASPS was seen in all histologic specimens. Above the site where the pituitary stalk penetrated the basal arachnoid membrane to reach the pituitary gland, the upward extension of basal arachnoid membrane ran along the pituitary stalk (Figure 3, A-E). Therefore, the ASPS was arachnoid mater membrane, but thinner than the basal arachnoid membrane.

At the upper part of the pituitary stalk, the ASPS was seen attached to the top of the pars tuberalis. But whether it ended at the top of the pars tuberalis or turned downward between the pars tuberalis and the infundibulum could not be determined in the Masson trichrome stain (Figure 3C). In histologic sections with immunohistochemical labeling for vimentin, it was clear the arachnoid sleeve ended at the top of the pars tuberalis and near the base of the infundibulum (Figure 3, D and E).

DISCUSSION

Architecture of Arachnoid Membrane Surrounding the Pituitary Stalk

Although a thorough knowledge of the microanatomy of the pituitary stalk is important in sellar and suprasellar surgery, the relevant literature provided little and incomplete information on the detailed topographic relationship between the pituitary stalk and surrounding arachnoid membrane.2,4,6-13 According to Yaşargil4 in his masterpiece, Microneurosurgery, the Liliequist membrane “is fused with the chiasmatic cistern around the infundibulum and pituitary stalk.” Fox7 proposed the existence of a “hypophyseal cistern” and made the following statement: “in many cases the membrane of Lillequist, which lies caudal to the pituitary stalk, sends an anterior reflection of arachnoid membrane in front of the pitu-
The pituitary stalk is a reverse type. From an anatomical point of view, the pituitary stalk can be divided into 3 parts according to their relationship with the arachnoid membrane: 

1. **Extraarachnoid part:** This part is above the upper end of the ASPS, which comprises the base of the infundibulum. The second part, the intraarachnoid part, refers to the segment of pituitary stalk enveloped in the ASPS, which is the longest among the 3 parts. The third part, the subarachnoid part, presents when there is an interval between the basal arachnoid membrane and the superior surface of the pituitary gland.

Based on the results from this study, the “hypophyseal cistern,” initially described by Fox,2 does exist in the majority of cases, and contains variable length of the pituitary stalk. The inner wall of this cistern is the ASPS, and the outer wall comprises arachnoid trabeculae originating from the basal arachnoid membrane, the Liliequist membrane, and medial carotid membrane. Its completeness and length depend on the contribution by these 3 arachnoid membranes.

**Embryogenesis of the Arachnoid Membrane Surrounding the Pituitary Stalk**

Embryologically, the neural tube is enveloped by a mesenchymal layer, from which the meninges subsequently differentiate.16
Histologically, the hypophysis comprises a neural component (infundibular stalk and pars nervosa) derived from the embryonic diencephalon and an epithelial component (pars distalis, pars intermedia, and pars tuberalis) derived from the Rathke pouch. Chi and Lee demonstrated that the mesenchymal cells around the Rathke pouch eventually form the pituitary capsule enveloping the whole pituitary gland, which is distinct from the pia arachnoid membrane. However, in cases of congenital absence of the adenohypophysis, the remaining neurohypophysis in the pituitary fossa was entirely surrounded by the pia arachnoid membrane, as reported by Brewer. These facts suggest that the embryogenesis of the adenohypophysis may regulate the mesenchymal differentiation; that is, in normal development of the hypophysis, the mesenchymal cells differentiate into the pia arachnoid membrane in the suprasellar region covering the pituitary stalk and into the fibrous capsule in the pituitary fossa enveloping the pituitary gland.

In a detailed study of hypophyseal organogenesis in humans by Solov’ev et al., the Rathke pouch is initially separated from the wall of the diencephalon by a layer of mesenchyme. They noticed that when the infundibulum contacts the Rathke pouch, newly formed connective tissue appears around the epithelial elements, this being absent only at the point of contact of the epithelial and neural elements of the organ. Because the pars tuberalis (originating from these epithelial elements) eventually wraps around the infundibular stalk (originating from the neural elements), it explains the results of our study: the ASPS only envelops the outer surface of the pituitary stalk and does not extend downward from the top of the pars tuberalis into the pituitary stalk between the infundibular stalk and the pars tuberalis.

**Clinical Significance of the Arachnoid Membrane Surrounding the Pituitary Stalk**

Although it is much thinner, the intact ASPS is physically much more flexible and durable than the neural tissue. In suprasellar meningiomas, though the pituitary stalk could be severely compressed, the ASPS may protect the pituitary stalk and provide a plane of cleavage for tumor dissection, which may partially explain why the incidence of postoperative hypophyseal dysfunction is fewer in patients with suprasellar meningiomas than that in patients with other intra-axial suprasellar tumors. The arachnoid membrane surrounding the suprasellar tumor can also act as a true barrier to limit its cisternal extension. In craniopharyngiomas, the tumor may arise from anywhere along the pituitary stalk, extending from the pituitary gland to the tuber cinereum, which means the tumor may arise in the extraarachnoid, intrarachnoid, or subarachnoid space. The varying patterns of ASPS and the location of the tumor origin relative to the ASPS may be relevant in determining growth patterns and the adhesion between the tumor and the suprasellar neurovascular structures.

**CONCLUSION**

Using the combination of anatomical dissection and histologic study, this study reveals that (1) the pituitary stalk is enveloped by arachnoid mater sleeve (the ASPS) in variable length, which is the direct upward extension of the basal arachnoid membrane; (2) the ASPS begins where the pituitary stalk penetrates the basal arachnoid membrane and ends at the top of the pars tuberalis; (3) the ASPS constantly presents and is reinforced by the arachnoid trabeculae originating from the basal arachnoid membrane, the Liliequist membrane, and the medial carotid membrane in the majority of specimens; and (4) the pituitary stalk can be divided into 3 parts according to their relationship with the ASPS: the subarachnoid, intraarachnoid, and extrarachnoid.

**REFERENCES**


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