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ABSTRACT

The Liliequist membrane is a critical membrane located at the base of the brain separating the supratentorial from the infratentorial cisterns. The advantages of Liliequist membrane fenestration as a critical part of the pterional trans-Sylvian approach for ruptured anterior circulation aneurysm clipping is not well established. We demonstrated that the fundamental role of Liliequist membrane fenestration is brain relaxation through the egress of CSF that is not usually gained from other modalities (e.g., placement of a lumbar drain, fenestration of lamina terminalis) in this specific setting.

BACKGROUND

Dissection through the arachnoid planes and fenestration of the accessible cisterns are the cornerstones of modern microsurgery while dealing with intracranial lesions.

The Liliequist membrane is a horizontal arachnoid membrane attached to the dorsum sellae anteriorly, the mammillary body superiorly and the basilar artery posteriorly. It is bounded by the oculomotor nerve on each side. Embryologically, the Liliequist membrane is considered a remnant of the primary tentorium (1).

The first recognition of the Liliequist membrane was in 1875 by Key and Retzius (2). Eight decades later, it was rediscovered by an eminent Swedish radiologist named Bengt Liliequist (1923-1972) as part of his doctoral thesis titled "The subarachnoid cisterns. An anatomical and roentgenologic study" (3). The Liliequist membrane became a universally accepted medical eponym and officially settled through

Yasargil's paper "Anatomical observations of the subarachnoid cisterns of the brain during surgery" in1976 (34). Since that time, the Liliequist membrane underwent detailed descriptions in literature based on cadaveric and radiological studies (4-8).

In this article, we describe the technique and benefits of Liliequist membrane fenestration to achieve brain relaxation during the pterional trans-Sylvian approach for ruptured anterior circulation aneurysm clipping.

Pertinent anatomy of the Liliequist membrane

Intracranially, the arachnoid membranes can be either outer or inner membranes. The outer membranes include both the convexity and the basal arachnoid membranes, while the inner membranes include the trabecular arachnoid membranes which encase the neurovascular bundle within the cisterns (8). The Liliequist membrane is an inner rather than outer arachnoid membrane (9).

There is some controversy regarding the number of layers of the Liliequist membrane. The early literature published by Liliequist and Yasargil described a single-layer membrane (5,10-12). Later studies by Matsuno and Rhoton (13,14) assumed the two-layer model (the diencephalic membrane and the mesencephalic membrane). Recently, the existence of a third layer was described, but it was questionable as to whether this third layer represents a distinct layer or sparse arachnoid trabeculae (8).

From the dorsum sellae, the diencephalic membrane extends superoposteriorly to the mammillary bodies between the chiasmatic and the interpeduncular cisterns and can sometimes be identified radiologically in the sagittal MRI view. The mesencephalic membrane is a thin sheet that extends inferoposteriorly to the pontomesencephalic junction, between the interpeduncular and the prepontine cisterns. Laterally, the Liliequist membrane is attached to the oculomotor nerve and/or the uncus and tentorium. The Liliequist membrane is closely related and variably penetrated by the posterior communicating and basilar arteries and their perforating branches (4-8,10-14).

The general indications for Liliequist membrane fenestration

Liliequist Membrane fenestration plays an important

role in multiple procedures related to microscopic or endoscopic cranial surgery:

1. In surgery for tumors in the sellar and parasellar regions such as craniopharyngiomas, meningiomas, basilar tip aneurysms, and arachnoid cysts, Liliequist membrane fenestration provides an effective surgical corridor and promotes brain relaxation through CSF egress. (1,15,17).

2. Liliequist membrane fenestration is one of the most critical steps for endoscopic third ventriculostomy success.

3. Some reports consider the microscopic fenestration of the basal subarachnoid cisterns as an effective method to decrease the intracranial pressure in acute intra-operative brain swelling and also in severe traumatic brain injury. These reports advocate the inclusion of Liliequist membrane fenestration as a mandatory procedural step to achieve a good surgical outcome (16,18)

The technique for Liliequist membrane fenestration during the pterional approach for anterior circulation aneurysm clipping

The pterional approach is the preferred approach for the clipping of most anterior circulation aneurysms except for the distal anterior cerebral artery aneurysm. Using the trans-Sylvian route, the Liliequist membrane can be approached laterally. Opening the Liliequist membrane can be achieved through different corridors; namely, the carotid-oculomotor triangle, the optico-carotid triangle and even through the interoptic space. Fenestration through the carotid-oculomotor space is the most convenient, relatively wide and safe technique.

After dural opening, the Sylvian fissure is widely opened from inside to outside on the frontal side of the Sylvian veins and the proximal segment of the middle cerebral artery until the internal carotid artery bifurcation. Frontal and temporal retractors are gently applied; these retractors should "hold" the brain tissue with intermittent retraction to avoid vascular compromise. The frontal lobe is elevated, and the temporal lobe is retracted gently downward and posteriorly. The carotid cistern is opened and the thickened arachnoid fibers over the origins of the anterior and middle cerebral arteries are released. Once the 3rd nerve is identified, the carotid-oculomotor triangle is dissected and subsequently

the deeper membrane of Liliequist can be identified. As the exposure is deepened, the surgeon will extend the arachnoid opening laterally over the third nerve. Sectioning of the Liliequist membrane should be started from its anterior part as there is a large space behind the membrane. Then, the interpeduncular cistern is opened through caudal dissection of the Liliequist membrane between the oculomotor nerve and the internal carotid artery to release the cerebrospinal fluid. At this point, the posterior communicating and the anterior choroidal arteries may be visualized as they arise from the posterior surface of the internal carotid artery (the posterior communicating artery courses perpendicular to the Liliequist membrane whereas the anterior choroidal artery courses obliquely into the crural cistern) (12).

The egress of the CSF and the identification of the basilar artery within the inter-peduncular cistern is the critical step that ensures the completion of the fenestration process. Additional steps were suggested by some reports including irrigation and mechanical cleaning of blood clots beyond the Liliequist membrane to minimize the possibility of postoperative vasospasm and hydrocephaly (15,16).

Sharp dissection is always advised to minimize the risk of uncontrolled bleeding from tearing of the vessel wall. Also, the blunt and vigorous dissection may cause disastrous consequences by injuring the hypothalamus either directly or indirectly, by affecting its blood supply. Structures at risk during this step include the posterior communicating artery or its perforators, the oculomotor nerve or its blood supply and the proximal part of the superior cerebellar artery.

In the case of SAH due to a ruptured aneurysm, several studies have described the effectiveness of Liliequist membrane fenestration, either alone or in tandem with lamina terminalis fenestration, in reducing the incidence of post-SAH hydrocephalus, (9, 12, 15, 19-21). However, None of these studies focused on the effect of Liliequist membrane fenestration on brain relaxation specifically, which is crucial in such complex procedures regardless of the presence of hydrocephalus.

Liliequist membrane fenestration will create a free connection between the supratentorial and infratentorial compartments which represents the crucial advantage of Liliequist membrane fenestration over the opening of the cisterns or

lamina terminalis; this fact was supported by Yaşargil and Winkler-Lawton et al reports through the "Fifth ventricle theory" (12, 19). The fifth ventricle theory can be described as the following; in cases of aneurysmal SAH, the Liliequist membrane will entrap blood clots and it will be inflamed and thickened, thus the interpeduncular and prepontine cisterns will be isolated and dilated with CSF creating a "fifth ventricle". At this point, Liliequist membrane fenestration will result in dramatic CSF egress with striking brain relaxation which renders further surgical steps safer and more effective. Castro-Flores et al have suggested that in several patients, even after the opening of the supratentorial cisterns, the CSF pathway will remain constricted until the Liliequist membrane is opened (15).

An illustrative case

A 59-year male presented to the emergency department with an altered level of consciousness (Glasgow Coma Scale:9) of sudden onset. Initial resuscitation was done and the patient was transferred to the intensive care unit. A brain CT scan showed left gyrus rectus hemorrhage. Contrasted brain CT scan and CT angiography revealed complex ruptured anterior communicating artery aneurysm with a wide neck, and hypoplastic left Proximal anterior cerebral artery. The anterior communicating artery was vertically oriented, and the anterior cerebral arteries were connected distally to the anterior communicating artery, with two Murphy's teats (Figure 1A).

Surgical clipping through the standard right pterional trans-Sylvian approach was chosen. After dural opening, around 20cc of CSF was drained through a lumbar drain. A microsurgical arachnoid dissection was performed using an operative microscope; starting with the opening the proximal Sylvian fissure and the carotid cisterns; there was minimal egress of CSF.

The Liliequist membrane was identified and opened lateral to the supracliniod internal carotid artery through the carotid-oculomotor space. At this point, there was a striking CSF egress that filled the surgical field despite repetitive suctioning. This CSF egress had a profound effect on brain relaxation, provided us a wide operative corridor, and rendered the subsequent steps of aneurysm dissection and clipping more feasible. (Figure 2).

The postoperative course was uneventful and the patient gradually improved and was discharged with no neurological deficits (Figure 1B and C).
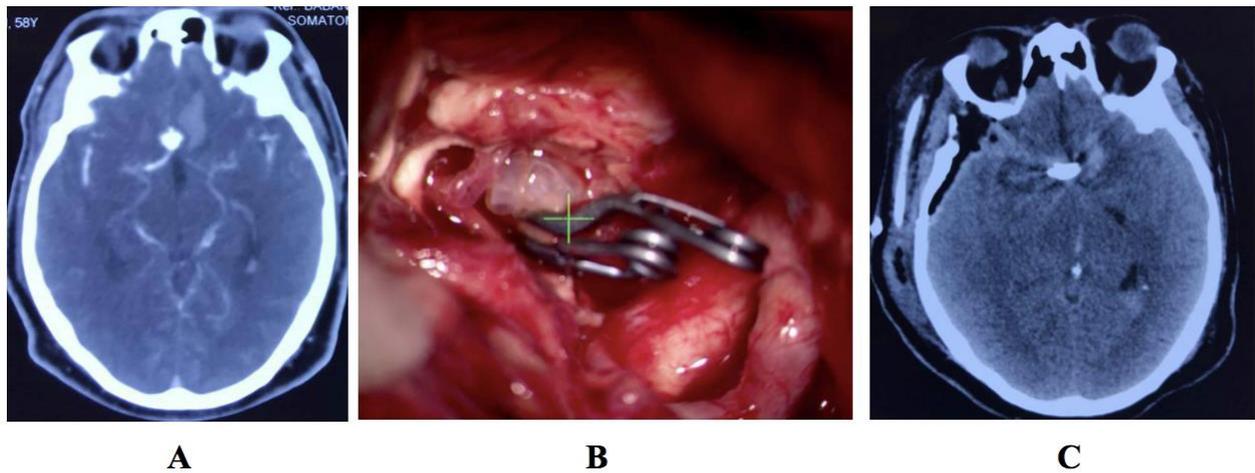
Figure 1. Illustrative case of a ruptured anterior communicating artery aneurysm. **A**: contrasted CT scan of the brain showing the left gyrus rectus due to a ruptured anterior communicating artery aneurysm. **B**: An intraoperative microscopic view showing a two-clip reconstruction for the aneurysmal neck through the right pterional trans-Sylvian approach. **C**: An early postoperative brain CT scan showing the clipping result.
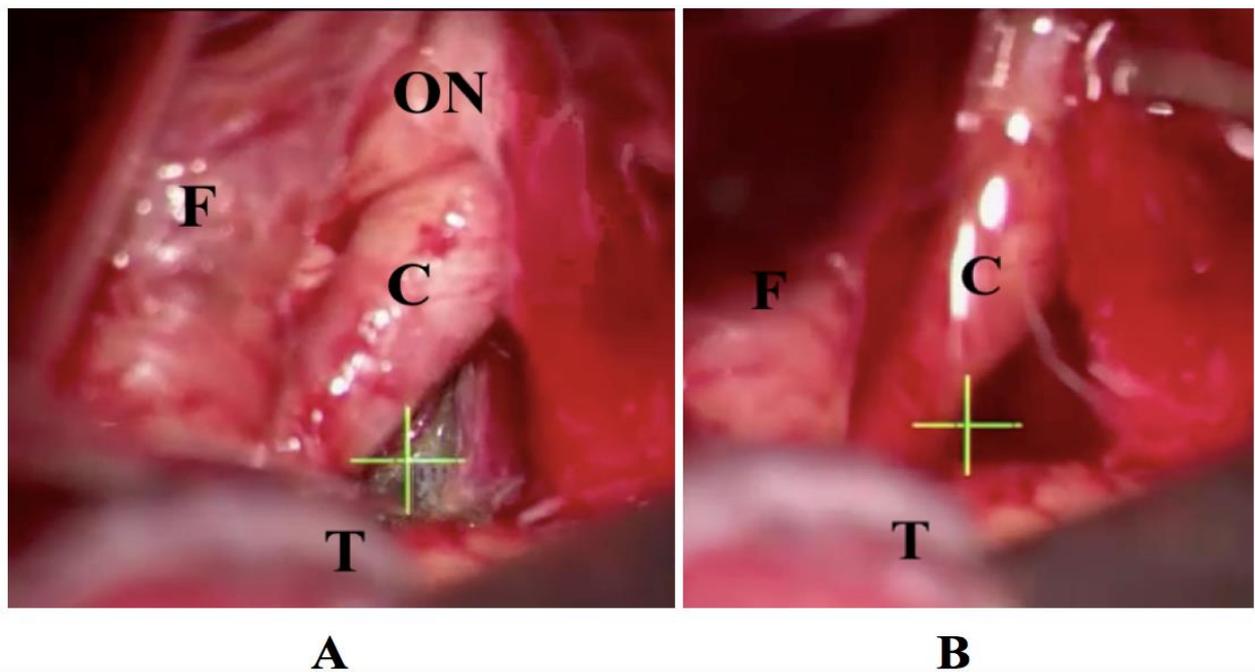
Figure 2. Stages of Liliequist membrane fenestration through the right pterional trans-Sylvian approach (Intraoperative microscopic view). The Liliequist membrane identified as a whitish layer lateral to the supraclinoid internal carotid artery through the carotid-oculomotor space. (**A**) Opening the Liliequist membrane resulted in striking CSF egress that filled the surgical field several times (**B**). (+): pointer on the Liliequist membrane, F: Frontal lobe, T: Temporal lobe, C: internal carotid artery, ON: optic nerve.

CONCLUSION

Fenestration of the Liliequist membrane has a fundamental role during the pterional trans-Sylvian approach for ruptured anterior circulation aneurysm clipping as it allows brain relaxation through egress of CSF that is not usually achieved through other

modalities (e.g, placement of a lumbar drain, fenestration of lamina terminalis). Further studies are needed to verify this observation towards making the fenestration of the Liliequist membrane a recommended surgical step rather than an optional one.

ABBREVIATIONS

MRI: magnetic resonance imaging;
CSF: cerebrospinal fluid, SAH: subarachnoid hemorrhage.

DECLARATION

Consent for publication: Our local institutional consent was obtained from the patient.
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