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Microsurgical Anatomic Features of the Olfactory Nerve: Relevance to Olfaction Preservation in the Pterional Approach

OBJECTIVE: The pterional approach represents the standard approach for most lesions of the anterior and middle cranial fossa. It requires some degree of frontal lobe retraction, which may result in temporary or permanent damage of olfaction because of nerve avulsion or mechanical compression. The purpose of this study, based on microanatomic dissection of human cadaveric specimens, was to review the microsurgical anatomic features of the nerve and suggest operative nuances that may contribute to reducing the rate of postoperative olfactory dysfunction.

METHODS: Twenty olfactory nerves and tracts were examined in 10 human cadaveric heads obtained from three fresh and seven formalin-fixed adult cadavers. A standard pterional craniotomy was performed. The olfactory nerve was dissected from its arachnoidal envelopes and then mobilized for an average length of 30 mm (range, 25–35 mm).

RESULTS: The possible retraction of the frontal lobe was 10 to 15 mm. More retraction invariably resulted in nerve disruption.

CONCLUSION: The standard sylvian and basal cistern opening may be insufficient to guarantee preservation of olfactory function. Early identification and arachnoidal dissection of the nerve may reduce the rate of olfaction compromise. The opening of the subarachnoidal space should be performed in a proximal-to-distal manner to allow early visualization of the olfactory bulb and its dissection. The arachnoidal dissection should be performed with sharp instruments, avoiding any traction on the posterior portion of the olfactory tract. Any direct retractor compression should also be avoided to spare the microvasculature lying on the dorsal surface of the nerve.

KEY WORDS: Microsurgical anatomy, Olfactory nerve, Pterional approach

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The pterional approach represents the standard approach for surgery of most lesions extending in and about the anterior and middle cranial fossa, down to the upper portion of the clivus. This approach offers distinct advantages over others for the treatment of frontotemporal lesions (10–12).

In the pterional approach, some degree of frontal lobe retraction is needed. If the retractor is placed across the olfactory nerve, it may cause strain on the nerve and striae. The olfactory nerve may also be pulled out of the cribriform plate as a result of excessive lobe retraction or may be damaged by the ischemic effects of retraction pressure (1–3).

In his original description of the pterional approach, Yaşargil (12) emphasized the importance of the dissection of the olfactory nerve along the sulcus to prevent its inadvertent avulsion. Precise knowledge regarding the normal anatomic features of the olfactory nerve and striae and the variations thereof is therefore important.

The purpose of this article, which is based on microanatomic dissections of human cadaveric specimens, is to describe the microsurgical anatomic features of the olfactory nerve and its arachnoidal, neural, and vascular relationships. Although the olfactory nerves were thoroughly examined from all directions, particular emphasis was placed on observations made from the perspective corresponding to the microsurgical pterional-transsylvian approach. The surgical implications of the morphometric data are briefly discussed.

MATERIALS AND METHODS

Twenty olfactory nerves and tracts were examined in 10 human cadaveric heads obtained from three fresh adult cadavers and seven formalin-fixed adult cadavers. In cadaveric head specimens, the arterial and venous systems were injected, under pressure, with colored silicone rubber (Dow Corning, Midland, MI) via the internal carotid arteries and internal jugular veins, respectively. An operating microscope (Carl Zeiss Co., Oberkochen, Germany) set at a magnification of ×6 to ×40 was used for all dissections and measurements.

The cadaveric head specimens were positioned in the usual manner for the right pterional approach. In all cases, a standard pterional craniotomy was performed, with flattening of the lateral sphenoid ridge and wide opening of the sylvian fissure. A self-retraining retractor was adjusted to gently elevate the basal posterior aspect of the frontal lobe with minimal retraction pressure. The degree of retraction applied was based on our previous surgical experience regarding the retraction that is possible without causing injury to neural or vascular structures, taking into account the decreased tissue compliance of cadaveric brain tissue. The ipsilateral optic nerve and internal carotid artery were exposed. The carotid, chiasmatic, interpeduncular, lamina terminalis, and basal sylvian cisterns were entered and dissected (*Fig. 1A*). The terminal portion of the olfactory tract was identified as lying under the surface of the orbital gyrus (*Fig. 1B*). The olfactory nerve was dissected from its arachnoidal envelopes, and the nerve was mobilized, facilitating retraction of the frontal lobe (*Fig. 1C*). The dissection was continued posteriorly until complete dissection of the olfactory nerve was obtained (*Fig. 1D*).

In all cases, the falx was opened to visualize the contralateral olfactory nerve. The contralateral nerve was dissected from its arachnoidal envelopes in a similar manner (*Fig. 1E*). At the end of the procedure, full control of both olfactory nerves, the medial portion of the anterior cranial fossa, the ipsilateral internal carotid artery, the ipsilateral optic nerve, and the complex anterior cerebral-anterior communicating artery was obtained (*Fig. 1F*).

Anatomic features under such surgical perspectives were analyzed, and anatomic measurements were performed directly on the selected structures. The length of the ipsilateral and contralateral olfactory tract and bulb was measured, as well as the length and width of the olfactory groove. The adequate technique of dissection of the nerve was also studied, and, finally, the degree of frontal lobe retraction allowed by the nerve mobilization was determined.

RESULTS

Under a perspective corresponding to the microsurgical pterional-transsylvian approach, three different portions of the olfactory nerve, the bulb anteriorly, the tract, and the trigone posteriorly, were identified. The olfactory tract was the first portion of the nerve that came into view after initial fontal lobe elevation, followed by identification of the anteriorly placed bulb. The olfactory nerve was enveloped by a double arachnoidal layer along its extension from the middle to the anterior cranial fossa. Those arachnoidal envelopes continued on the ventral portion of the bulb, covering the olfactory fila in their passage through the foramina of the cribriform lamina. This arachnoidal envelope, constituting the olfactory cistern, was identified in all anatomic specimens. The cistern contained the frontopolar branch of the anterior cerebral artery, despite vascular nourishment being provided by ethmoidal branches.

The arachnoidal dissection was performed in a proximal-to-distal manner, toward the bulb. The arachnoidal opening was

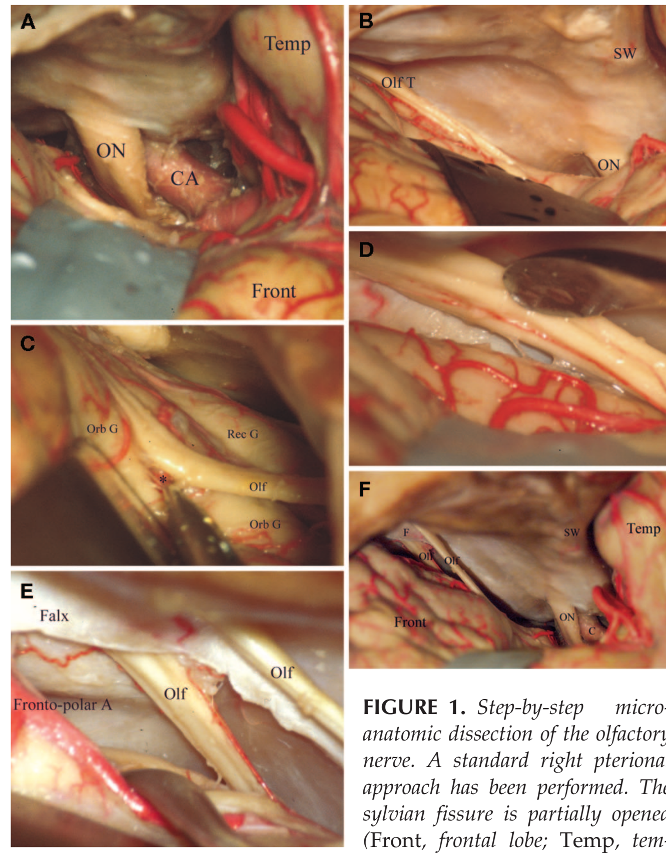

FIGURE 1. *Step-by-step microanatomic dissection of the olfactory nerve. A standard right pterional approach has been performed. The sylvian fissure is partially opened* (Front, *frontal lobe;* Temp, *temporal lobe). The internal carotid artery* (CA) *at its bifurcation and the optic nerve* (ON) *are visualized* (A). *The frontal lobe is gently retracted, exposing the olfactory nerve and tract* (Olf T). *The optic nerve* (ON) *and the sphenoid wing* (SW) *are also visualized* (B). *Sharp dissection in distal-proximal manner of the arachnoidal membranes around the olfactory nerve and tract* (Olf) *in the olfactory cistern (*). The orbital* (Orb G), *olfactory* (Olf G), *and rectus* (Rec G) *gyri are also visualized* (C). *After dissection, the olfactory nerve can be completely mobilized* (D). *The falx is incised, and the contralateral olfactory nerve is dissected by use of the same technique. The two nerves are now mobilized. The frontopolar artery* (Fronto-polar A) *in the olfactory sulcus was also identified* (E). *Overview of the surgical field at the end of dissection at low magnification. Careful dissection of the olfactory nerve allows safe retraction of the frontal lobe, decreasing the risk of tearing the olfactory fila and of battering of the nerve and tract by the spatula* (F).

performed on the dorsal surface of the nerve, using both sharp and blunt dissection. It is noteworthy that the arachnoidal dissection turned out to be safer when the instruments were moved in an anteroposterior direction, whereas nerve disruption resulted when it was performed in the opposite direction, because of the traction exerted at the junction of the posterior olfactory tract with the trigone. After the bulb was freed from the arachnoidal envelopes, the arachnoidal dissection was completed along the posterior olfactory tract and trigone.

The overall length of the olfactory nerve averaged 55 mm (range, 50.7–59.3 mm). Under the view of the operating microscope, the bulb appeared as an ovoidal structure with a convex medial edge and a straight lateral edge. At the posterior limit, a slight impression (olfactory sulcus) indicated the borderline to the olfactory tract. The olfactory bulb was situated in the olfactory groove, where it was linked to the ethmoidal cribriform plate by means of the olfactory filaments, or fila. An average of 20 (range, 18–22) olfactory fila for each side were present.

The olfactory bulb turned out to be 12 mm (range, 10.5–13 mm) in length and 5 mm (range, 4.5–5.8 mm) in width. The olfactory groove containing the olfactory bulb was 15.8 mm (range, 13–16.5 mm) in length and 5 mm (range, 4.6–5.9 mm) in width.

The main axis of the bulb was oblique with respect to the olfactory tract, describing an angle of 165 degrees. The superior aspect of the bulb was in contact with the two olfactory gyri, separated from them by a double arachnoidal layer. The inferior aspect was crossed by a number of subtle filaments of the nasal nerve that passed from the anterior internal ethmoidal channel to the ethmoidal foramen. The anterior extremity was insinuated into a dural fold that is known as the "olfactory curtain of Trolard." At the posterior extremity, a sulcus separates the bulb from the olfactory tract.

The olfactory tract is a tie-shaped structure averaging 30 mm in length (range, 23–35 mm). The transverse diameter averaged 5 mm anteriorly, becoming narrower in the posterior portion, where it averaged 2 mm.

The tract tended to became thicker in the posterior portion, assuming a triangular section with three crests: internal, external, and superior. The olfactory tract ends as a pyramid-shaped neural structure, indistinguishable from the brain parenchyma, just in front of the anterior perforated substance, called the olfactory trigone.

In all specimens, the falx was opened, exposing the contralateral olfactory nerve. The falx was identified over the crista galli and incised for 20 mm (range, 11–24 mm). Olfactory bulbs seemed to be represented symmetrically in all specimens.

The ipsilateral portion of the olfactory nerve that could be mobilized averaged 30 mm (range, 25–35 mm) in length (*Fig. 2*). Such mobilization of the olfactory nerve allowed a higher degree of retraction of the frontal lobe without damaging the nerve. The possible retraction increased from an average of 10 mm to a maximum of 15 mm (*Fig. 3, A* and *B*). More retraction invariably resulted in nerve disruption in all specimens.

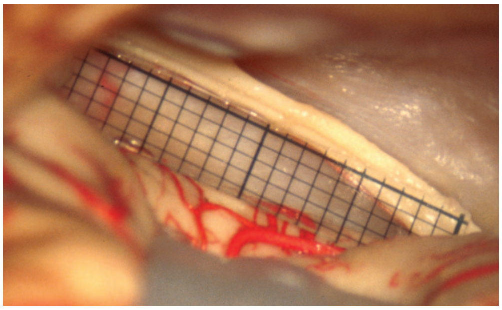

FIGURE 2. *Cadaveric photograph. After complete dissection of olfactory nerve arachnoid membranes, the nerve could be mobilized for an average length of 30 mm (range, 25–35 mm).*

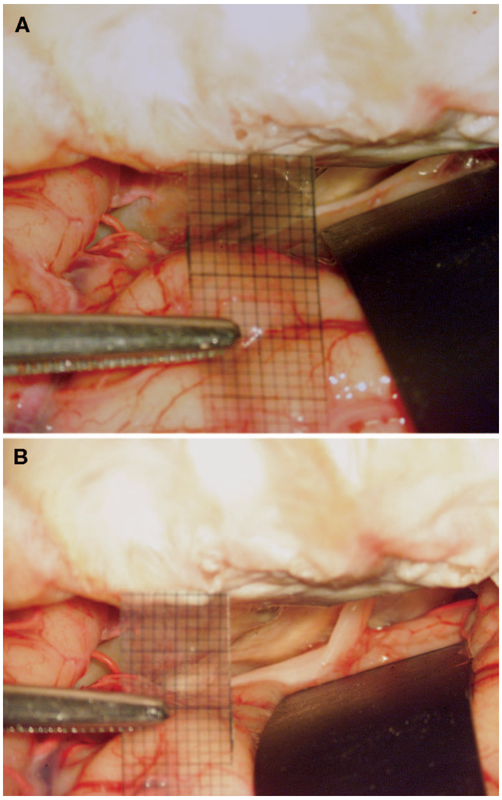

FIGURE 3. *Cadaveric photographs. Frontal lobe retraction before* (A) *and after* (B) *olfactory nerve dissection. Olfactory nerve dissection and mobilization allowed a higher degree of retraction of the frontal lobe. In this specimen, the possible frontal lobe elevation from the cranial base increased from approximately 10 to 15 mm, significantly increasing the window of surgical exposure.*

DISCUSSION

Recent clinical studies have addressed olfaction preservation during surgery for various lesions of the anterior cranial fossa in either craniofacial approaches or bifrontal craniotomies (5, 7–9). Concerning the pterional approach, the relevant literature is rather sparse. Only a few studies have addressed the issue of

TABLE 1. Mechanisms of olfactory nerve damage and complication avoidance

Mechanisms of olfactory nerve damage	Complication avoidance
Partial or total avulsion from the cribriform plate during frontal lobe retraction	Opening the nerve arachnoidal envelopes
Injury during nerve dissection	Sharp dissection in a proximal-to-distal fashion
Direct pressure damage	Respect microvascular supply lying on the dorsal surface of the nerve

olfaction preservation for lesions approached via the pterional route (1–3). There is a lack of microanatomic studies providing information relevant to modern microneurosurgery.

Potential Mechanisms of Olfactory Nerve Damage

According to our observations, three main mechanisms of olfactory nerve damage can be identified (*Table 1*). The first one is related to the course of the olfactory tract and the bulb within the subarachnoid space. A subtle arachnoid layer invariably runs between the olfactory tract and its sulcus. The olfactory tract becomes increasingly surrounded by subarachnoid space as one moves from the middle to the anterior cranial fossa.

Olfactory filaments are prone to a partial or total avulsion from the cribriform plate during the frontal lobe retraction maneuvers when not preceded by opening of their arachnoidal envelopes. After the sylvian fissure is opened and the frontal lobe slightly elevated, the olfactory tract can be identified. The double arachnoidal layer constituting the olfactory cistern should be opened on the dorsal surface, proceeding anteriorly from the tract to the bulb (*Fig. 1C*). It is important to identify the bulb as early as possible and to maintain it in direct contact with the cribriform plate (*Fig. 1E*). Such a procedure is mandatory to maintain the anatomic integrity of the nerve because of the fragility of the olfactory filaments.

The nerve can be damaged at the level of the posterior third of the olfactory tract as a consequence of tractions performed during the dissection maneuvers. Such an event is primarily a result of the anatomic features of the nerve, which passes from an average diameter of 5 mm anteriorly to 2 mm posteriorly (*Fig. 1E*). We observed that the dissection should be performed with sharp instruments and with the instruments moved posteriorly toward the trigone in a proximal-to-distal direction to avoid such an event.

Finally, a further cause of postoperative olfactory nerve dysfunction is represented by direct pressure damage. Even mild retractor pressure on the nerve can lead to temporary or permanent lesions. We suggest that such a phenomenon could be attributed to damage of the microvasculature lying on the dorsal surface of the nerve, constituted of microscopic branches of the ethmoidal arteries nourishing the nerve (4, 6) (*Fig. 1D*).

This study offers an opportunity to increase our understanding of the anatomic features of the intradural olfactory nerve under the microsurgical perspective of the pterional approach. Such awareness increased the degree of anatomic integrity of the nerve during the elevation of the frontal lobe feasible in the individual anatomic specimens.

We measured the overall portion of the nerve that can be freed from the arachnoid envelope and mobilized. The mobilized portion measured 25 to 35 mm. This maneuver permitted a higher degree of elevation of the frontal lobe. We also measured the degree of such elevation. A mobilization up to 15 mm from the cranial base turned out to be possible without damaging the olfactory nerve (*Fig. 3B*). Further mobilization invariably resulted in nerve disruption in all specimens. This observation is in line with the clinical considerations of Aydin et al. (1, 2), who stated that a degree of frontal lobe elevation limited to 1 to 1.5 cm resulted in a lower rate of postoperative olfactory dysfunction.

CONCLUSIONS

In the performance of a pterional approach, standard sylvian and basal cistern opening may be insufficient to guarantee anatomic preservation of the olfactory nerve after frontal lobe elevation. Early identification and arachnoidal dissection of the nerve may reduce the rate of postoperative olfaction compromise. The opening of the subarachnoidal space should be performed in a posteroanterior direction to allow early visualization of the olfactory bulb and its dissection. The arachnoidal dissection should be performed with sharp instruments, avoiding any traction on the posterior portion of the olfactory tract. Such maneuvers allow for an overall mobilization of the nerve of 25 to 35 mm in length, which enables a greater degree of the frontal lobe retraction window up to 15 mm, maintaining olfactory nerve integrity. Any compression exerted by the retractor should also be avoided to spare the microvasculature lying on the dorsal surface of the nerve.

REFERENCES

1. Aydin IH, Kadioğlu HH, Tüzün Y, Kayaoğlu R, Takçi E, Öztürk M: Postoperative anosmia after anterior communicating artery aneurysms surgery by the pterional approach. **Minim Invasive Neurosurg** 39:71–73, 1996.
2. Aydin IH, Önder A, Kadioğlu HH, Tahmazoğlu I, Kayaoğlu R: Postoperative anosmia after removal of pituitary gland adenomas using the pterional approach. **Acta Neurochir (Wien)** 119:101–103, 1992.
3. Eriksen KD, Boge-Rasmussen T, Kruse-Larsen C: Anosmia following operation for cerebral aneurysms in the anterior circulation. **J Neurosurg** 72:864–865, 1990.

4. Favre JJ, Chaffanjon P, Passagia JG, Chirossel JP: Blood supply of the olfactory nerve: Meningeal relationships and surgical relevance. **Surg Radiol Anat** 17:133–138, 1995.
5. Fujiwara H, Yasui N, Nathal-Vera E, Suzuki A: Anosmia after anterior communicating artery aneurysm surgery: Comparison between the anterior interhemispheric and basal interhemispheric approaches. **Neurosurgery** 38:325–328, 1996.
6. Lang J, Shäfer K: Ethmoidal arteries: Origin, course, regions supplied and anastomoses [in German]. **Acta Anat (Basel)** 104:183–197, 1979.
7. Sepehrnia A, Knopp U: Preservation of the olfactory tract in bifrontal craniotomy for various lesions of the anterior cranial fossa. **Neurosurgery** 44:113–117, 1999.
8. Spetzler RF, Herman JM, Beals S, Joganic E, Milligan J: Preservation of olfaction in anterior craniofacial approaches. **J Neurosurg** 79:48–52, 1993.
9. Suzuki J, Yoshimoto T, Mizsoi K: Preservation of the olfactory tract in bifrontal craniotomy for anterior communicating artery aneurysms and the functional prognosis. **J Neurosurg** 54:342–345, 1981.
10. Tomasello F, de Divitiis O, Angileri FF, Salpietro FM, d'Avella D: Large sphenocavernous meningiomas: Is there still a role for the intradural approach via the pterional-transsylvian route? **Acta Neurochir (Wien)** 145: 273–282, 2003.
11. Turazzi S, Cristofori L, Gambin R, Bricolo A: The pterional approach for the microsurgical removal of olfactory groove meningiomas. **Neurosurgery** 45:821–826, 1999.
12. Yaşargil MG: *Microneurosurgery: Microneurosurgery of CNS Tumors*. Stuttgart, Georg Thieme, 1996, vol IVB.

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COMMENTS

In this simple anatomic study, Cardali et al. have called attention to the problem of olfactory denervation after excessive brain retraction during pterional and frontotemporal approaches. Loss of smell function is more likely to be experienced when the surgeon is approaching a more medially located lesion such as an anterior communicating artery aneurysm, or a planum sphenoidale meningioma. In such cases, if the retraction is likely to be more than 1 cm from the cranial base, the neurosurgeon may wish to separate the olfactory tract from the frontal lobe before retraction. On the other hand, when the olfactory tract is in the surgical field, there is also a danger of damaging it during manipulation of the structures. The removal of the orbital walls increases the space available for the surgeon to work, and thus reduces the amount of brain retraction required.

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Although the olfaction plays a fundamental role in social life, only recent clinical studies have addressed olfaction preservation during surgical approaches. The purpose of this careful and detailed microanatomic study is to describe the anatomic features of the olfactory nerve and its arachnoidal, neural, and vascular relationships during the pterional transsylvian approach.

Ten cadaveric heads, three of fresh adult cadavers and seven of formalin-fixed adult cadavers were examined by the authors. The olfactory nerve was dissected from its arachnoidal envelopes and mobilized for 25–35 mm. A frontal lobe retraction window up to 10–15 mm invariably resulted in nerve disruption. The authors suggest operative procedures that may contribute to a reduction in the rate of postoperative olfactory dysfunction. The main technical point in the management of the olfactory nerve during surgery is represented by a sharp painstaking dissection of the arachnoidal envelope, especially at the level of the posterior third of the olfactory tract, avoiding disruption of small filaments, and microscopic feeders of the nerve arising from the ethmoidal arteries.

Anatomic information and recognition are highly useful for the problem of preservation of the often underestimated olfactory function, and this article makes a significant contribution to our knowledge. Preserving the olfactory nerve in course of aneurysm or tumor surgery shows different aspects. As a matter of fact, the anatomic situation during an aneurysm approach is very similar to microsurgical dissection. On the contrary, the removal of tumors extending into the anterior cranial base faces modified anatomic landmarks and the olfactory nerve should be often mobilized from the olfactory sulcus, to provide the necessary surgical access to the tumor and avoid undue retraction of the nerve. Certainly, this article is useful reading for residents before practice in the laboratory or in the operating room.

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This is a nicely done study describing the subarachnoid course and microsurgical anatomic aspects of the olfactory bulb and tract. In the context of the pterional approach as originally described, I think the risk to olfaction to be higher than it might be when incorporating certain cranial base techniques such as an orbitocranial approach. This results in a lower approach angle and diminished degrees of frontal lobe retraction. My sense is that this type of approach is more and more commonplace in neurosurgical practice versus the standard pterional technique. Nevertheless, the focus of this study on the microsurgical anatomy of the olfactory bulb and tract is certainly relevant and helpful information in terms of avoiding what can be a very annoying complication to the patient and significantly impact their overall enjoyment of life.

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