Microsurgical Anatomy for Intraoperative Preservation of the Olfactory Bulb and Tract

Ayhan Cömert, MD, Hasan Çağlar Uğur, MD, PhD,† Gökmen Kahiloğulları, MD,† Ela Cömert, MD,‡ Alaittin Elhan, PhD,* and Ibrahim Tekdemir, MD**

Abstract: Damage to the olfactory bulb and tract is a frequently described complication of brain surgery in the frontal region, and it seems to be influenced by the surgical approaches. Eighty cerebral hemispheres and 5 formalin-fixed cadavers filled with colored latex were used. Parameters were directly measured, and after olfactory bulb and tract were mobilized with careful dissections, retraction of the frontal lobe was noted. The anterior border of the olfactory bulb is 22.21 (SD, 5.45) mm posterior to the frontomarginal sulcus, and arachnoidal dissection should be performed parallel to olfactory structures using sharp instruments to allow early visualization. Overall mobilization of the olfactory bulb and tract as 29.3 (SD, 6.4) mm in length is possible without disrupting the structures and enables a greater degree of the frontal-lobe elevation window up to 13.1 (SD, 3.2) mm. Using the morphometric data and anatomic knowledge may prevent unwanted anosmia complication during surgical approaches.

Key Words: Olfactory bulb, olfactory tract, olfactory artery, anatomy, surgical implications, anosmia

(*J Craniofac Surg* 2011;22: 1080–1082)

In patients who underwent pterional craniotomy to heal parasellar pathologies, anosmia is the most common complaint. Olfactory dysfunction occurs on the side ipsilateral to surgery. The cause of anosmia may be olfactory nerve injury sustained during retraction of the frontal lobe by intraoperative shearing or stretching of the olfactory filaments, by direct pressure from the spatula to the nerve, or by destruction of the vessels supplying the olfactory structures.[1–3]

A precise knowledge of anatomic landmarks is important to avoid unnecessary injury to neural or vascular structures within the anterior skull base. In performing a pterional approach, standard sylvian and basal cistern opening may be insufficient to guarantee anatomic preservation of the olfactory bulb and tract after frontal-lobe elevation. Recent clinical studies have addressed olfaction preservation during surgery for various lesions of the anterior cranial fossa in either craniofacial approaches or bifrontal craniotomies.[1,4,5] The use of endoscopic approach tangential to the skull base may minimize the injury. Kabil and Shahinian[6] reported their experience with a supraorbital endoscopic approach to tumors of the anterior cranial base minimizing unnecessary brain retraction.

The olfactory bulb and tract and the olfactory cistern are previously well defined.[7] However, their surgical anatomy and its relation with the olfactory cistern have not been comprehensively defined, except for scant anatomic studies.[8,9] There is still a lack of microanatomic studies providing morphometric information relevant to modern operative microsurgery. This study aimed to provide direct normal morphometric information and current relations of the olfactory bulb and tract.

MATERIALS AND METHODS

Eighty cerebral hemispheres from 40 adult cadaveric brains were obtained. The anterior cerebral arteries were cannulated and injected with red-colored latex. The brains were then fixed in formaldehyde. In addition, 5 cadaveric heads filled with colored latex were used. Brains having signs of central nervous system trauma or disease were excluded. The dissections were performed using microsurgical instruments and a surgical microscope (Zeiss Opmi 9FC; Carl Zeiss, Jena, Germany). The following parameters were obtained: (1) the distance between the frontomarginal sulcus and the anterior margin of the olfactory bulb, (2) the distance between the frontomarginal sulcus and the posterior border of the olfactory bulb that can be freely turned out (without any dissection), (3) the length of the olfactory bulb that can be freely turned out (without any dissection), (4) the distance between the frontomarginal sulcus and the posterior parolfactory sulcus,[10] (5) the overall length of the olfactory bulb and tract that can be freely mobilized after careful dissection by preserving their integrity, and (6) greater degree of the frontal-lobe retraction, after opening the arachnoidal membrane.

The olfactory bulb and tract were dissected from its arachnoidal envelopes, and the olfactory bulb and tract were mobilized, facilitating retraction of the frontal lobe. The arachnoidal dissection was performed in an anterior-to-posterior manner, from the frontomarginal sulcus toward the dorsal surface of the olfactory bulb and tract.

Anatomic features, arterial loops in the olfactory sulcus, and microvascular relations were observed. All the measurements were performed using a digital caliper and a ruler. The adequate technique of minimally invasive dissections of the arachnoids was applied in all the specimens. Craniotomies were performed, and the degree of frontal-lobe retraction allowed by the nerve mobilization was determined in 5 cadavers.

RESULTS

The olfactory bulb and tract can be mobilized up to 29.3 mm that enables a greater degree of the frontal-lobe retraction window up

From the Departments of *Anatomy, and †Neurosurgery, Faculty of Medicine, Ankara University; and ‡Otolaryngology Clinic, Ankara Oncology Education and Research Hospital, Ankara, Turkey.

Received December 2, 2010.
Accepted for publication January 30, 2011.

Address correspondence and reprint requests to Ayhan Cömert, MD, Department of Anatomy, Faculty of Medicine, Ankara University, 06100 Sihhiye, Ankara, Turkey; E-mail: comertayhan@yahoo.com
E.C. is a PhD student in the Department of Anatomy, Faculty of Medicine, Ankara University, Ankara, Turkey.

The authors report no conflicts of interest.

ISSN: 1049-2275
DOI: 10.1097/SCS.0b013e3182139884

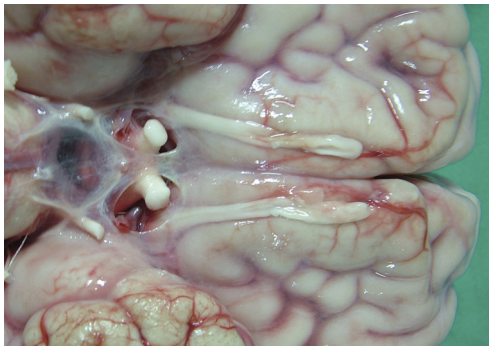

FIGURE 1. Relation of the olfactory bulb and tract with the arachnoidal layer in intact and unembalmed specimen.

to 13.1 mm. The olfactory bulb and tract were enveloped by a double arachnoidal layer along its extension from the middle to the anterior cranial fossa (Fig. 1). These arachnoidal envelopes constituting the olfactory cistern in the superficial part of the olfactory sulcus were identified in all the specimens. The olfactory cistern extends longitudinally (anteroposteriorly) as a slender space from the level of anterior olfactory tentorium to the olfactory trigone. Its inferior wall was a layer of arachnoid membrane bridging the gyrus rectus and the orbital gyrus; its medial-superior wall was pia mater covering the gyrus rectus, and its lateral-superior wall was pia mater covering the orbital gyrus.

It was observed that arachnoidal dissection turned out to be safer when the instruments were moved in an anteroposterior direction because traction was not applied. Retractors should be carefully applied to avoid compression and to spare the microvasculature lying on the dorsal surface of the nerve (Figs. 2A, B). It was observed that the arachnoidal dissection should be performed parallel to olfactory structures using sharp instruments, avoiding any traction on the posterior portion of the olfactory tract. The technique of dissecting the structures and opening the subarachnoidal space is important. It should be performed in a parallel direction to allow early visualization of the olfactory bulb and its dissection.

The frontomarginal sulcus was observed as a reliable landmark, and the mean of the distances of the measured parameters was represented in Table 1 (Fig. 3). Additional care should be applied during dissection near the supplying arteries lying under the arachnoid membrane commonly identified as medial orbitofrontal and olfactory artery (branch; Fig. 4). The arteries arise from

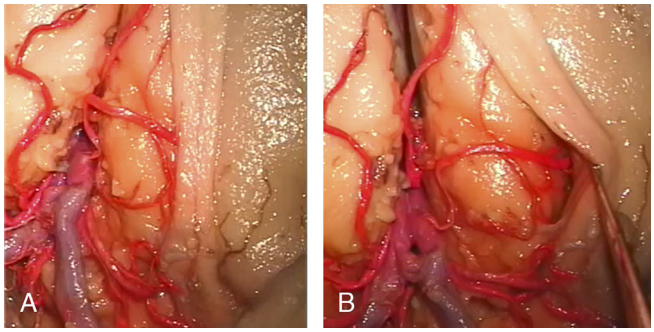

FIGURE 2. A and B, Photographs taken from surgical microscope (original magnification ×0.6) demonstrating relation of the olfactory tract with the olfactory artery that supplied microvasculature lying on the dorsal surface of the nerve.

TABLE 1. Measured Parameters

Parameters	Mean (SD), mm
1. The distance between the frontomarginal sulcus and the anterior margin of the olfactory bulb	22.21 (5.45)
2. The distance between the frontomarginal sulcus and the posterior border of the olfactory bulb that can be freely turned out (without any dissection)	37.9 (9.1)
3. The length of the olfactory bulb that can be freely turned out (without any dissection)	15.9 (4.3)
4. The distance between the frontomarginal sulcus and the posterior parolfactory sulcus	64.9 (8.9)
5. The overall length of the olfactory bulb and tract that can be freely mobilized after careful dissection with preserving their integrity	29.3 (6.4)
6. Greater degree/distance of the frontal-lobe retraction/elevation, after opening the arachnoidal membrane	13.1 (3.2)

the distal anterior cerebral artery, course laterally, and then extend under the olfactory tract in the olfactory sulcus; and occasionally 2 loops can occur in this region. Blood supply can be in segmental style, or the artery may originate anteriorly, that limits dissection of the arachnoid and limits mobilization. In this case, separation of the olfactory tract is not safe. There are many small branches of the olfactory artery near the olfactory bulb, and damage of these distal branches may explain small amount of bleeding near the anterior pole of the olfactory cistern during retraction applied in surgery.

DISCUSSION

The microanatomy of the arachnoidal envelopes and the neurovascular relationship of the olfactory bulb and tract are important to physicians and neurosurgeons during approaches to the anterior skull base. Spetzler et al[11] described an approach to the posterior midline structures in the cranial base with olfactory

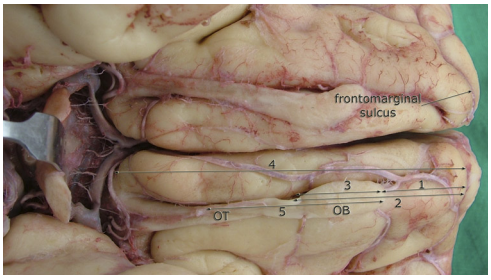

FIGURE 3. Photographs demonstrating measured parameters: (1) the distance between the frontomarginal sulcus and the anterior margin of the olfactory bulb (OB), (2) the distance between the frontomarginal sulcus and the posterior border of the olfactory bulb that can be freely turned out (without dissection), (3) the length of the olfactory bulb that can be freely turned out (without dissection), (4) the distance between the frontomarginal sulcus and the posterior parolfactory sulcus, and (5) the overall length of the olfactory bulb and the olfactory tract (OT) that can be freely mobilized after careful dissection with preserving their integrity.

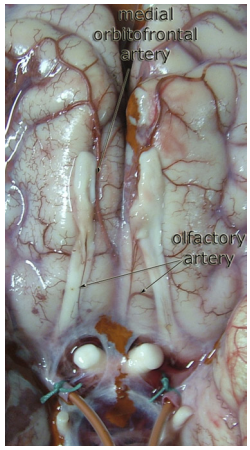

FIGURE 4. Relation of the olfactory bulb and tract with the medial orbitofrontal and olfactory artery in unembalmed specimen.

preservation that involves en bloc elevation of the olfactory unit in the cranial base and preservation of its attachment to the frontal-lobe dura. However, during horizontal mobilization of the olfactory unit at 5 to 10 mm below the cribriform plate, the olfactory nerves are inevitably transected in the skull base. Recently, a higher incidence of olfactory dysfunction was found in those patients in whom a contralateral pterional approach and a pterional approach for an anterior communicating artery aneurysm were used.[12] Browne and Mims[13] concluded that with localized frontal subcranial approach, minimized frontal-lobe retraction, and the possibility of olfactory preservation should be considered when possible in patients with unilateral disease of the anterior skull base.

Yasargil[9] emphasized the importance of the olfactory sulcus and noted the looping of arteries into the sulcus and stated that early identification and arachnoidal dissection of the nerve may reduce the rate of postoperative olfaction compromise. Favre et al[14] studied the microanatomy of the basic structure and vascular features of the olfactory cistern using cross-sections of the specimens. In the current study, we found more connections with the cistern wall that cannot be easily separated as they described; we agree with the authors in that fibrous connections can be separated for several centimeters. However, we believe it is not an easy task. The olfactory bulb and tract could not be separated always from the frontal lobe in some cases as easily and safely because if the elevation is not gentle, structures may be damaged by the ischemic effects of retraction pressure. In previous studies, it was stated that a degree of frontal-lobe elevation limited to 10 to 15 mm resulted in a lower rate (15% of the patients) of postoperative olfactory dysfunction.[15,16] These clinical considerations are parallel to the cadaveric findings in this study. Using the morphometric data and anatomic knowledge during surgical interventions may prevent unwanted iatrogenic complications. Any kind of olfactory injury can result in anosmia. Frontobasal fractures generally injure olfactory or optic nerves, and the anterior skull base fractures may involve injury of the first 6 cranial nerves (I, II, III, IV, and VI).[17] Coagulation or injury of the arteries supplying the olfactory structure also may result in loss of olfaction. Knowledge of the anatomic features reported herein may reduce surgical morbidity following operative approaches to anterior communicating artery aneurysms and is important during the treatment of frontotemporal lesions and pterional approaches. To perform confident surgical interventions, overall mobilization of the olfactory bulb and tract as 29.3 (SD, 6.4) mm in length that enables a greater degree of the frontal-lobe retraction window up to 13.1 (SD, 3.2) mm usually maintaining intact olfactory bulb and tract should be kept in mind.

REFERENCES

1. Eriksen KD, Boge-Rasmussen T, Kruse-Larsen C. Anosmia following operation for cerebral aneurysms in the anterior circulation. *J Neurosurg* 1990;2:864–865
2. Fujiwara H, Yasui N, Nathal-Vera E, et al. Anosmia after anterior communicating artery aneurysm surgery: comparison between the anterior interhemispheric and basal interhemispheric approaches. *Neurosurgery* 1996;38:325–328
3. Suzuki J, Yoshimoto T, Mizoi K. Preservation of the olfactory tract in bifrontal craniotomy for anterior communicating artery aneurysms, and the functional prognosis. *J Neurosurg* 1981;54:342–345
4. Cardali S, Romano A, Angileri FF, et al. Microsurgical anatomic features of the olfactory nerve: relevance to olfaction preservation in the pterional approach. *Neurosurgery* 2005;57:17–21
5. Sepehrnia A, Knopp U. Preservation of the olfactory tract in bifrontal craniotomy for various lesions of the anterior cranial fossa. *Neurosurgery* 1999;44:113–117
6. Kabil MS, Shahinian HK. Application of the supraorbital endoscopic approach to tumors of the anterior cranial base. *J Craniofac Surg* 2005;16:1070–1074
7. Lang J, Reiter U. Intracisternal length of the brain path and nerve tracts of the I to IV cranial nerves [in German]. *Neurochirurgia (Stuttg)* 1984;27:125–128
8. Wang SS, Zheng HP, Zhang X, et al. Microanatomy and surgical relevance of the olfactory cistern. *Microsurgery* 2008;28:65–70
9. Yasargil MG. *Microneurosurgery, Vol IIIA*. Stuttgart: Georg Thieme, 1987:284–295
10. Ono M, Abernathey CD, Kubik S. *Atlas of the Cerebral Sulci*. New York: Thieme Medical Publishers, 1990
11. Spetzler RF, Herman JM, Beals S, et al. Preservation of olfaction in anterior craniofacial approaches. *J Neurosurg* 1993;79:48–52
12. Park J, Lee SH, Kang DH, et al. Olfactory dysfunction after ipsilateral and contralateral pterional approaches for cerebral aneurysms. *Neurosurgery* 2009;65:727–732
13. Browne JD, Mims JW. Preservation of olfaction in anterior skull base surgery. *Laryngoscope* 2000;110:1317–1322
14. Favre JJ, Chaffanjon P, Passagia JG, et al. Blood supply of the olfactory nerve. Meningeal relationships and surgical relevance. *Surg Radiol Anat* 1995;17:133–138, 12–14
15. Aydin IH, Önder A, Kadioglu HH, et al. Postoperative anosmia after removal of pituitary gland adenomas using the pterional approach. *Acta Neurochir (Wien)* 1992;119:101–103
16. Aydin IH, Kadioglu HH, Tüzün Y, et al. Postoperative anosmia after anterior communicating artery aneurysms surgery by the pterional approach. *Minim Invasive Neurosurg* 1996;39:71–73
17. Mandrioli S, Tieghi R, Galiè M, et al. Anterior skull base fractures: guidelines for treatment. *J Craniofac Surg* 2008;19:713–717