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CLINICAL ARTICLE - NEUROSURGICAL TECHNIQUES

Unilateral endonasal transcribriform approach with septal transposition for olfactory groove meningioma: can olfaction be preserved?

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Abstract
Background Loss of olfaction has been considered inevitable in endoscopic endonasal resection of olfactory groove meningiomas. Olfaction preservation may be feasible through an endonasal unilateral transcribriform approach, with the option for expansion using septal transposition and contralateral preservation of the olfactory apparatus.
Methods An expanded unilateral endonasal transcribriform approach with septal transposition was performed in five cadaver heads. The approach was applied in a surgical case of a 24 × 26-mm olfactory groove meningioma originating from the right cribriform plate with partially intact olfaction.
Results The surgical approach offered adequate exposure to the anterior skull base bilaterally. The nasal/septal mucosa was preserved on the contralateral side. Gross total resection of the meningioma was achieved with the successful preservation of the contralateral olfactory apparatus and preoperative olfaction. Six months later, the left nasal cavity showed no disruption of the mucosal lining and the right side was at the appropriate stage of healing for a harvested nasoseptal flap. One year later, the preoperative olfactory function was intact and favorably viewed by the patient. Objective testing of olfaction showed microsomia.
Conclusions Olfaction preservation may be feasible in the endoscopic endonasal resection of a unilateral olfactory groove meningioma through a unilateral transcribriform approach with septal transposition and preservation of the contralateral olfactory apparatus.

Keywords Olfactory groove · Meningioma · Olfaction preservation · Septal dislocation · Transcribriform

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Introduction

Olfaction is the most undervalued of the senses in modern cultures. Smell is not just a biological and psychological experience, it is also a social and cultural phenomenon. The sense of olfaction provides protection against environmental hazards, contributes to interpersonal relationships, and impacts nutritional and eating habits. Considering that olfactory input is highly interconnected with the limbic system, it is predictable that impairments in the sense of smell may result in psychophysiological changes. The olfactory epithelium is located high in the nasal cavity on the inferior portion of the superior turbinate, medial portion of the middle turbinate, cribriform plate, and the superior portion of the posterior nasal septum. This area is highly vulnerable during expanded endoscopic endonasal approaches to the anterior cranial fossa. Loss of olfaction has been inevitable in the transcribriform approach for olfactory groove meningiomas (OGMs). Preservation of olfaction should be the cornerstone of management decisions for OGMs.

OGMs can start as a small lesion unilaterally or bilaterally, cause destruction of the olfactory nerves via compression

overtime, and some lesions can reach giant sizes with bilateral loss of olfaction. Lateralization of olfactory processes may play a significant role in the quality of olfaction before and after surgery depending on the side of origin of tumor. In such instances, olfaction preservation on the contralateral side is conceivably achievable through an open or even endonasal approach. If complete resection of the meningioma is achieved with preserved olfaction even unilaterally, these patients may be able to live a more satisfactory lifestyle, especially if the intact side is the dominant side. Applying this concept, an endoscopic endonasal unilateral transcribriform approach with septal dislocation can be utilized to preserve the contralateral olfactory apparatus both anatomically and functionally. In the current study this approach was successfully performed in the cadaveric laboratory as well as in one qualifying surgical case with the successful preservation of olfaction. We describe the surgical approach in a detailed stepwise fashion and report the surgical results from the representative surgical case.

Methods

Endoscopic endonasal unilateral transcribriform approach with septal transposition was utilized in five colored silicone injected cadaver heads. In all specimens, adequate exposure and visualization of the contralateral anterior cranial fossa was achieved. The contralateral olfactory tract was safely dissected and preserved (Fig. 1a and b), however the working window was small in the absence of tumors that usually create additional working space. Angled endoscopes (30–45 degrees) and angled instruments provided better visualization and bimanual dissection in the contralateral skull base. The approach was utilized in a real surgical case of a small progressive olfactory groove meningioma and partially intact olfaction.

Results

Surgical technique

Endoscopic endonasal unilateral transcribriform approach with septal dislocation is utilized for a lesion originating from the right cribriform plate. The septal transposition technique has been previously reported to help achieve extreme contralateral access [12], but in this approach it is utilized to facilitate binostril four-hand surgical access while preserving olfactory epithelium on the contralateral side. A left-sided hemitransfixion incision is used. The olfactory epithelium is carefully elevated off the septum, including the epithelium from the perpendicular plate of the ethmoid bone and from the olfactory fossa, thus preserving neuronal inputs (Fig. 2a–d). The central and superior portion of the septal cartilage and bone are resected, allowing binostril access to the right cribriform plate. The right middle turbinate and ethmoid air cells are opened in order to expand the working window. Subsequently, the cribriform plate on the right is resected using the Sonopet (Stryker, Kalamazoo, MI, USA) or high-speed drill. An angled tip is used to trim the medial edge of the cribriform plate and avoid the violation of the contralateral olfactory bulb/tract. The anterior ethmoidal artery and dural base of the meningioma are coagulated for devascularization. After dural opening, internal tumor debulking is performed. The capsule is then carefully dissected from the fronto-orbital cortex on the right side. Following this medially, the base of the crista galli is resected, the falx attachments are divided, and the midline portion of the tumor is approached and similarly debulked. The dural base on the contralateral side is sharply incised and dissected thus exposing the olfactory tract and the orbitofrontal artery. The tumor capsule on the contralateral side is meticulously dissected off the orbito-frontal cortex while maintaining the arachnoid plane of the olfactory nerve thus preserving its microvasculature. Gross total resection can be achieved with successful anatomical preservation of the contralateral olfactory apparatus (Fig. 2a–d). A multilayer closure is performed according to surgeon preference; in this scenario, we prefer to use a gasket seal closure of a PDS plate (KLS Martin, Jacksonville, FL, USA) and Duragen (Integra, Plainsboro, NJ, USA). A nasoseptal flap is mobilized from the ipsilateral side for reconstruction of the skull base defect. The total operative time was 2.5 h.

Illustrative case

A 55-year-old female was diagnosed with Lyme disease in the past and as part of workup for headaches had undergone an MRI showing a 16-mm OGM. Two years later, she presented to our clinic with constant right frontal headaches and an interval MRI showing enlargement of the lesion up to 24 × 26 mm (Fig. 3). She reported decreased sense of smell and taste and a recent progressive dysosmia, where she experienced distorted smell of familiar substances. For increasing size of the lesion and symptomatology, she was advised to undergo surgical resection of the tumor. As shown in the MRI, her tumor appeared to have originated exclusively from the right cribriform plate with no extension to the contralateral cribriform plate (Figs. 3 and 4a, b). An endonasal endoscopic unilateral trans cribriform approach with septal transposition was favored as a minimally invasive approach to achieve definitive treatment with contralateral preservation of the olfactory apparatus. Gross total resection of the meningioma and dural base was achieved, as confirmed by the postoperative

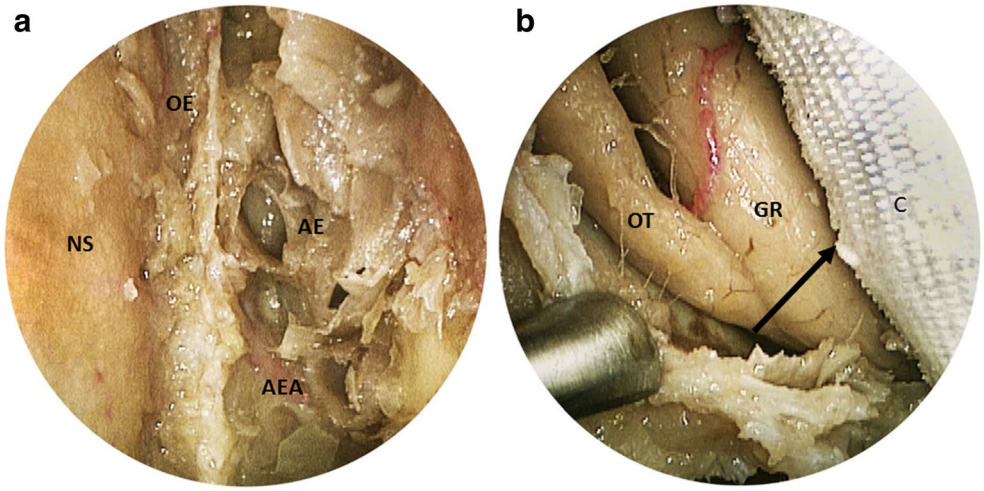

Fig. 1 **a**, **b** Cadaveric images of a left-sided approach. **a** Left nostril approach showing nasal septum (*NS*), olfactory epithelium (*OE*), anterior ethmoid air cells (*AE*), and anterior ethmoid artery (*AEA*). **b** Post left cribriform removal showing right olfactory tract (*OT*), gryus rectus (*GR*). **c** Cottonoid over left gyrus rectus; *arrow* interhemispheric fissure

imaging. The total operative time was two and a half hours and the patient was discharged home on postoperative day 5. Six months later, outpatient nasal endoscopy demonstrated no disruption of the mucosal lining on the left and the right side was at the appropriate stage of healing for a harvested nasoseptal flap. There was no evidence of a CSF leak and the nasoseptal flap was tightly adherent to the skull base. The patient had the same preoperative olfactory function with persistent dysosmia and no residual tumor or recurrence (Fig. 5). Twelve months later, the patient's olfactory function was subjectively at the same preoperative level. However, The University of Pennsylvania Smell Identification Test (UPSIT) [4] was conducted in order to objectively assess the olfactory function. The patient

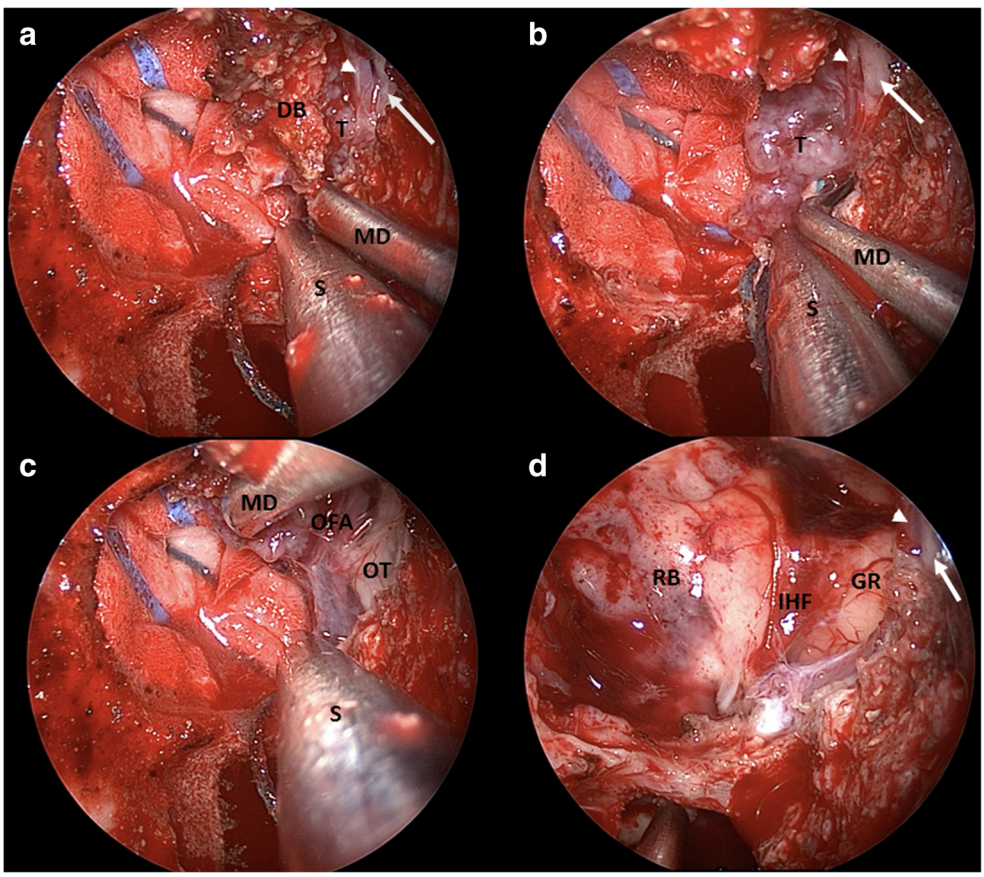

Fig. 2 **a–d** Intraoperative images. A right nostril approach showing **a** dural base resection, **b** tumor dissection from contralateral olfactory tract, **c** intact arachnoid plane around olfactory tract, **d** post resection, intact neurovascular bundle. *DB* dural base, *T* tumor, *S* suction tip, *MD*, microdissector, *OFA* orbitofrontal artery, *RB* resection bed, *IHF* interhemispheric fissure, *GR* contralateral gyrus rectus. *Arrow* contralateral olfactory tract (*OT*); *Arrowhead* contralateral orbitofrontal artery (*OFA*)

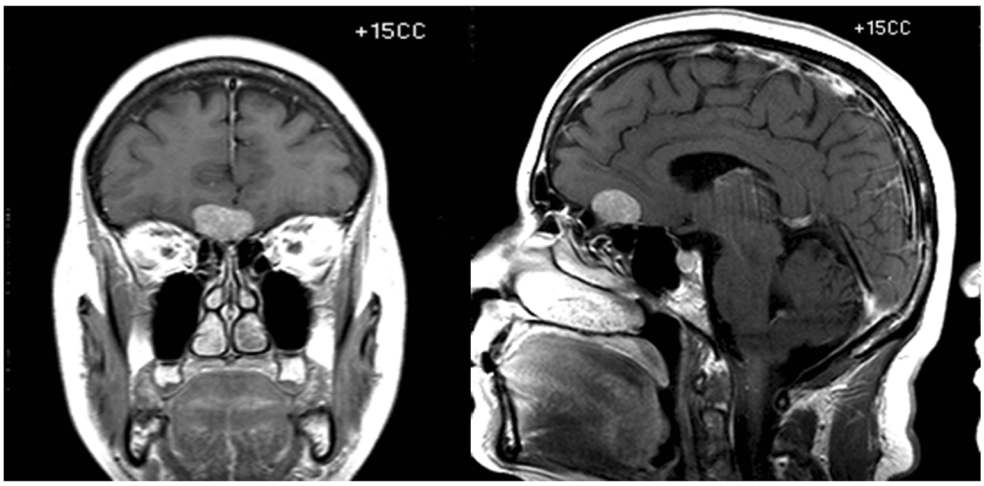

Fig. 3 Preoperative MRI showing the 24 × 26 mm olfactory groove meningioma (OGM)

scored 18, meaning that she has microsomia or decreased sense of smell.

Discussion

Preservation of olfaction may be feasible in endoscopic transnasal surgery for OGMs. This is contingent upon the following: unilateral origin of the tumor from the cribriform plate, intact contralateral olfactory function, lateralization of olfactory function to the contralateral side, preservation of the contralateral olfactory epithelium through a septal transposition technique, and preservation of the contralateral cribriform plate and olfactory apparatus by performing a unilateral transcribriform approach. Such an approach is described as an endonasal endoscopic unilateral transcribriform approach with septal transposition.

Current surgical strategies

Several surgical approaches have been utilized in the management of OGMs. Traditionally, the bifrontal approach has been the de facto standard surgical approach for giant tumors while the anterolateral approaches are reserved for smaller lesions. The evolution of endoscopic and keyhole approaches in contemporary neurosurgery has emphasized precision and minimal tissue disruption regardless of the size or location of the pathology.

Advantages of the extended endoscopic approaches include the absence of brain retraction, early tumor devascularization, and the possibility of more complete tumor

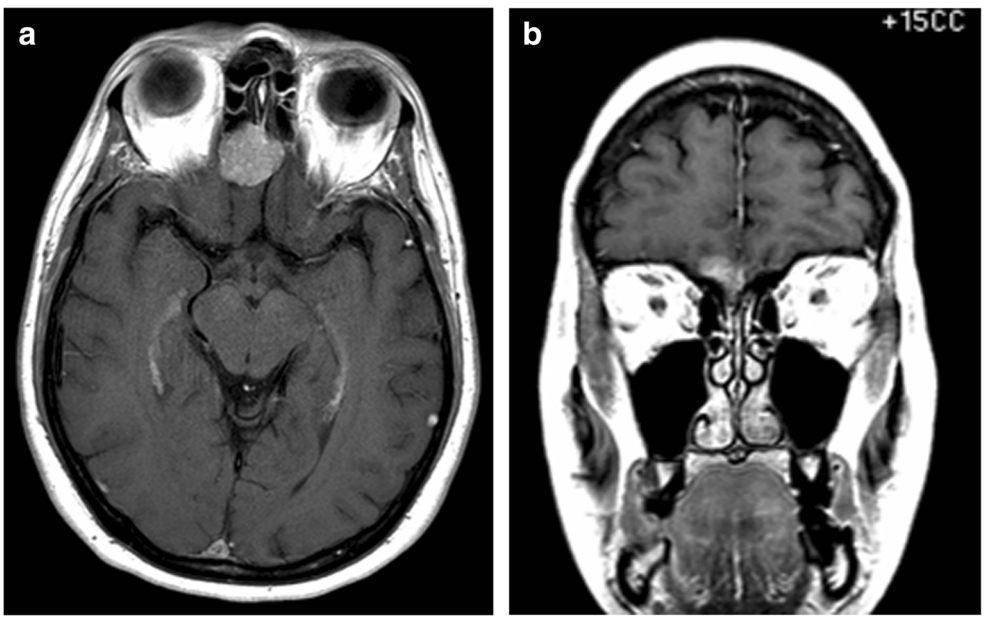

Fig. 4 Preoperative axial (**a**) and coronal (**b**) MRI showing right-sided origin of the tumor base

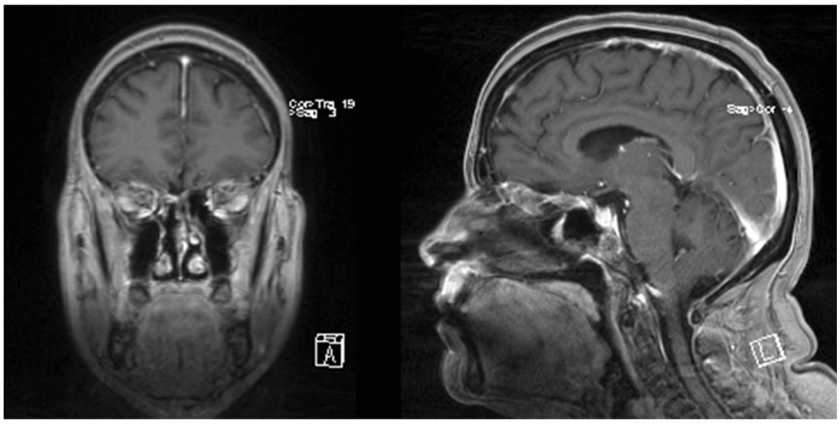

Fig. 5 Six month post-operative MRI showing no recurrence of OGM

resection with the dural base and any underlying abnormal bone. Disadvantages of the transcribriform endoscopic endonasal approach are significant disruption of normal sinonasal anatomy including the turbinates and the nasal septum in addition to damage to the olfactory apparatus and the risk of CSF rhinorrhea. Ultimately, the decision to use a particular surgical approach for OGMs should be tailored to patient specifics and should aim for preservation of olfaction.

As skull base surgery has evolved, there has been a paradigm shift in outcome assessment from extent of resection to functional outcome. Traditionally, outcome assessment in the management of OGMs has not involved thorough analysis of olfactory functional outcomes despite its tremendous impact on quality of life. For instance, a recent large series evaluating outcomes and limitations of OGM surgery briefly tackled olfaction [10]. Various reports have been published about olfaction preservation with a common theme of superiority of transcranial to transnasal approaches. de Almeida et al. [3] showed less frontal lobe injury on FLAIR sequence MRI postoperatively with the endoscopic approach. Banu et al. reported that endoscopic assistance added superiority to the supraorbital approach [1]. The authors nonetheless state that "the inevitability of anosmia will never be overcome" when an endonasal endoscopic approach is employed in those with intact olfaction preoperatively. Other authors similarly prefer the supraorbital approach with endoscopic assistance for small (<3–4 cm) OGMs with intact olfaction in order to preserve the olfactory tracts, thus emphasizing that the endonasal approach is suitable only when olfaction has already been lost [14]. A recent editorial stated that for smaller OGMs with intact olfaction, the transcranial route should be the preferred method [15]. Overall, experts seem to agree that endoscopic endonasal approaches for OGMs inevitably result in complete loss of olfaction [10, 11, 15].

Lateralization of olfaction

The olfactory epithelium is located high in the nasal cavity-specifically, on the inferior portion of the superior turbinate, medial portion of the middle turbinate, cribriform plate, and the superior portion of the posterior nasal septum. Several studies suggested a correlation between lateralization of olfactory processes and the quality of odor. The quality of odor is a complex property but the two most important characteristics

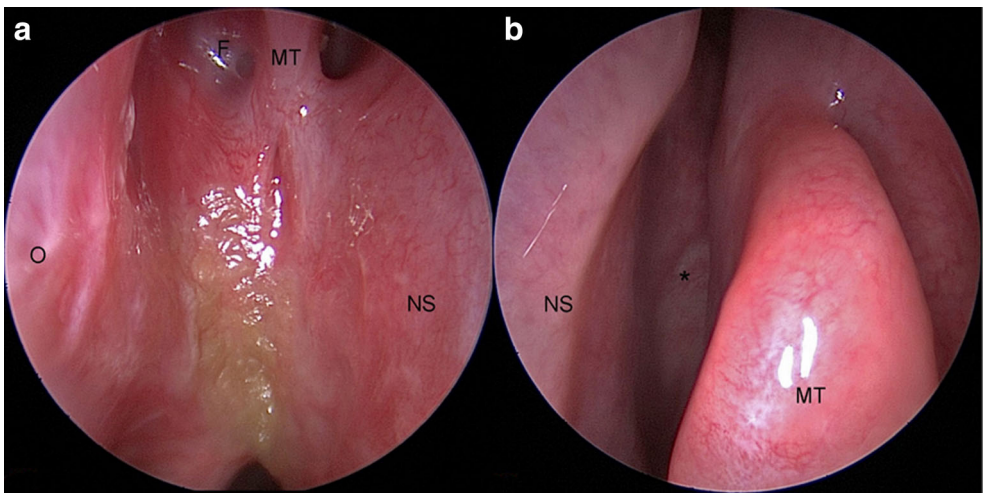

Fig. 6 **a**, **b** Six-month postoperative endoscopic images. **a** Right nasal cavity with a 30 degree endoscope demonstrating scarring at the healed surgical site. **b** Normal appearance of left nasal cavity including olfactory cleft (*). *O* orbit, *F* frontal sinus, *MT* partially resected middle turbinate, *NS* nasal septum

could be the hedonic valence (i.e., pleasant/unpleasant character) [5, 6, 9] and the trigeminal component (irritant/non-irritant character) [8]. The hedonic valence is the predominant component with a high level of ipsilateral connectivity to the limbic system and primary sensory cortex. The olfactory system coexists in the nasal cavity with other sensorial systems, especially the trigeminal system, which projects contra laterally. The study by Brand et al. in a sample of 30 right-handed subjects (15 males and 15 females) showed a predominance of the right hemisphere in the treatment of olfactory information not depending on the quality of odor, except the trigeminal-nerve activation [2]. The right hemispheric dominance in the perceptual processing of olfaction has been well studied and reported [16–19]. Preserving the olfactory apparatus on a dominant side may preserve unilateral olfaction with subsequent tremendous functional outcome.

Unilateral transcribriform approach

Small OGMs originating from one cribriform plate with partially/unilaterally intact olfaction may be candidates for a unilateral endoscopic endonasal transcribriform approach with contralateral preservation of the olfactory apparatus. Recently, a septal transposition technique has been described to preserve the bony integrity of the anterior septum thus avoiding septal perforation in a patient with OGM (the patient had preoperative anosmia) [13]. We sought to utilize this technique in order to create binostril access for a unilateral transcribriform approach while preserving the contralateral septal/nasal mucosa including the olfactory epithelium. Expanded unilateral endonasal approach after middle turbinectomy, maxillary antrostomy and ethmoidectomy(ies) when needed, provides additional working space for access and bimanual dissection of the contralateral tumor capsule. Angled 30–45 degree endoscopes and instruments are specifically helpful for the final step of tumor resection across the midline. This maximizes visualization and extra-arachnoidal dissection of the contralateral neurovascular structures namely the olfactory tract and orbitofrontal artery (Fig. 2a–d). Maintaining the arachnoid around the olfactory bulb/tract helps to preserve the nerve microvasculature and the functional integrity of the nerve. This approach was utilized both in cadavers and in a real surgical case. The patient had a right-sided progressively enlarging meningioma (Figs. 3 and 4a, b) with partially intact olfactory function as confirmed by clinical examination. Six months after surgery, outpatient nasal endoscopy was performed. As described above, the left nasal cavity showed no disruption of the mucosal lining and the right side was at the appropriate stage of healing for a harvested nasoseptal flap (Fig. 6a and b). Twelve months later, the preoperative olfactory function was intact and favorably viewed by the patient. Objective testing (UPSIT) showed partially intact olfaction. In light of these findings, we believe that the contralateral olfactory apparatus was anatomically and functionally preserved.

Limitations

The concept of contralateral olfaction preservation is feasible in a unilateral endoscopic transcribriform approach; however, with some limitations. For example, partial involvement of the contralateral cribriform plate and intact olfactory function would necessitate a craniotomy as shown in another case example (Fig. 7). Tumor extension into the contralateral ethmoids will result in destruction of the olfactory apparatus on both sides if an endoscopic approach is utilized for radical tumor resection, or risk leaving tumor behind if contralateral olfaction preservation is attempted. Other factors such as invasiveness through the arachnoid plane in addition to tumor size play an important role in olfactory function and surgical outcome. Jang et al. [7] noted that the size of a tumor is an important determinant in the choice of a surgical approach and preservation of olfaction (<4 cm being favorable). Peritumoral edema has also been adjudged to affect the olfactory functional outcome [7]. Lateralization of olfaction with right side dominance will impact the postoperative olfactory functional outcome for right-sided tumors.

The transnasal resection of anteriorly located meningiomas may result in a skull base defect that is difficult to reconstruct. This is true for large lesions requiring large exposure and often times removal of the posterior wall of the frontal sinus that may make reconstruction challenging. We do not foresee this issue with small lesions. In our practice, a small defect in the anterior skull base remote from the frontal sinus is technically

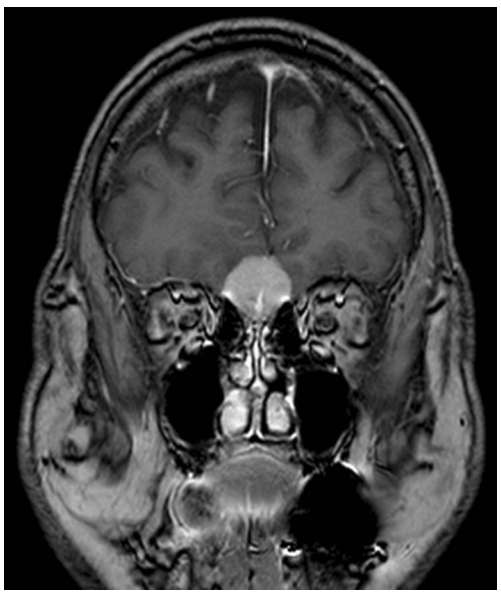

Fig. 7 Coronal MRI of a different patient showing bilateral origin/ base of the OGM with extension of the attachment into bilateral ethmoid sinuses

easy to reconstruct in a multilayered fashion. We use a gasket seal reconstruction technique and ensure that a circumferential shelf of bone is intact for this purpose.

Finally, this approach should be assessed in a large patient series with pre- and postoperative objective assessment of olfaction before admitting its generalized efficacy. The difficult question to answer is whether an endoscopic endonasal approach would be favored if olfaction is bilaterally intact. In such case, a tailored/keyhole craniotomy would be an intuitive answer.

Conclusions

Olfaction preservation may be feasible in endoscopic transnasal surgery for small unilateral olfactory groove meningiomas with partial olfaction. This is contingent upon the following factors: unilateral origin of the tumor from the cribriform plate, intact dominant contralateral olfactory function, preservation of the contralateral olfactory epithelium through a septal transposition technique, and preservation of the contralateral cribriform plate and olfactory apparatus by performing a unilateral transcribriform approach.

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Compliance with ethical standards

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Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent For this type of study formal consent is not required.

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Comments

The authors describe five cadaveric dissection and one illustrative case of unilateral transcribriform plate access to preserve unilateral anosmia through an expanded endonasal approach. The idea is interesting considering the impact of olfactory loss in a given patient. This is, however, of very limited use, as most often the tumor originates from the midline and the olfactory epithelium will inevitably be disturbed. Also, the limited exposure makes operation on larger tumor difficult and suboptimal.

The expanded endonasal approach is routinely criticized for treating anterior skull base meningiomas, and although I am an advocate for this approach for selected cases(mainly tuberculum sella location), I feel a more anterior tumor is less ideal for endonasal exposure, as it necessitates a significant skull base destruction for a tumor which otherwise is easily removed through a small craniotomy (e.g., case shown here) and also much quicker. The 5–20 % risk of CSF leak in authors' experience is unfortunately too high to warrant resection of a more anteriorly located meningioma through an endonasal approach. Also, one should emphasize that we are not at the beginning of the endonasal skull base surgery era, and we still have a high rate of CSF leak. There is no question that a mini craniotomy will be quicker in removal of this particular tumor from an unbiased view of my personal practice dealing with these lesions routinely through both open and endoscopic approach.

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This is a very nice study on the concept of trying to preserve olfactory function in smaller olfactory groove meningiomas with unilateral attachment while applying an endoscopic endonasal approach. In the ongoing debate between proponents for either surgical approach from above or from below, this indeed adds something new. In larger olfactory meningiomas, olfaction is often already lost before surgery, so preservation of olfaction is not an issue. However, in smaller lesions it certainly is! For me, this was the main reason to approach such lesions from above because preservation of olfaction is a real option then, especially when applying the technique of protective coating of the exposed olfactory bulb and nerve with fibrin glue (as already published by our group in 1998; de Vries J, Menovsky T, Grotenhuis JA, van Overbeeke JJ. Protective coating of cranial nerves with fibrin glue (Tissucol) during cranial base surgery: technical note. Neurosurgery. 1998 Nov;43(5):1242–6). The big advantages of the endoscopic endonasal approach for smaller meningiomas are twofold: early devascularization and complete removal of the bony and dural origin of the meningioma. The disadvantage is: difficulty of watertight closure of the skull base/dural defect and loss of olfaction. The latter has been dealt with in this excellent study, also showing that even with anatomical preservation of the olfactory bulb and tract, functional preservation is an arduous task but any attempt is worthwhile.

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