Endoscopic Unilateral Transethmoid-Paraseptal Approach to the Central Skull Base

Márton Eördögh, MD 🆔; Hans Rudolf Briner, MD; Daniel Simmen, MD;
Nicholas Jones, MD, BDS, FRCS, FRCS (ORL); Robert Reisch, MD

Objectives: The endoscopic technique in transnasal skull base surgery offers optimal visualization and free manipulation in the surgical field. However, it may cause approach-related sinonasal injury, influencing patients' quality of life (QOL). To minimize rhinological morbidity without restrictions in surgical manipulation and tumor resection, we introduced the unilateral transethmoidal-paraseptal approach. In this article, we analyzed the long-term results and sinonasal outcome of this technique.

Study Design: Retrospective analysis of medical records.

Methods: Forty-two consecutive patients underwent surgery between June 2010 and March 2014 using the transethmoid-paraseptal approach. Perioperative work-up included neurological, radiological, endocrinological, ophthalmological, and rhinological analysis. Patients' preoperative, 1-month and 1-year postoperative QOL was measured using the Sino-Nasal Outcome Test (SNOT-22).

Results: At all individuals, a unilateral transethmoid-paraseptal approach was performed. Removal of the turbinates, posterior septal resection or a conversion to biportal surgery could be avoided in all cases. There were no intraoperative neurovascular complications. All patients had a notable improvement in any disease-related symptoms, as well as by objective criteria. Complete tumor resection was aimed in 39 cases and achieved in 31 of them. The SNOT-22 scores transiently worsened 1 month after surgery and non-significantly improved after 1 year, compared with the preoperative status. A subgroup of 7 patients with preoperative sinonasal disease evidence showed continuous significant improvement ($p < .05$) of SNOT-22 scores across time. The smell screening tests showed no significant difference across time.

Conclusion: The described approach allows safe removal of various skull base lesions without deterioration in sinonasal QOL and smell function.

Key Words: Transnasal endoscopy, transethmoidal approach, skull base surgery, sinonasal outcome, quality of life.

Level of Evidence: 4.

INTRODUCTION

"Every step of the procedure must be conducted under the eye of the operator," emphasized Harvey Cushing in 1912.[1] This more than 100-year-old wisdom is generally accepted in contemporary transnasal endoscopic surgery; namely access and visual control are essential for the precise and unhindered manipulation of instruments.[2]

To achieve optimal exposure, surgeons often use a wide approach with extensive intranasal dissection including the resection of nasal turbinates and part of the nasal septum.[3,4] However, creating a wide exposure can cause approach-related morbidity affecting the nasal cavity and the paranasal sinuses. Rhinological symptoms secondary to surgery may only be recognized in the late postoperative period[5] and this may be one of the reasons why sinonasal complications in transnasal procedures are rarely mentioned in the literature.[6] Intranasal adhesions, delayed secondary healing, and extensive crusting may result from mucosal trauma of the transnasal technique and lead to symptoms such as a blocked nose, nasal discharge, hyposmia or anosmia and pain. These symptoms may contribute to sleep problems and impaired productivity.[7]

In our technique, we have introduced rhinosurgical principles based on sinonasal physiology in transnasal neuroendoscopy in order to avoid the complications listed above. While exposing the central skull base through a unilateral (mononostril) approach we performed a partial ethmoidectomy, thus creating significant surgical space within the nasal cavity. With gentle lateralization of the intact middle and superior turbinates into the additional space made by the ethmoidectomy, an enlarged endonasal paraseptal corridor could be gained toward the sphenoid sinus. Despite its unilateral design, this approach creates sufficient exposure of

TABLE I.	
Disease Characteristics.	
Pathology	N (%)
Pituitary adenoma	30 (71.4)
inactive	17 (40.5)
PRL-producing	6 (14.3)
GH-producing	5 (11.9)
ACTH-producing	2 (4.8)
Rathke's cyst	3 (7.1)
Meningioma	3 (7.1)
Craniopharyngioma	2 (4.8)
Clival chordoma	1 (2.4)
Juvenile angiofibroma	1 (2.4)
Lymphoma	1 (2.4)
Pituitary hyperplasia	1 (2.4)

the central skull base and allows unhindered surgical manipulation.

MATERIALS AND METHODS

Patient Population

In this study, we retrospectively analyzed the course of 42 consecutive patients treated between June 2010 and March 2014 in our skull base center, using the unilateral transethmoid-paraseptal approach. Medical records were retrospectively reviewed for demographic data, histopathological diagnosis, characteristics of surgery, length of hospital stay as well as radiological, neurological, endocrinological, ophthalmological and rhinological outcome.

Patients ranged in age from 18 to 77 years at the operation (mean age: 50.3 years) and consisted of 21 female and 21 male individuals. Pituitary adenoma was the most common pathology (30 patients, 71.4%), with a variety of tumors comprising the remainder (Table I). Preoperative ophthalmologic investigations showed visual symptoms in 25 of all cases (59.5%) and 23 of the patients (54.8%) presented with endocrine disorders.

Surgical Technique

The objective of the unilateral transethmoid-paraseptal approach is to reach the central skull base without removing the nasal turbinates and to avoid excessive resection of the nasal septum. Furthermore, the mucosal surface (principally in the olfactory cleft) should be preserved and the patency of the natural paranasal sinus ostia should be kept intact in order to protect physiological sinonasal function.

Patients are placed supine. After general anesthesia and navigation system setup (Fusion ENT Navigation System, Medtronic AG, Münchenbuchsee, Switzerland), cottonoid pledgets impregnated with adrenaline solution (1:1000) are inserted bilaterally toward the olfactory clefts and the sphenoethmoid recesses to decongest the nasal mucosa. Submucosal injection of vasoconstrictor solution is avoided.

The better side for the unilateral approach is determined by both the individual anatomy and position of the lesion, access being the primary determining factor. The entire approach is performed 4-handed. After removal of the cottonoids, the intranasal anatomical landmarks are identified, and then the middle turbinate is gently medialized to expose the middle meatus (Fig. 1). As the first step of the unilateral

ethmoidectomy, the uncinate process is removed with preservation of its superior part and the mucosa around the natural maxillary sinus ostium.[8] Then the ethmoid bulla is opened and removed. The basal lamella of the middle turbinate is recognized and dissected to get access into the posterior ethmoid cells. After identifying the coronal plane of posterior wall of the maxillary sinus, which corresponds to the anterior wall of the pterygopalatine fossa, the anterior wall of the sphenoid sinus is opened through the ethmoid cells. If necessary, the sphenopalatine foramen is identified and the posterior septal branches of the sphenopalatine artery are cauterized. After ethmoidectomy, the middle and superior turbinates are gently lateralized and placed into the cavity created by the ethmoidectomy to reveal the ipsilateral ostium of the sphenoid sinus. This safely enlarges the nasal cavity and facilitates paraseptal endonasal surgical manipulation, as the sphenoidotomy can be broadened up to the skull base, toward the medial aspect of the orbit and to the contralateral side. An incision is made over the posterior septal mucosa which is then elevated, the posterior part (3–4 mm) of the vomer is dissected and removed along with the sphenoid rostrum and the anterior wall of the sphenoid sinus. Excessive removal of the posterior part of the nasal septum is unnecessary and can be avoided in all cases. Parts of the anterior wall of the sphenoid sinus of the contralateral side can be resected to gain more space, however, the overlying mucosa with the sphenopalatine branches is preserved in these cases to maintain the option of a nasoseptal flap.

After entering the sphenoid sinus, its anatomical landmarks can be identified. The sphenoid mucosa is removed only in the surgical field. The panoramic endoscopic view allows control of the vital structures of the central skull base. Beyond the sphenoid sinus, a corridor of access is created and this can be extended laterally to the sphenopalatine foramen, the pterygopalatine fossa, the pterygoid (Vidian) canal as well as the cavernous sinus, sagittally from the sphenoid planum to the lower clivus.

After pure endoscopic tumor removal, the sphenoid sinus is cleaned from congealed blood. The nasal cavity is inspected and the middle turbinate is replaced in a moderately lateralized position. In case of uneventful surgery, pedicled nasoseptal flap, nasal packing or lumbar drain are not used.

Perioperative Course

Each patient underwent detailed preoperative neurological, endocrinological, ophthalmological, and radiological examination. Rhinological investigations included nasal endoscopy and smell screening test (SmellDiskettes Olfaction Test, Novimed AG, Dietikon, Switzerland), consisting of 8 smell diskettes and a questionnaire. Seven or 8 correct answers indicate normosmic function, 6 or less show anosmia/hyposmia or low compliance. The left and the right side are investigated separately. In case of at least 7 correct answers on one side, the patient is considered to be normosmic.

Assessment of quality of life was offered to the patients asking to score preoperative symptoms using the Sino-Nasal Outcome Test (SNOT-22; Table II). The SNOT-22 contains 22 questions that can be answered on a Likert scale from 0 to 5, producing a total score from 0 to 110, with lower scores indicating fewer symptoms. Items pertain to specific sinonasal, ear/facial, sleep dysfunction and psychological domains.

Preoperative cranial CT- and MRI-imaging was used to plan the approach and for navigation purposes. Additional intraoperative CT- (Siemens Somatom Sensation, Siemens AG, Erlangen, Germany) or MRI-scan (Polestar, Medtronic AG) was available to help the evaluation of the extent of resection.

Intranasal endoscopy was performed on the 1–3. postoperative days to carefully remove congealed blood and mucus in
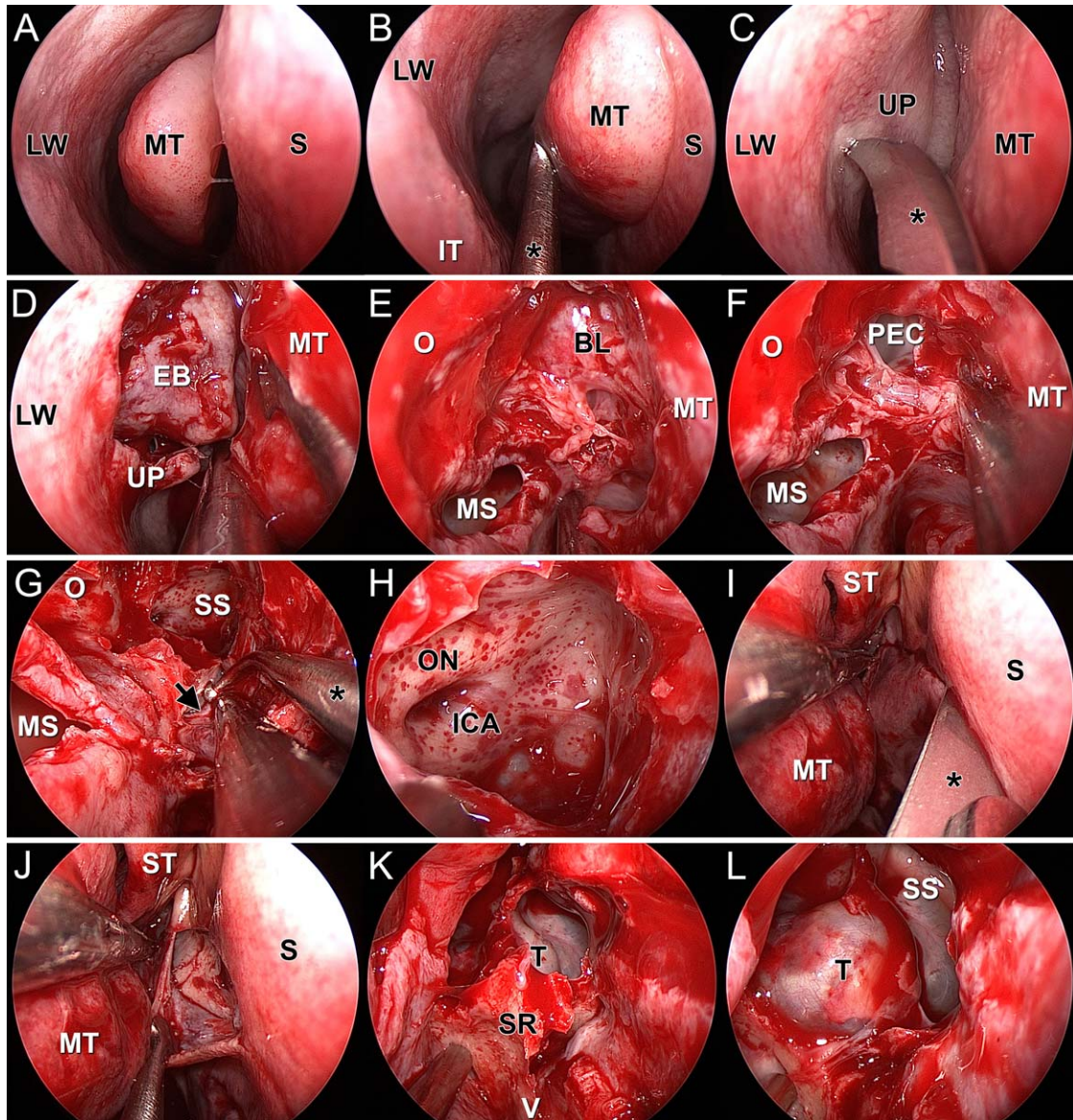
Fig. 1. Surgical steps of the endoscopic unilateral transethmoid-paraseptal approach, right side
A: View of the lateral wall (LW) of the right nasal cavity, the middle turbinate (MT) and the nasal septum (S). B: The middle turbinate is pushed to medial with a dissector (*). The inferior turbinate (IT) can be also seen. C: An incision is performed with a sickle knife (*) on the lateral nasal wall at the lateral part of the uncinate process (UP). D: After the removal of the uncinate process (uncinectomy), the ethmoid bulla (EB) is identified. E: The ethmoid bulla and further anterior ethmoid cells are dissected to find the basal lamella (BL) of the middle turbinate. The posterior wall of the maxillary sinus (MS) and the medial wall of the orbit (O) can be identified. F: After the removal of the basal lamella of the middle turbinate, the posterior ethmoid cells (PEC) are opened. G: The posterior septal branches of the sphenopalatine artery (arrow) are dissected with a ball probe (*). Superiorly to them, the posterior ethmoid cells are removed to enter the sphenoid sinus (SS). H: View of the sphenoid sinus with the prominence of the ipsilateral optic nerve (ON) and the internal carotid artery (ICA). I: The endoscope is pulled back and positioned medially from the middle turbinate and the superior turbinate (ST). An incision is performed with a scalpel (*) on the posterior nasal septum. J: The mucosa and the periosteum of the nasal septum is gently pulled away to get access to the underlying posterior bony nasal septum. K: The mucoperiosteal sheath is carefully detached on both sides. View of the tumor (T), the sphenoid rostrum (SR) and the vomer (V). L: View of the tumor in the sphenoid sinus after rostrectomy.

order to provide a nasal airway yet not disturb any grafts. Nasal douching, sprays and ointments were applied to help wound healing and prevent drying and excessive crusting. Routine endoscopic examination was repeated at 1 month and 1 year, and the smell screening test at 1 year after surgery.

In all cases, the postoperative neurological, endocrinological, and ophthalmological status was evaluated. MRI-scans were routinely performed on the first day after surgery, after 3

months and 1 year, and repeated in the late postoperative course according to the particular case.

1-month and 1-year postoperative SNOT-22 scores of patients were also measured. Thus, results at three different time points became comparable. A smell screen test was repeated 1 year after surgery.

Statistical analysis of results was performed with Excel software (Microsoft Corp., Redmond, Washington, USA).

TABLE II.
Sino-Nasal Outcome Test (SNOT-22).

Considering how severe the problem is when you experience it and how often it happens, please rate each item below on how "bad" it is by circling the number that corresponds with how you feel using this scale:	No problem	Very mild problem	Mild or slight problem	Moderate problem	Severe problem	Problem as bad as it can be
1. Need to blow nose	0	1	2	3	4	5
2. Nasal blockage	0	1	2	3	4	5
3. Sneezing	0	1	2	3	4	5
4. Runny nose	0	1	2	3	4	5
5. Cough	0	1	2	3	4	5
6. Post-nasal discharge	0	1	2	3	4	5
7. Thick nasal discharge	0	1	2	3	4	5
8. Ear fullness	0	1	2	3	4	5
9. Dizziness	0	1	2	3	4	5
10. Ear pain	0	1	2	3	4	5
11. Facial pain/pressure	0	1	2	3	4	5
12. Decreased sense of smell/taste	0	1	2	3	4	5
13. Difficulty falling asleep	0	1	2	3	4	5
14. Wake up at night	0	1	2	3	4	5
15. Lack of good night's sleep	0	1	2	3	4	5
16. Wake up tired	0	1	2	3	4	5
17. Fatigue	0	1	2	3	4	5
18. Reduced productivity	0	1	2	3	4	5
19. Reduced concentration	0	1	2	3	4	5
20. Frustrated/restless/irritable	0	1	2	3	4	5
21. Sad	0	1	2	3	4	5
22. Embarassed	0	1	2	3	4	5

Ethics

This study was conducted in accordance with the ethical standards and the 1964 Helsinki Declaration and its later amendments as well as local ethical standards. Prior filling out the above described questionnaires, patients consented to the evaluation of the obtained data.

RESULTS

In each case an endoscopic unilateral transethmoid-paraseptal approach was performed. The majority were done (24 patients, 57.1% of all cases) on the right side. Eight individuals (19.0%) had undergone previous transnasal neurosurgical procedure at another institute. There was clinical evidence of concurrent paranasal sinusitis in 7 cases (16.7%). Nine individuals (21.4%) presented with a marked septal deviation leading to an additional septoplasty. Inferior turbinoplasty was performed of 1 patient (2.38%) to achieve adequate access.

There were no intraoperative nasal, paranasal, intraorbital or intracranial neurovascular complications. The skull base defect was routinely covered with Tachosil (Takeda Pharmaceuticals International GmbH, Zurich, Switzerland). In 2 cases with intraoperative cerebrospinal fluid (CSF)-leak from the sellar region (related to tumor removal), abdominal fat graft was used. A pedicled nasoseptal flap for reconstruction was created in 5 patients (11.9%) with large skull base defects. A lumbar drainage was never used. The average

duration of surgery was 189.0 ± 90.5 minutes (range: 80–555 minutes).

After surgery, all patients had a notable improvement in any disease-related symptoms, as well as by objective neurological and endocrinological criteria. There were no postoperative neurovascular complications. Postoperative hospitalization ranged from 3 to 10 days (mode: 5 days). There were 2 cases (4.8%) of CSF-leak postoperatively, making surgical revision necessary. Transient diabetes insipidus was seen in 5 patients (11.9%) who were treated satisfactorily with desmopressin and electrolyte replacement. Reoperation was needed in 1 case (2.4%) to manage intractable nasal bleeding. Complete resection was aimed in 39 cases. Among them, an early postoperative MRI showed residual tumor in 2 cases, necessitating further therapy. Minimal and/or stable contrast agent enhancement was seen in 6 cases, considered as possible residual tumor. These patients showed no further subjective or objective symptoms of residual disease across time. Based on that, a complete removal was achieved in 31 cases (79.5% of 39 patients) according to the latest postoperative investigation performed at least 1 year after surgery.

Twenty-nine patients (69.0%) have completed the SNOT-22 tool at all the 3 time points. In the later course, 2 unrelated deaths were reported.

Clinician-assessed early postoperative rhinological symptoms were minor in all cases. Compared to SNOT-

Time since surgery	Preoperative score*	Postoperative score*	p[†]
1 month	17.7 ± 18.9	19.8 ± 15.6	0.524
1 year	17.7 ± 18.9	15.9 ± 16.9	0.665

*Scores range from 0 to 110, values are mean ± standard deviation.
[†]Paired 2-tailed t test, alpha < 0.05.

22 scores prior surgery, in the early postoperative period there was a marked deterioration (Table III). Mean domain scores of the SNOT-22 improved but did not differ significantly from the preoperative period to 1 year after surgery (Table IV). There was a significant improvement (p = .041) of the total scores from 1 month to 1 year after surgery.

The mean score of any items was 0.8 (± 0.4) showing majority of answers "no problem" and "very mild problem". Most rhinological items enquired about in the questionnaire show a non-significant improvement 1 year after surgery from the preoperative situation.

Pre- and postoperative side-specific smell function test results were available in 17 patients for comparison. Most of them (15 individuals, 88.2%) presented with preoperative normosmic function. The average preoperative result for the smell screening test was 6.9 (± 0.9) on the right side (range: 5–8) and 6.9 ± 1.0 on the left side (range: 5–8). One year after surgery, normosmic smell function was found in 94.1% of the investigated patients (16 individuals). The average score was 7.2 (± 1.2) on the right side (range: 5–8) and 7.2 (± 1.1) on the left (range: 4–8). There was no significant difference between pre- and postoperative results (p = .119). There was no marked change of smell function on the side of the performed approach.

A subgroup of patients with evidence of paranasal sinusitis prior surgery (7 individuals) was separately examined. Their preoperative SNOT-22 scores were significantly improved 1 month (p = .027) and also 1 year

Domain	Preoperative score*	1 year postoperative score*	p[†]
Rhinological[‡]	4.1 ± 7.2	3.8 ± 5.1	0.789
Psychological[§]	6.9 ± 7.2	5.9 ± 6.6	0.506
Ear/facial[∥]	2.7 ± 3.8	2.4 ± 3.2	0.768
Sleep dysfunction[¶]	4.0 ± 4.9	3.8 ± 4.7	0.871

*Values are mean ± standard deviation.
[†]Paired 2-tailed t test, alpha < 0.05.
[‡]Scores range from 0 to 40. Items: need to blow nose, sneezing, cough, runny nose, postnasal discharge, thick nasal discharge, nasal obstruction, loss of smell and/or taste.
[§]Scores range from 0 to 30. Items: fatigue, reduced productivity, reduced concentration, frustration/restlessness/irritability, sadness, embarrassment.
[∥]Scores range from 0 to 20. Items: ear fullness, dizziness, ear pain, facial pain and/or pressure.
[¶]Scores range from 0 to 20. Items: difficulty falling asleep, waking up at night, waking up tired, lack of good night's sleep.

after surgery (p = .011). There was no significant change of smell function across time (p = .448).

DISCUSSION

The goal in the endoscopic transnasal approach is to gain safe and wide exposure to the central skull base. Early interest has focused on the completeness of surgical removal and only recently has there been more attention in other aspects of the patient's postoperative symptoms and subjective well-being. Various tools have been developed to evaluate QOL, and a multidimensional questionnaire that examines an individual's overall perception of well-being provides a broader overview. The SNOT-22 is a well-recognized QOL tool consisting of rhinological, ear/facial, sleep dysfunctional and psychological items and assesses symptoms along with the social and emotional consequences of paranasal sinus disease.[9,10] It is also able to detect sinonasal morbidity caused by transnasal neurosurgical intervention.

In this study, we demonstrated our initial experience with the transethmoid-paraseptal approach. Beyond radiological, neurological and endocrinological data, we thoroughly analyzed patient's nasal functions and satisfaction after surgery.

Gil et al. were to first to study QOL related to anterior skull base surgery using a specific tool, the Anterior Skull Base Questionnaire (ASBQ).[11] Abergel et al. administered it to 39 patients undergoing skull base surgery and prospectively recognized a transient worsening of QOL that improved in the late postoperative course.[12] McCoul et al. prospectively analyzed the SNOT-22 and ASBQ scores of 85 patients undergoing endoscopic binostril skull base surgery.[13] Compared to SNOT-22 data prior surgery, they observed an early postoperative impairment and a significant late improvement. We found a notable, but statistically not significant improvement in the SNOT-22 outcome after a transient postoperative deterioration, nor was a significant change noted when SNOT-22 domains were analyzed separately. However, we analyzed a small subgroup of 7 individuals with preoperative sinonasal disease evidence who showed continuous and significant improvement in their SNOT-22 data across time. Pant et al. reported on a prospective series of 51 patients undergoing endoscopic skull base surgery using numerous approaches. Similarly to our results, they found that the early postoperative SNOT-22 scores are significantly higher than the late ones.[14] However, the lack of preoperative data supplied detracts from the evaluation of their patients' entire course. In their retrospective study, Suberman et al. administered

another instrument, the Rhinosinusitis Disability Index to 50 patients who underwent uni- or binostril approaches[15]. Their patients did not show significant score changes. Graham et al. retrospectively compared SNOT-22 data of endoscopic and sublabial-transseptal procedures for treatment of pituitary tumors.[16] Endoscopic cases had a better rhinological outcome. Hong et al. compared outcomes of patients undergoing unilateral microscopic and bilateral endoscopic surgery using the ASK nasal inventory, a derivative of the recently introduced ASK Nasal-12; microsurgical cases showed better scores 3 months after surgery.[17–19] Here, a further follow-up would be necessary. In another comparative study of microscopical and bilateral endoscopical surgery, Pledger et al. found no significant difference between the late postoperative SNOT-20 scores.[20] Similarly, to Hong et al., they applied bilateral endoscopic techniques that may have a greater impact on QOL than the unilateral approaches, suggested in this article.

An analysis of the oncoming patients is necessary, as a larger sample size would facilitate more accurate detection of QOL changes.

Any correlation between middle turbinate resection–a common act to gain additional space during surgery–and impaired QOL remains unclear. According to Friedman et al. its partial removal has no effect on olfaction.[21] However, Swanson et al. demonstrated that middle turbinate resection can increase the risk of frontal sinus disease.[22] Rice et al. point out that excessive turbinate removal can lead to crusting, bleeding, paradoxical breathing difficulty, recurrent infections, nasal odor, pain and often clinical depression and empty nose-syndrome.[23]

In case of a large tumor extension, a biportal techniqe may be necessary. However, the transethmoid-paraseptal approach, described in this article, has become our standard treatment choice for most skull base lesions. The advantage of this technique based on functional endoscopic sinus surgery is the wide exposure of the sphenoid sinus and central skull base, yet still being able to preserve important sinonasal structures that affect QOL.[24] Protection of the nasal mucosa and the olfactory cleft could be achieved without turbinate and septal resection. Patients reported on minor postoperative discomfort with normal ventilation after surgery. With minimal endonasal dissection and coagulation, scarring of the olfactory mucosa could be avoided, resulting in a diminished risk of developing iatrogenic hyposmia. According to our results, the described technique does not influence the sense of smell. The middle turbinate's controlled slight lateralization facilitates patency of the ethmoid infundibulum and the olfactory cleft.

Ethmoidectomy is the key act to gain additional space in order to temporarily lateralize the turbinates without resecting them. The transethmoidal approach of various paranasal sinus pathologies has often been described in the rhinological literature.[25–29] In his landmark paper from 1950, Takahashi described the removal of ethmoid cells to treat chronic ethmoiditis.[30] However, this did not gain wide acceptance among neurosurgeons as it assumes detailed anatomical knowledge and

thought to be time-consuming. A recent meta-analysis on endoscopic pituitary surgery found the range of mean surgical duration to be 102–255 minutes.[31] Our data (189 minutes) is acceptable compared with these results, particularly in view of the spectrum of diseases in this group. After ethmoidectomy, the neurosurgical time may be subjectively shorter as maneuverability is increased.

Rhino-neurosurgical cooperation is advocated during the patient's entire treatment as there is common decision making, a shorter intraoperative time, better surgical results and it may also shorten the surgical learning curve.[32,33] Each phase of the care (treatment planning, surgical preparation, surgery, postoperative care, management of complications) is done together. The endoscopically assisted four hand technique initially described by May et al. enables bimanual surgery.[34]

CONCLUSION

The majority of surgeons use a binostril approach and remove a large part of the nasal septum.[3,35–37] With the transethmoid-paraseptal technique a free, two-handed manipulation and wide skull base visualization was still possible using mononostril dissection, without the need of turbinate resection.

The unilateral transethmoid-paraseptal approach allowed safe and fast removal of various skull base lesions without any deterioration in long term sinonasal QOL and smell function scores. Surgery does not lead to a deterioration in QOL according to the SNOT-22 survey. In the subgroup who had sinonasal disease, SNOT-22 scores showed a significant improvement across time. A prospective analysis of further patients is necessary to entirely evaluate this technique. The technique described advocates rhino-neurosurgical cooperation.

BIBLIOGRAPHY

1. Cushing H. The pituitary body and its disorders: clinical states produced by disorders of the hypophysis cerebri. Philadelphia: J.B. Lippincott. 1912.
2. Jankowski R, Auque J, Simon C, Marchal JC, Hepner H, Wayoff M. Endoscopic pituitary tumor surgery. *Laryngoscope* 1992;102:198–202.
3. Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. *Neurosurg Focus.* 2005;19:E3.
4. Juraschka K, Khan OH, Godoy BL, et al. Endoscopic endonasal transsphenoidal approach to large and giant pituitary adenomas: institutional experience and predictors of extent of resection. *J Neurosurg* 2014;121:1–9.

5. Kimmelman CP. The risk to olfaction from nasal surgery. *Laryngoscope* 1994;104:981–988.
6. Kassam AB, Prevedello DM, Carrau RL, et al. Endoscopic endonasal skull base surgery: analysis of complications in the authors' initial 800 patients. *J Neurosurgery* 2011;114:1544–1568.
7. Gliklich RE, Metson R. The health impact of chronic sinusitis in patients seeking otolaryngologic care. *Otolaryngol Head Neck Surg* 1995;113: 104–109.
8. Kennedy DW. Prognostic factors, outcomes and staging in ethmoid sinus surgery. *Laryngoscope* 1992;102(12 Pt 2 Suppl 57):1–18.
9. Hopkins C, Gillett S, Slack R, Lund VJ, Browne JP. Psychometric validity of the 22-item Sinonasal Outcome Test. *Clin Otolaryngol* 2009;34:447–454.
10. Piccirillo JF, Merritt MG, Richards ML. Psychometric and clinimetric validity of the 20-Item Sino-Nasal Outcome Test (SNOT-20). *Otolaryngol Head Neck Surg* 2002;126:41–47.
11. Gil Z, Abergel A, Spektor S, et al. Quality of life following surgery for anterior skull base tumors. *Arch Otolaryngol Head Neck Surg* 2003;129: 1303–1309.
12. Abergel A, Fliss DM, Margalit N, Gil Z. A prospective evaluation of short-term health-related quality of life in patients undergoing anterior skull base surgery. *Skull Base* 2010;20:27–33.
13. McCoul ED, Anand VK, Bedrosian JC, Schwartz TH. Endoscopic skull base surgery and its impact on sinonasal-related quality of life. *Int Forum Allergy Rhinol* 2012;2:174–181.
14. Pant H, Bhatki AM, Snyderman CH, et al. Quality of life following endonasal skull base surgery. *Skull Base* 2010;20:35–40.
15. Suberman TA, Zanation AM, Ewend MG, Senior BA, Ebert CS. Sinonasal quality-of-life before and after endoscopic, endonasal, minimally invasive pituitary surgery. *Int Forum Allergy Rhinol* 2011;1:161–166.
16. Graham SM, Iseli TA, Karnell LH, Clinger JD, Hitchon PW, Greenlee JDW. Endoscopic approach for pituitary surgery improves rhinologic outcomes. *Ann Otol Rhinol Laryngol* 2009;118:630–635.
17. Little AS, Jahnke H, Nakaji P, Milligan J, Chapple K, White WL. The anterior skull base nasal inventory (ASK nasal inventory): a clinical tool for evaluating rhinological outcomes after endonasal surgery for pituitary and cranial base lesions. *Pituitary* 2012;15:513–517.
18. Little AS, Kelly D, Milligan J, et al. Prospective validation of a patient-reported nasal quality-of-life tool for endonasal skull base surgery: The Anterior Skull Base Nasal Inventory-12. *J Neurosurg* 2013;119:1068–1074.
19. Hong SD, Nam DH, Seol HJ, et al. Endoscopic binostril versus transnasal transseptal microscopic pituitary surgery: Sinonasal quality of life and olfactory function. *Am J Rhinol Allergy* 2015;29:221–225.
20. Pledger CL, Elzoghby MA, Oldfield EH, Payne SC, Jane JA Jr. Prospective comparison of sinonasal outcomes after microscopic sublabial or endoscopic endonasal transsphenoidal surgery for nonfunctioning pituitary adenomas. *J Neurosurg* 2016;125:323–333.
21. Friedman M, Caldarelli DD, Venkatesan TK, Pandit R, Lee Y. Endoscopic sinus surgery with partial middle turbinate resection: effects on olfaction. *Laryngoscope* 1996;106:977–981.
22. Swanson P, Lanza D, Vining EM, Kennedy DW. The Effect of Middle Turbinate Resection Upon the Frontal Sinus. Kountakis SE, Senior BA, Draf W, eds. *Am J Rhinol* 1995;9:191–195.
23. Rice DH, Kern EB, Marple BF, Mabry RL, Friedman WH. The turbinates in nasal and sinus surgery: a consensus statement. *Ear Nose Throat J* 2003;82:82–84.
24. Marchioni D, Alicandri-Ciufelli M, Mattioli F, et al. Middle turbinate preservation versus middle turbinate resection in endoscopic surgical treatment of nasal polyposis. *Acta Otolaryngol* 2008;128:1019–1026.
25. Chiari O. Ueber eine Modifikation der Schlofferschen Operation von Tumoren der Hypophyse. *Wien Klin Wochenschr*; 1912;25:5–6.
26. Bateman GH. Trans-sphenoidal hypophysectomy. *J Laryngol Otol* 1962;76: 442–455.
27. Briant T. Transsphenoidal hypophysectomy. *Proc Can Otolaryngol Soc* 1964;18:159–174.
28. Angell-James J. Hypophysectomy–the combined role of neuro- and rhino-surgeons. *Acta Neurochir (Wien)* 1974;(Suppl 21):145–149.
29. Kirchner JA, VanGilder JC. Transethmoidal hypophysectomy: some surgical landmarks. Trans Sect Otolaryngol Am Acad Ophthalmol Otolaryngol. 1975;80(4 Pt 1):391–396.
30. Takahashi R. Intranasal operation of chronic ethmoiditis [in Japanese]. *Shujutsu* 1950;4:134–145.
31. Abtin Tabaee, Vijay K Anand, Yolanda Barrón, et al. Endoscopic pituitary surgery: a systematic review and meta-analysis. *J Neurosurg* 2009;111: 545–554.
32. Castelnuovo P, Pistochini A, Locatelli D. Different surgical approaches to the sellar region: focusing on the "two nostrils four hands technique". *Rhinology* 2006;44:2–7.
33. Briner HR, Simmen D, Jones N. Endoscopic sinus surgery: advantages of the bimanual technique. *Am J Rhinol* 2005;19:269–273.
34. May M, Hoffmann DF, Sobol SM. Video endoscopic sinus surgery: a two-handed technique. *Laryngoscope* 1990;100:430–432.
35. Thomas RF, Monacci WT, Mair EA. Endoscopic image-guided transethmoid pituitary surgery. *Otolaryngol Head Neck Surg* 2002;127:409–416.
36. Hofstetter CP, Shin BJ, Mubita L, et al. Endoscopic endonasal transsphenoidal surgery for functional pituitary adenomas. *Neurosurg Focus* 2011;30:E10.
37. Cavallo LM, Messina A, Cappabianca P, et al. Endoscopic endonasal surgery of the midline skull base: anatomical study and clinical considerations. *Neurosurg Focus* 2005;19:E2.