Endoscopic Endonasal Skull Base Surgery: 
Advantages, Limitations, and Our Techniques to 
Overcome Cerebrospinal Fluid Leakage: Technical Note

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Abstract

In recent years, resections of midline skull base tumors have been conducted using endoscopic endonasal skull base (EESB) approaches. Nevertheless, many surgeons reported that cerebrospinal fluid (CSF) leakage is still a major complication of these approaches. Here, we report the results of our 42 EESB surgeries and discuss the advantages and limits of this approach for resecting various types of tumors, and also report our technique to overcome CSF leakage. All 42 cases involved midline skull base tumors resected using the EESB technique. Dural incisions were closed using nasoseptal flaps and fascia patch inlay sutures. Total removal of the tumor was accomplished in seven pituitary adenomas (33.3%), five craniopharyngiomas (62.5%), five tuberculum sellae meningiomas (83.3%), three clival chordomas (100%), and one suprasellar ependymoma. Residual regions included the cavernous sinus, the outside of the intracranial part of the internal carotid artery, the lower lateral part of the posterior clivus, and the posterior pituitary stalk. Overall incidence of CSF leakage was 7.1%. Even though the versatility of the approach is limited, EESB surgery has many advantages compared to the transcranial approach for managing midline skull base lesions. To avoid CSF leakage, surgeons should have skills and techniques for complete closure, including use of the nasoseptal flap and fascia patch inlay techniques.

Key words: cerebrospinal fluid leakage, endonasal, endoscope, skull base surgery

Introduction

Midline skull base tumors, such as meningiomas, craniopharyngiomas, and large pituitary adenomas, were commonly resected using various transcranial skull base approaches that required long operating times.1–13) Minimally invasive keyhole approaches through eyebrow incisions have also been described for these tumors.2,6–8,14) Over the past 25 years, the microsurgical transsphenoidal approach has been utilized to remove skull base tumors.15–21) With the development of endoscope technology and endoscopic surgery, resection of these tumors has been achieved using endoscopic endonasal skull base (EESB) approaches.20,22–30) Many surgeons have reported the usefulness of this approach; however, they do not yet lead to the complete arrest of cerebrospinal fluid (CSF) leakage, which is a major complication.31–42) Here, we report the results of our 42 EESB surgeries and discuss the advantages and limits of this approach in each disease, and also report our technique to overcome the CSF leakage.

Methods

I. Patients

From April 2001 to January 2014 we performed a total of 1320 endoscopic endonasal surgeries, of which 48 were EESB surgeries. Among these, three petrous apex tumors, two ear, nose and
throat malignancies, and one germ cell tumor were excluded because their operative strategy was only mass reduction and decompression or biopsy. The remaining 42 cases are summarized in Table 1 and included 21 pituitary adenomas that extended to the intra-cranial space, 8 craniopharyngiomas, 8 meningiomas (6 tuberculum sellae meningiomas, 1 cavernous sinus meningioma, and 1 clival meningioma), 3 clival chordomas, 1 pituicytoma, and 1 ependymoma. All were resected using a binocular and a so-called expanded endonasal approach (EEA).

II. Closure techniques after removing tumors:

fascia patch inlay suture

After removing the tumor, insertion of abdominal fat fragments, recently, suturing of the dura, and suturing of a femoral fascia patch inlay, were carried out as needed or according to the surgeon’s skill. The nasoseptal mucosal flap was used in all cases. As a preparation for closure, a nasoseptal flap was made before removing the tumor, and the dura was carefully opened, if possible, without cutting off or coagulation. Following resection, the closure was started by sewing the dura together with 5-0 nylon sutures (Fig. 1A, B). After suturing those edges that could be seamed directly together, the dural gap was closed by a patchwork technique, using fascia obtained from the femur or abdomen (Fig. 1C–E). The fascia was laid in the intracranial epi-arachnoid space (Fig. 1C) and patch-sutured around the entire circumference (Fig. 1C, D), yielding an inlay patch.42,43) During deep-suturing, making knots is very difficult and complicated, but using the “easy-slip knot” technique that we previously described,44) knots are easily applied to the operative field by slipping into position, and sutures can be tied securely. Finally, the nasoseptal flap was applied to cover the entire operative field (Fig. 1F).

Surgical Results

Total removal of the tumor was accomplished in 21 cases (50.0%). The details are summarized in Table 1. Residual regions included the cavernous sinus and the outside of the intracranial part of the internal carotid artery (ICA), the cavernous sinus, the lower lateral part of the posterior clivus, and the posterior pituitary stalk.

Complications included two new pituitary dysfunctions, one in a pituitary adenoma case and one in a craniopharyngioma case; four cases of permanent diabetes insipidus in craniopharyngiomas; and postoperative anosmia in one pituitary adenoma and in one tuberculum sellae meningioma. CSF leakages were seen in two pituitary adenomas and one tuberculum sellae meningioma. Overall incidence of CSF leakage was 7.1%.

Advantages and Limitations of EESB Surgery for Various Tumors

I. Pituitary adenomas

Pituitary adenomas that greatly extend into the subarachnoid space beyond the capsule and involve peripheral arteries may be safely resected by observing from outside of the tumor capsule by EEA. We open the anterior skull base widely during endoscopic endonasal surgeries enough to manage large pituitary

| Tumor type | Total resection (%) | Residual sites (n) | Complications (n) | Course |
|------------|---------------------|--------------------|-------------------|--------|
| Pituitary adenoma | 7/21 (33.3%) | Cavernous sinus (10) | Pituitary function (1) | Course observation |
| | | | Anosmia (1), CSFL (2) | |
| Craniopharyngioma | 5/8 (62.5%) | Post pituitary stalk (3) | Pituitary function (1) | SRT (3) |
| | | | DI (4) | |
| Meningioma | 5/6 (83.3%) | Outside ICA (1) | Anosmia (1), CSFL (1) | Course observation |
| Tuberculum sellae | 0/1 (0%) | Cavernous sinus (1) | None | SRT (1) |
| Cavernous sinus | 0/1 (0%) | Cavernous sinus (1) | None | SRT (1) |
| Clivus | 3/3 (100%) | Posterior clivus* (1) | None | SRT (1) |
| Chordoma (clivus) | | | | |
| Others | 3/3 (100%) | | | |
| Pituicytoma | 0/1 (0%) | Outside ICA (1) | None | SRT (1) |
| Ependymoma | 0/1 (0%) | | | |
| Total | 21/42 (50.0%) | | | |

*Outside of the intracranial part of the ICA. *Lower lateral part of the posterior clivus. CSFL: cerebrospinal fluid leakage, DI: diabetes insipidus, ICA: internal carotid artery, SRT: stereotactic radiotherapy.

Table 1 Summary of results of our endoscopic endonasal skull base surgeries

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II. Craniopharyngiomas

EESB surgery was a good approach for removing craniopharyngiomas due to their origin and progress. Especially for their removal under the optic chiasm, this approach is safer than the transcranial approach because the boundary between the tumor and the optic nerve can be clearly seen (Fig. 3). However, if the tumor extends behind the pituitary stalk or the dorsum sellae, it is barely visible and can be removed only by pulling forcibly because delicate detachment of the tumor is difficult. As recent
and resection of tumors in the optic canal, this approach is superior to the transcranial approach. But tumors that involve intra-cranial arteries cannot be removed totally.

In cavernous sinus meningiomas, total removal of the tumor is very difficult because it is impossible to completely shut off tumor-feeding arteries. But in symptomatic cases, opening the floor of the cavernous sinus and decompression via an endonasal approach have been reported to be useful.50)

III. Meningiomas

The advantage of EESB surgery for meningiomas varied according to the location of the tumor. This approach has many advantages in managing tuberculum sellae meningiomas (Fig. 4). Especially for clearing the tumor-feeding arteries away before removal, early decompression of optic nerves, and resection of tumors in the optic canal, this approach is superior to the transcranial approach. But tumors that involve intra-cranial arteries cannot be removed totally.

In cavernous sinus meningiomas, total removal of the tumor is very difficult because it is impossible to completely shut off tumor-feeding arteries. But in symptomatic cases, opening the floor of the cavernous sinus and decompression via an endonasal approach have been reported to be useful.50)

For clivus meningiomas, this approach is appropriate for tumors limited to the midline. If tumors have a rich blood supply from feeding arteries, an

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advantage of embolization by catheterization makes the operation safer. To manage these tumors, surgeons should be very careful of the petrous portion of the ICA and the abducens nerve crossing the basilar plexus. Tumors extending laterally, such as petroclival meningiomas, cannot be removed completely for the same reasons ascribed to pituitary adenomas with lateral extensions.

Discussion

As transcranial and transsphenoidal microsurgical approaches became increasingly popular for skull base lesions. Many surgeons recognized that these approaches led to restricted viewing angles and limited light intensity, which caused difficulty in achieving gross total tumor resection. With the introduction of the endoscope in skull base surgery, many of the previous problems associated with microsurgical techniques were eliminated; better visualization of anatomical detail could be attained through wider viewing angles. Use of the endoscope in endoscopic-assisted anterior craniofacial tumor resection paved the way for an operative revolution of performing purely endoscopic endonasal resection. Casiano et al. described the first purely endoscopic endonasal approach for the resection of esthesioneuroblastomas. Since its introduction, this method has been internationally recognized and duplicated for resection of a variety of anterior skull base tumors.

The removal of sellar, suprasellar, and anterior skull base tumors via a purely endoscopic endonasal approach was initially described by Jho and Ha and Cappabianca et al. Although this approach was not immediately accepted, the purely endoscopic endonasal approach became more accepted after further popularization by Kassam and Snyderman and Cavallo and Cappabianca. In managing tuberculum sellae meningioma, in addition to the superior cosmesis and minimal brain retraction provided by endoscopic skull base surgery, EESB surgeries resulted in improved visual outcomes due to decreased manipulation of the optic apparatus and enabled early devascularization of the tumor. Despite the clear advantages that this approach provides to select patients, its versatility is limited to smaller tuberculum sellae meningiomas without significant involvement of surrounding vessels. Patients with larger tumors that have more lateral extensions may be difficult to treat with this approach.

Other challenges with this technique include the requirement for specialized technical skills with the endoscope and instrumentation as well as the ability to reconstruct large skull base and dural incisions to prevent postoperative CSF leakage, which tends to have an increased incidence with this approach. Recently, several techniques have been developed to reduce this risk, including the gasket seal, direct suturing of graft material, and the vascularized nasoseptal flap.

The nasoseptal flap is a pedicled regional flap with an axial blood supply derived from the posterior septal branches of the sphenopalatine artery. Its substantial length and wide arc of rotation allows intranasal coverage of various anterior skull base targets. Several reports have described favorable rates of postoperative CSF leakage using this and other vascularized reconstructive techniques. In but in addition, the functional disorder of the nose was also described. In our series, two cases of postoperative anosmia which was caused by the obstruction of the superior nasal meatus were observed.

Although our overall incidence of the CSF leakage was favorable compared with other reports in the literature, we have used the fascia patch inlay technique to close the dural incision extensively since January 2011. Since then, 32 cases were operated using the EESB approach and 26 were closed using this technique. There were no CSF leakages in these 26 cases, while 3 of the 6 non-fascia patch inlay cases had CSF leakages despite use of the nasoseptal flap. That may have been caused by shrinkage or movement of inserted fat fragments, as it is impossible to make a tight packing under the optic nerves. We think that the addition of the fascia patch inlay suture in closure techniques may solve the CSF leakage problem even if the CSF flow volume is relatively high.

It is said that another problem of endoscopic surgery is 2-dimensional (2D), which lack depth of field and contribute to image distortion. Recently, a new generation of 3-dimensional (3D) endoscopes has been introduced and it has provided the improved depth of field and stereoscopic vision. Although it is said that there are no significant differences of operative outcomes between 2D and 3D, the improved depth of field by 3D would be more useful in the very deep situation of removing skull base tumors.

Conclusion

Even though the versatility of the approach is limited to smaller tumors without significant involvement of surrounding vessels, EESB surgery has many advantages compared to transcranial surgery for managing midline skull base lesions. To avoid CSF leakage, surgeons should be skilled in complete closing of
the opening after removing the tumor, and also should master the described suturing techniques.

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Conflicts of Interest Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online with the Self-reported COI Disclosure Statement Forms through the website for JNS members.

References

1) Kinoshita M, Tanaka S, Nakada M, Ozaki N, Hamada J, Hayashi Y: What bone part is important to remove in accessing the suprachiasmatic region with less frontal lobe retraction in frontotemporal craniotomies. World Neurosurg 77: 342–348, 2012

2) Hayhurst C, Teo C: Tuberculum sella meningioma. Otolaryngologic Clinics of North America 44: 953–963, viii–ix, 2011

3) Yang YM, Wang ZW, Jiang HZ, Sha C, Yuan QC, Xie HW, Wang DM: [Microsurgical management of tuberculum sellae meningiomas]. Zhonghua Yi Xue Za Zhi 90: 2348–2350, 2010 (Chinese)

4) Scholz M, Parvin R, Thissen J, Lohnert C, Harders A, Blaeser K: Skull base approaches in neurosurgery. Head Neck Oncol 2: 16, 2010

5) Cunha AM, Aguiar GB, Carvalho FM, Simões EL, Pinto JR, Telles C: The orbitoptorional approach for large and giant middle cerebral artery aneurysms: a report of two cases and literature review. Skull Base 20: 261–267, 2010

6) Fatemi N, Dusick JR, de Paiva Neto MA, Malkasian D, Kelly DF: Endonasal versus supraorbital keyhole removal of craniopharyngiomas and tuberculum sellae meningiomas. Neurosurgery 64: 269–284; discussion 284–286, 2009

7) Reisch R, Pernecky A: Ten-year experience with the supraorbital subfrontal approach through an eyebrow skin incision. Neurosurgery 57: 242–255; discussion 242–255, 2005

8) Reisch R, Pernecky A, Filippi R: Surgical technique of the supraorbital key-hole craniotomy. Surg Neurol 59: 223–227, 2003

9) Andaluz N, Van Loveren HR, Keller JT, Zuccarello M: Anatomic and clinical study of the orbitoptorional approach to anterior communicating artery aneurysms. Neurosurgery 52: 1140–1148; discussion 1148–1149, 2003

10) Andaluz N, van Loveren HR, Keller JT, Zuccarello M: The one-piece orbitoptorional approach. Skull Base 13: 241–245, 2003

11) Gonzalez LF, Crawford NR, Horgan MA, Deshmukh P, Zabramski JM, Spetzler RF: Working area and angle of attack in three cranial base approaches: ptorional, orbitozygomatic, and maxillary extension of the orbitozygomatic approach. Neurosurgery 50: 550–555; discussion 555–557, 2002

12) Shanno G, Maus M, Bilyk J, Schwartz S, Savino P, Simeone F, Goldman HW: Image-guided transorbital roof craniotomy via a suprabrow approach: a surgical series of 72 patients. Neurosurgery 48: 559–567; discussion 567–568, 2001

13) Zabramski JM, Kiris T, Sankhla SK, Cabiol J, Spetzler RF: Orbitozygomatic craniotomy. Technical note. J Neurosurg 89: 336–341, 1998

14) Zhang MZ, Wang L, Zhang W, Qi W, Wang R, Han XD, Zhao JZ: The supraorbital keyhole approach with eyebrow incisions for treating lesions in the anterior fossa and sellar region. Chin Med J 117: 323–326, 2004

15) Bowers CA, Altay T, Couldwell WT: Surgical decision-making strategies in tuberculum sellae meningioma resection. Neurosurg Focus 30: E1, 2011

16) Arai H, Sato K, Okuda, Miyajima H, Hishii M, Nakamichi H, Ishii H: Transcranial transsphenoidal approach for tuberculum sellae meningiomas. Acta Neurochir (Wien) 142: 751–756; discussion 756–757, 2000

17) Couldwell WT, Weiss MH, Rabb C, Liu JK, Apfelbaum RI, Fukushima T: Variations on the standard transsphenoidal approach to the sellar region, with emphasis on the extended approaches and parasellar approaches: surgical experience in 105 cases. Neurosurgery 55: 539–547; discussion 547–550, 2004

18) de Divitiis E, Esposito F, Cappabianca P, Cavallo LM, de Divitiis O: Tuberculum sellae meningiomas: high route or low route? A series of 51 consecutive cases. Neurosurgery 62: 556–563, 2008

19) Fraioli MF, Moschettoni L, Floris R, Catena E, Fraioli B: Extended transsphenoidal microsurgical approach for diaphragma sellae and tuberculum meningiomas. Minim Invasive Neurosurg 52: 267–270, 2009

20) Frank G, Pasquini E: Tuberculum sellae meningioma: the extended transsphenoidal approach—for the virtuoso only? World Neurosurg 73: 625–626, 2010

21) Ogawa Y, Tominaga T: Extended transsphenoidal approach for tuberculum sellae meningioma—what are the optimum and critical indications? Acta Neurochir (Wien) 154: 621–626, 2012

22) Wang Q, Lu XJ, Li B, Ji WY, Chen KL: Extended endoscopic endonasal transsphenoidal removal of tuberculum sellae meningiomas: a preliminary report. J Clin Neurosci 16: 889–893, 2009

23) Mahmoud M, Nader R, Al-Mefty O: Optic canal involvement in tuberculum sellae meningiomas: influence on approach, recurrence, and visual recovery. Neurosurgery 67: ons108–118; discussion
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onS118–119, 2010

24) Cook SW, Smith Z, Kelly DF: Endonasal transsphenoidal removal of tumor cells for meningiomas: technical note. Neurosurgery 55: 239–244; discussion 244–246, 2004

25) Gardner PA, Kassam AB, Thomas A, Snyderman CH, Carrau RL, Mintz AH, Prevedello DM: Endoscopic endonasal resection of anterior cranial base meningiomas. Neurosurgery 63: 36–52; discussion 52–54, 2008

26) Liu JK, Christiano LD, Patel SK, Tubbs RS, Eloy JA: Surgical nuances for removal of tumor cells for meningiomas with optic canal involvement using the endoscopic endonasal endoscopic transsphenoidal transplanum transtuberculum approach. Neurosurg Focus 30: E2, 2011

27) Jho HD, Ha HG: Endoscopic endonasal skull base surgery: Part 1—The midline anterior fossa skull base. Minim Invasive Neurosurg 47: 1–8, 2004

28) Cappabianca P, Cavallo LM, Colao A, Del Basso De Caro M, Esposito F, Cirillo S, Lombardi G, de Divitiis E: Endoscopic endonasal transsphenoidal approach: outcome analysis of 100 consecutive procedures. Minim Invasive Neurosurg 45: 193–200, 2002

29) Ceylan S, Koc K, Aník I: Extended endoscopic transphenoidal approach for skull base tumors: basic approaches, avoidance of pitfalls, and recent innovations. Neurosurg Focus 10: 371–379, 2009

30) Shin M, Kondo K, Saito N: Neuroendoscopic transnasal surgery for skull base tumors: basic approaches, avoidance of pitfalls, and recent innovations. Neurosurg Focus 10: 371–379, 2009

31) Patel KS, Komotor RJ, Szentirmai O, Moussazadeh N, Raper DM, Anand VK, Schwartz TH: Case-specific protocol to reduce cerebrospinal fluid leakage after endonasal endoscopic surgery. J Neurosurg 119: 661–668, 2013

32) Mamelak AN, Carmichael J, Bonert VH, Cooper O, Melmed S: Single-surgeon fully endoscopic endonasal transsphenoidal surgery: outcomes in three-hundred consecutive cases. Pituitary 16: 393–401, 2013

33) Malik MU, Aberle JC, Flitsch J: CSF fistulas after transsphenoidal pituitary surgery—a solved problem? J Neurol Surg A Cent Eur Neurosurg 73: 275–280, 2012

34) Berker M, Hazer DB, Yücel T, Gürlek A, Cila A, Aldur M, Onerci M: Complications of endoscopic surgery of the pituitary adenomas: analysis of 570 patients and review of the literature. Pituitary 15: 288–300, 2012

35) Gondim JA, Schops M, de Almeida JP, de Albuquerque LA, Gomes E, Ferraz T, Barroso FA: Endoscopic endonasal transsphenoidal surgery: results of 228 pituitary adenomas treated at a pituitary center. Pituitary 13: 68–77, 2010

36) Harvey RJ, Nogueira JF, Schlosser RJ, Patel SJ, Vellutini E, Stamm AC: Closure of large skull base defects after endoscopic transnasal craniotomy. Clinical article. J Neurosurg 111: 371–379, 2009

37) Leng LZ, Brown S, Anand VK, Schwartz TH: “Gasket-seal” watertight closure in minimal-access endoscopic cranial base surgery. Neurosurgery 62: ONS342–343; discussion ONS343, 2008

38) Kassam AB, Thomas A, Carrau RL, Snyderman CH, Vescan A, Prevedello D, Mintz A, Gardner P: Endoscopic reconstruction of the cranial base using a pedicled nasoseptal flap. Neurosurgery 63: ONS44–ONS52; discussion ONS52–ONS53, 2008

39) Han ZL, He DS, Mao ZG, Wang HJ: Cerebrospinal fluid rhinorrhea following trans-sphenoidal pituitary surgery: Part 1—evolution, basic concept, and current technique. Neurosurgery 42: 219–224; discussion 224–225, 1998

40) Cukurova I, Getinkaya EA, Aslan IB, Ozkul D: Endonasal endoscopic repair of ethmoid roof cerebrospinal fluid fistula by suturing the dura. Acta Neurochir (Wien) 150: 897–900; discussion 900, 2008

41) Hadad G, Bassagasteguy L, Carrau RL, Mataza JC, Kassam A, Snyderman CH, Mintz A: A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. Laryngoscope 116: 1882–1886, 2006

42) Kitano M, Taneda M: Subdural patch graft technique for watertight closure of large dural defects in extended transsphenoidal surgery. Neurosurgery 54: 653–660; discussion 660–661, 2004

43) Choudhari KA: ‘In-lay’ duraplasty: a useful method of effective dural closure. Br J Neurosurg 15: 533–535, 2001

44) Ishii Y, Tahara S, Oyama K, Kitamura T, Teramoto A: Easy slip-knot: a new simple tying technique for deep sutures. Acta Neurochir (Wien) 153: 1543–1545, discussion 1545, 2011

45) Saleem MA, Hashim AS, Rashid A, Ali M: Role of gamma knife radiotherapy in multimodality management of craniopharyngioma. Acta Neurochir Suppl 116: 55–60, 2013

46) Khamlirich AE, Melhaoui A, Arkha Y, Jiddane M, Gueddari BK: Role of gamma knife radiosurgery in the management of pituitary adenomas and craniopharyngiomas. Acta Neurochir Suppl 116: 49–54, 2013

47) Aggarwal A, Fersht N, Brada M: Radiotherapy for craniopharyngioma. Pituitary 16: 26–33, 2013

48) Liu X, Yu Q, Zhang Z, Zhang Y, Li Y, Liu D, Jia Q, Zheng L, Xu D: Same-day stereotactic aspiration and Gamma Knife surgery for cystic intracranial tumors. J Neurosurg 117(Suppl): S45–S48, 2012

49) Clark AJ, Cage TA, Aranda D, Parsa AT, Auguste KI, Gutpa N: Treatment-related morbidity and the management of pediatric craniopharyngioma: a systematic review. J Neurosurg Pediatr 10: 293–301, 2012

50) Akutsu H, Kreutzer J, Fahlbusch R, Buchfelder M: Transsphenoidal decompression of the sellar floor for cavernous sinus meningiomas: experience with 21 patients. Neurosurgery 65: 54–62; discussion 62, 2009

51) Pernczcky A, Fries G: Endoscope-assisted brain surgery: part 1—evolution, basic concept, and current technique. Neurosurgery 42: 219–224; discussion 224–225, 1998
52) McCutcheon IE, Blacklock JB, Weber RS, DeMonte F, Moser RP, Byers M, Goepfert H: Anterior transcranial (craniofacial) resection of tumors of the paranasal sinuses: surgical technique and results. *Neurosurgery* 38: 471–479; discussion 479–480, 1996

53) Thaler ER, Kotapka M, Lanza DC, Kennedy DW: Endoscopically assisted anterior cranial skull base resection of sinonasal tumors. *Am J Rhinol* 13: 303–310, 1999

54) Casiano RR, Numa WA, Falquez AM: Endoscopic resection of esthesioneuroblastoma. *Am J Rhinol* 15: 271–279, 2001

55) Gardner PA, Kassam AB, Snyderman CH, Carrau RL, Mintz AH, Grahovac S, Stefko S: Outcomes following endoscopic, expanded endonasal resection of suprasellar cranioopharyngiomas: a case series. *J Neurosurg* 109: 6–16, 2008

56) Cappabianca P, Cavallo LM, de Divitiis E: Endoscopic transnasal endosphenoidal surgery. *Neurosurgery* 55: 933–940; discussion 940–941, 2004

57) Kassam AB, Gardner PA, Snyderman CH, Carrau RL, Mintz AH, Prevedello DM: Expanded endonasal approach, fully endoscopic transnasal approach for the resection of midline suprasellar cranioopharyngiomas: a new classification based on the infundibulum. *J Neurosurg* 108: 715–728, 2008

58) Liu JK, Christiano LD, Patel SK, Eloy JA: Surgical nuances for removal of retrochiasmatic cranioopharyngioma via the endoscopic endonasal extended transphenoidal transplanum transtuberculum approach. *Neurosurg Focus* 30: E14, 2011

59) Liu JK, Eloy JA: Expanded endoscopic endonasal transcribriform approach for resection of anterior skull base olfactory schwannoma. *J Neurosurg* 32(Suppl): E3, 2012

60) Jho HD, Ha HG: Endoscopic endonasal skull base surgery: Part 3—The clivus and posterior fossa. *Minim Invasive Neurosurg* 47: 16–23, 2004

61) Jho HD, Ha HG: Endoscopic endonasal skull base surgery: Part 2—The cavernous sinus. *Minim Invasive Neurosurg* 47: 9–15, 2004

62) Jho HD: Endoscopic transphenoidal surgery. *J Neurooncol* 187–195, 2001

63) Gardner PA, Prevedello DM, Kassam AB, Snyderman CH, Carrau RL, Mintz AH: The evolution of the endonasal approach for cranioopharyngiomas. *J Neurosurg* 108: 1043–1047, 2008

64) 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* 19: E3, 2005

65) Cappabianca P, Cavallo LM, Esposito F, de Divitiis E: Endoscopic endonasal transphenoidal surgery: procedure, endoscopic equipment and instrumentation. *Childs Nerv Syst* 20: 796–801, 2004

66) Kitano M, Taneda M, Nakao Y: Postoperative improvement in visual function in patients with tuberculum sellae meningiomas: results of the extended transphenoidal and transcranial approaches. *J Neurosurg* 107: 337–346, 2007

67) Wang Q, Lu XJ, Ji WY, Yan ZC, Xu J, Ding YS, Zhang J: Visual outcome after extended endoscopic endonasal transphenoidal surgery for tuberculum sellae meningiomas. *World Neurosurg* 73: 694–700, 2010

68) de Divitiis E, Cavallo LM, Esposito F, Stella L, Messina A: Extended endoscopic transphenoidal approach for tuberculum sellae meningiomas. *Neurosurgery* 61: 229–237: discussion 237–238, 2007

69) Van Gompel JJ, Frank G, Pasquini E, Zoli M, Hoover J, Lanzino G: Expanded endonasal endoscopic resection of anterior fossa meningiomas: report of 13 cases and meta-analysis of the literature. *Neurosurg Focus* 30: E15, 2011

70) McCoul ED, Anand VK, Singh A, Nyquist GG, Schaber MR, Schwartz TH: Long-term effectiveness of a reconstructive protocol using the nasoseptal flap after endoscopic skull base surgery. *World Neurosurg* 81: 136–143, 2014

71) Fortes FS, Carrau RL, Snyderman CH, Prevedello D, Vescan A, Van Gompel JJ, Frank G, Pasquini E, Zoli M, Hoover J, Lanzino G: Expanded endonasal endoscopic resection of anterior fossa meningiomas: report of 13 cases and meta-analysis of the literature. *Neurosurg Focus* 30: E15, 2011

72) Shah RN, Surowitz JB, Patel MR, Huang BY, Snyderman CH, Carrau RL, Kassam AB, Germanwala AV, Zanation AM: Endoscopic pedicled nasoseptal flap reconstruction for pediatric skull base defects. *Laryngoscope* 119: 1067–1075, 2009

73) Zanation AM, Carrau RL, Snyderman CH, Germanwala AV, Gardner PA, Prevedello DM, Kassam AB: Nasoseptal flap reconstruction of high flow intraoperative cerebral spinal fluid leaks during endoscopic skull base surgery. *Am J Rhinol Allergy* 23: 518–521, 2009

74) Kim SW, Park KB, Khalmuratova R, Lee HK, Jeon SY, Kim DW: Clinical and histologic studies of olfactory outcomes after nasoseptal flap harvesting. *Laryngoscope* 123: 1602–1606, 2013

75) Kari E, Oyesiku NM, Dadashev V, Wise SK: Comparison of traditional 2-dimensional endoscopic pituitary surgery with new 3-dimensional endoscopic technology: intraoperative and early postoperative factors. *Int Forum Allergy Rhinol* 2: 2–8, 2012

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