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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 binosrtil- 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 post-operative 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

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

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

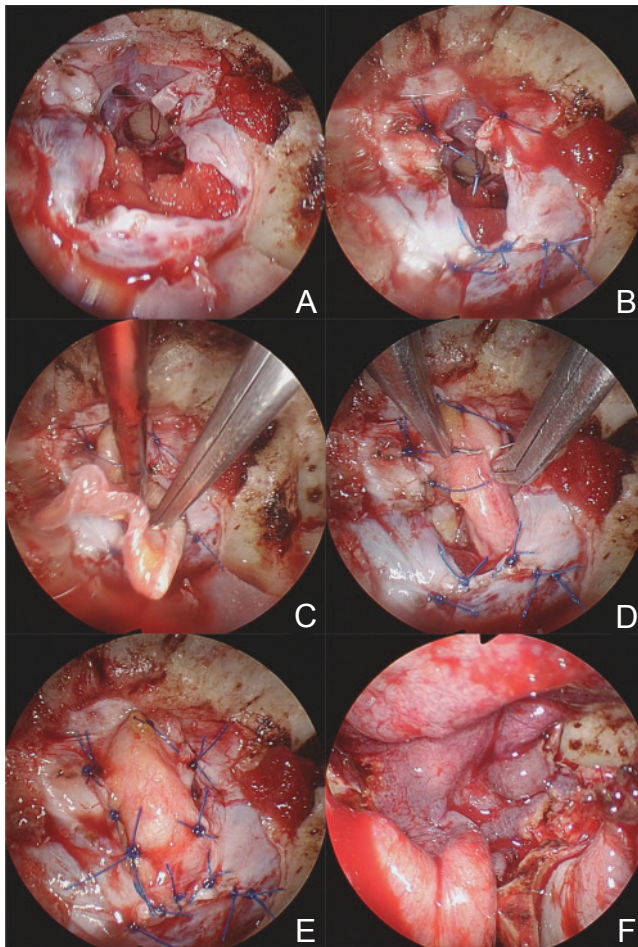


Fig. 1 Fascial inlay patch suture. After suturing the part of the dural incision that could be seamed directly together (A, B), the remaining dural gap was closed by a patchwork technique, using fascia obtained from the femur or abdomen (C–E). The fascia was laid in the intracranial epi-arachnoid space (C) and patch-sutured along the entire circumference of the opening (C, D). Finally the nasoseptal flap was applied to cover the entire operative field (F).

adenomas that extend into the subarachnoid space (Fig. 2). Therefore the positions of the tumor and peripheral arteries or optic nerves relative to one another are clearly observed and tumors are more safely removed without injuring them. To avoid the damage to the arteries and optic nerves when the tumor capsule is removed by force, tumor resection should be achieved by intra-capsular fashion. Using these techniques, most of the tumors that extended in the anterior-posterior or dorsal directions could be removed. But when the tumor extended outside the intracranial part of the ICA, it could not be removed due to the lack of adequate instruments that can reach there.

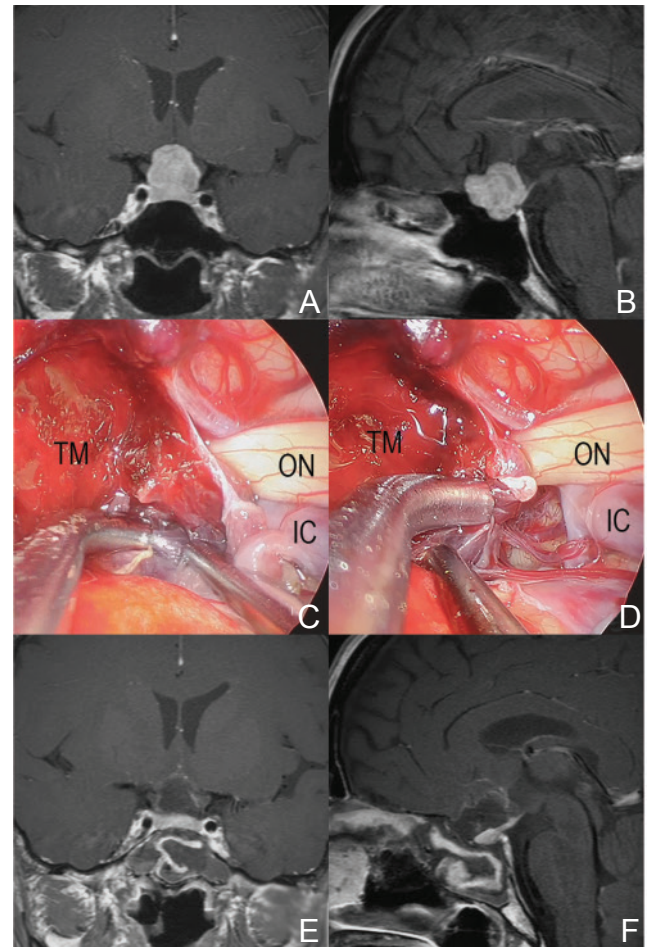


Fig. 2 A representative case of pituitary adenoma (48-year-old woman with visual field defect and headache). The tumor was not so large, but the shape was irregular that meant extension into the subarachnoid space (A, B). During operation, the tumor located outside of the sella and extended into the subarachnoid space (C). The tumor capsule adhered to surrounding arteries. Intra-capsular resection of tumor was performed and IC perforators were observed (D). Postoperative magnetic resonance imaging (MRI) showed no residual tumor and the preserved pituitary gland (E, F). IC: internal carotid, ON: optic nerve, TM: tumor.

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

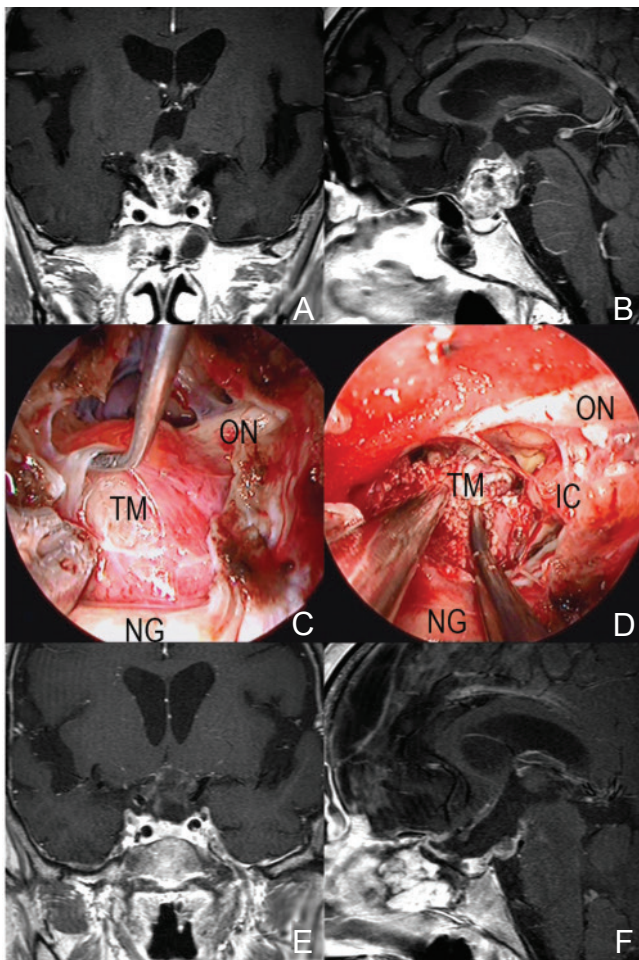


Fig. 3 A representative case of craniopharyngioma (64-year-old woman with loss of visual acuity). The tumor derived from the pituitary stalk pushed up the chiasm (A, B). In EESB approach, the boundary between the tumor and the optic nerve could be clearly seen and the tumor was removed safely without any injury of optic nerves and surrounding arteries (C, D). Most of tumor was removed on postoperative MRI (E, F). ESSB: endoscopic endonasal skull base, IC: internal carotid, MRI: magnetic resonance imaging, NG: normal pituitary gland, ON: optic nerve, TM: tumor.

papers reported good results using stereotactic radiotherapy (SRT),^{45–49} combined therapy with direct surgery and SRT may be a standard therapy for craniopharyngiomas.

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,

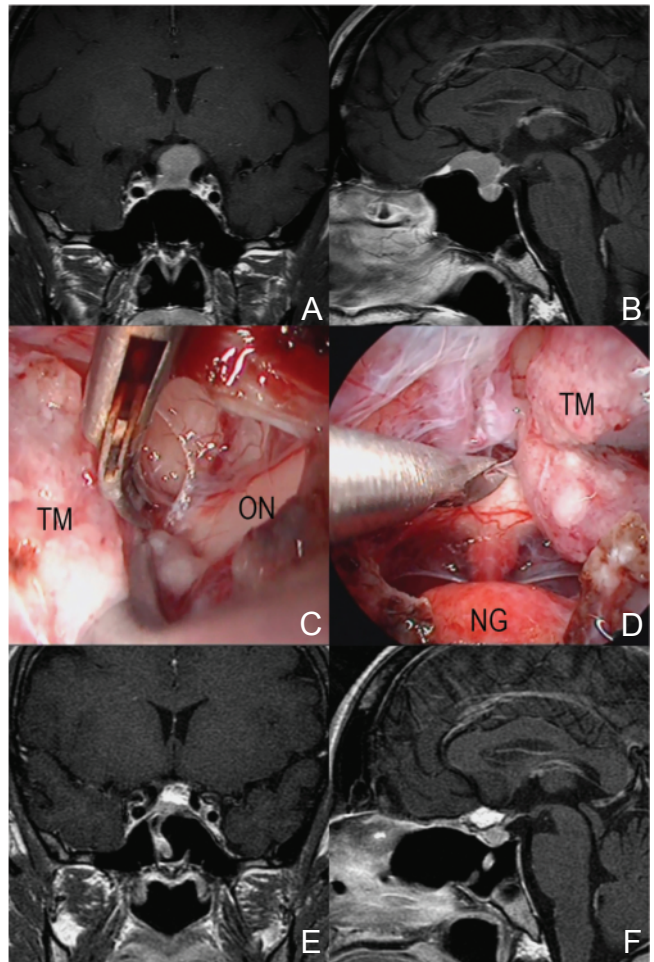


Fig. 4 A representative case of tuberculum sellae meningioma (37-year-old woman with headache). The tumor attached at the tuberculum and sphenoid planum, compressed the pituitary and the chiasm behind (A, B). During operation, there were no bleeding from tumor and the margin between the tumor and surroundings were clearly seen (C, D). Total removal of tumor was achieved on postoperative MRI (E, F). MRI: magnetic resonance imaging, NG: normal pituitary gland, ON: optic nerve, TM: tumor.

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

advance 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 abducent 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.⁵¹⁾ 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.^{52,53)} Casiano et al. described the first purely endoscopic endonasal approach for the resection of esthesioneuroblastomas.⁵⁴⁾ Since its introduction, this method has been internationally recognized and duplicated for resection of a variety of anterior skull base tumors.^{26,30,55-59)}

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.^{27,28,60-62)} Although this approach was not immediately accepted, the purely endoscopic endonasal approach became more accepted after further popularization by Kassam and Snyderman,^{25,57,63,64)} and Cavallo and Cappabianca.^{18,28,56,65)} 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^{66,67)} and enabled early devascularization of the tumor.^{20,55)} 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.^{18,29,68)} 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.^{2,20,69)} Recently, several techniques have been developed to reduce this risk, including the gasket seal,³⁷⁾ direct suturing of graft material,⁴⁰⁾ and the vascularized nasoseptal flap.^{41,70)}

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.³⁸⁾ Several reports have described favorable rates of postoperative CSF leakage using this and other vascularized reconstructive techniques.^{38,71-73)} But in addition, the functional disorder of the nose was also described.⁷⁴⁾ 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,^{38,71-73)} 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,⁷⁵⁾ 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.

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