

Original Article

Endoscopic endonasal skull base approach for parasellar lesions: Initial experiences, results, efficacy, and complications

Shigetoshi Yano, Takuichiro Hide, Naoki Shinojima, Yu Hasegawa¹, Takayuki Kawano, Jun-ichi Kuratsu

Departments of Neurosurgery, and ¹Pharmacology and Molecular Therapeutics, Faculty of Life Sciences Research, Kumamoto University Graduate School, Kumamoto, Japan

E-mail: *Shigetoshi Yano - yanos@kumamoto-u.ac.jp; Takuichiro Hide - thide@fc.kuh.kumamoto-u.ac.jp; Naoki Shinojima - nshinojima@hotmail.com; Yu Hasegawa - fpmhase@yahoo.co.jp; Takayuki Kawano - tkawano-nsu@umin.ac.jp; Jun-ichi Kuratsu - jkuratsu@kumamoto-u.ac.jp

*Corresponding author

Received: 15 August 13 Accepted: 11 November 13 Published: 16 April 14

This article may be cited as:

Yano S, Hide T, Shinojima N, Hasegawa Y, Kawano T, Kuratsu J. Endoscopic endonasal skull base approach for parasellar lesions: Initial experiences, results, efficacy, and complications. *Surg Neurol Int* 2014;5:51.

Available FREE in open access from: <http://www.surgicalneurologyint.com/text.asp?2014/5/1/51/130901>

Copyright: © 2014 Yano S. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Background: Endoscopic surgery is suitable for the transsphenoidal approach; it is minimally invasive and provides a well-lit operative field. The endoscopic skull base approach through the large opening of the sphenoid sinus through both nostrils has extended the surgical indication for various skull base lesions. In this study, we describe the efficacy and complications associated with the endoscopic skull base approach for extra- or intradural parasellar lesions based on our experiences.

Methods: Seventy-four cases were treated by an endoscopic skull base approach. The indications for these procedures included 55 anterior extended approaches, 10 clival approaches, and 9 cavernous approaches. The operations were performed through both the nostrils using a rigid endoscope. After tumor removal, the skull base was reconstructed by a multilayered method using a polyglactin acid (PGA) sheet.

Results: Gross total resection was achieved in 82% of pituitary adenomas, 68.8% of meningiomas, and 60% of craniopharyngiomas in anterior extended approach and in 83.3% of chordomas in clival approach, but only in 50% of the tumors in cavernous approach. Tumor consistency, adhesion, and/or extension were significant limitations. Visual function improvements were achieved in 37 of 41 (90.2%) cases. Cerebrospinal fluid (CSF) leakage (9.5%), infections (5.4%), neural injuries (4.1%), and vascular injuries (2.7%) were the major complications.

Conclusions: Our experiences show that the endoscopic skull base approach is a safe and effective procedure for various parasellar lesions. Selection of patients who are unlikely to develop complications seems to be an important factor for procedure efficacy and good outcome.

Key Words: Endonasal, endoscopic surgery, skull base, transsphenoidal approach

**Access this article
online****Website:**

www.surgicalneurologyint.com

DOI:

10.4103/2152-7806.130901

Quick Response Code:

INTRODUCTION

Endoscopic transsphenoidal surgery (ETSS) allows for safe and sufficient resection of sellar lesion tumors.

Recently, the standard endoscopic transsphenoidal approach has been modified in various ways to develop extended endonasal approaches.^[3,6,8] For instance, the transsphenoidal transplanum transtuberculum

approach for frontal base meningiomas^[2,4,23,28] or craniopharyngiomas,^[4,5] the lateral approach for intracavernous tumors,^[6] and the clival approach for chordoma^[16,18] carried out under endoscopy have been reported.

We began using the endoscopic endonasal transsphenoidal surgery with a bilateral nostril approach in 2001. In 2004, when we had performed the surgery for 84 sellar lesions,^[31] we adopted the extended removal for parasellar lesions. Among the 510 endoscopic skull base surgeries we had performed by the end of 2012, 74 were for extra- or intradural tumors originated at or extended to parasellar lesions, and these are discussed here. In our experience, minor modification of the standard ETSS technique through both the nostrils facilitates the approach to various parasellar lesions. However, the limitations of this approach should be recognized in order to select appropriate patients and perform safe and sufficient resection. We found that the main problems were control of hemorrhage from intracranial vessels and subsequent increased risk of postoperative cerebrospinal fluid (CSF) leakage and postoperative infections. In this report, we analyze our initial surgical results and discuss the present limitations and complications of this procedure.

MATERIALS AND METHODS

Patient characteristics

We used the endoscopic endonasal skull base approach for 74 cases in Kumamoto University and related hospitals between June 2004 and December 2012. Twenty-seven patients with pituitary adenomas were subjected in this study. Of them, 19 tumors extended to planum sphenoidale beyond the tuberculum sellae, 4 tumors extended into the retrochiasmatic space with a dumbbell shape, and 4 tumors extended to cavernous sinus. In four tumors extended to cavernous sinus, two cases were nonfunctioning pituitary adenomas and two were growth hormone (GH)-secreting adenoma that extended beyond the outside line of the internal carotid artery (ICA). All of these tumors required the subarachnoid dissection or cavernous dissection for removal. Other types of pituitary adenomas that were operated in parallel at the same time and did not require the opening of extrasellar bone were excluded from this study. Twelve cases of meningiomas were located on the tuberculum sellae, four were intraorbital or extended over the anterior clinoid process, two were in the cavernous sinus, and one was intradural meningioma attached to the clivus. Craniopharyngiomas (10 cases) and Rathke's cleft cysts (3 cases) were located in the suprasellar retrochiasmatic space. Two cases of astrocytomas originating from the optic chiasm and two dermoid cysts occurred at each location of the planum sphenoidale and cavernous sinus. Chordomas were located in the clivus

in six patients and mainly intracavernous in one patient. Ectopic physaliphora and plasmacytoma originating from the clival and pyramidal bone, fibrous dysplasia of the sphenoid bone, and adenoid cystic carcinoma in the cavernous sinus were also treated respectively. Visual field defect and decreased visual acuity were observed in 40 of the 55 patients with parasellar lesion and 1 patient with fibrous dysplasia. Diplopia due to oculomotor or abducens nerve palsy was observed in 8 of the 10 patients with clival lesion tumors, 4 of the 9 patients with cavernous lesion tumors, and 1 patient with clinoidal meningioma. Hormonal deficit was observed in 4 of the 55 patients with the tumors adjacent to the pituitary gland (1 with pituitary adenoma, 2 with craniopharyngioma, and 1 with Rathke's cleft cyst) and in 2 of the 9 patients with cavernous sinus tumors; both these patients had GH-secreting adenomas extending to the cavernous sinus. Seven patients did not present with any clinical symptoms, but their tumor showed growth during the follow-up period.

Surgical procedures

Our previously reported standard endoscopic endonasal transsphenoidal approach through both the nostrils^[31] was modified for the skull base approach to increase the working space and instrument maneuverability. The endoscope (KARL STORZ HOPKINS II rigid endoscope, 0° or 30°, Tuttlingen, Germany) was held by a gas-controlled holder (Unitrack, AESCULAP, Tokyo, Japan) or by another surgeon.

After confirmation of bilateral sphenoid ostia, we prepared a wide flap of unilateral septal mucosa to reconstruct the skull base. The mucosal flap was reflected to the inferior meatus and covered with gauze soaked in saline during tumor resection. The contralateral septal mucosa was dissected 7-9 mm in the length around the sphenoid ostium. The posterior part of the bony septum was partially removed, and both enlarged ostia were connected. The bony septum was used to reinforce the skull base after tumor removal. The contralateral septal mucosa was preserved. The sellar floor, tuberculum sellae, planum sphenoidale, or cavernous protuberance was opened depending on the degree of tumor extension [Figure 1a]. A microdrill was attached to a Suretrack system (StealthStation System, Medtronic, Minneapolis, MN, USA), and the surgeon confirmed the drilling area in the navigation monitor. For planum sphenoidale, tuberculum sellae or suprasellar retrochiasmatic lesion, the intercavernous sinus lying under the tuberculum sellae was dissected, coagulated, and cut using a Colorado microdissection needle (Stryker, Kalamazoo, MI, USA). Through the transplanum, transtuberculum sellae, or transdiaphragmatic route, the tumors were ultrasonically aspirated, and the tumor capsule was dissected and removed piece-by-piece. Finally, the tumor was sharply dissected from the surrounding

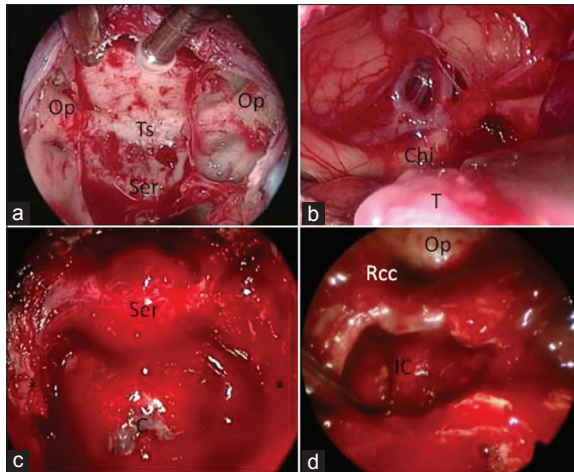


Figure 1: Intraoperative view of each approach. (a) Opening the planum sphenoidale. **(b)** The anterior extended approach. The tumor (T) was removed. Optic chiasm (Chi) and anterior cerebral arteries were visualized. **(c)** The clival approach after removing a chordoma. The dura of clivus (C) and bilateral carotid prominences (*) were visualized. **(d)** The cavernous approach after removing a pituitary adenoma. The right cavernous sinus was opened, and the ICA was visualized. OCR, optico-carotid recess; Op, optic nerve prominence; Ts, tuberculum sellae; Ser, sellar floor

structures under clear endoscopic visualization (Anterior extended approach; Figure 1b). For clival lesions, the sphenoid sinus mucosa was peeled away between both the carotid prominences. The clival bone was drilled, and the tumors were removed. Dura was dissected in the case of tumor extension (Clival approach; Figure 1c). For intracavernous lesions, removal of the inferior part of the middle and superior turbinate was performed. After dissection of ethmoid bulla and opening the posterior ethmoid cells, opening of the anterior wall of the sphenoid sinus was widely enlarged in the lateral direction of the vidian canal. The skull base was drilled, and tumors were ultrasonically aspirated under the navigation system. Angled endoscopes (an angle of 30° in most cases and 70° in one case) were used in the lateral area (Cavernous approach; Figure 1d). A curved suction aspirator and malleable curettes (Fujita Medical Instruments Co., Ltd., Japan) were used for tumor removal under direct visualization.

The skull base repair was performed by a multiple repair method. An abdominal fat graft was positioned inside the residual cavity, and the remaining dural edge was attached to the fat and covered by the polyglactin acid (PGA) sheet.^[32] The bony septum was set under the bony edge, and a large mucosal flap was used to cover the sellar floor. The PGA sheet was overlaid again and attached by the spray of fibrin glue. A balloon catheter (Sinus Balloon Catheter, Fuji Systems Co., Ltd., Tokyo, Japan) was inflated with 5-8 ml of distilled water in the posterior nasal cavity for 1 week to reinforce the attachment [Figure 2].

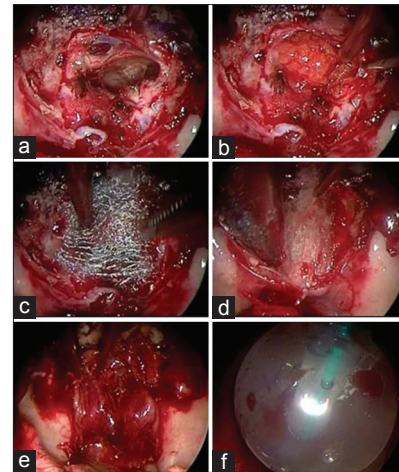


Figure 2: Intraoperative photograph of skull base reconstruction. (a) After removing the tumor, a wide opening of the skull base dura was observed. **(b)** Abdominal fat was inserted into the cavity and attached to surrounding dura. **(c)** The defect was covered with a PGA sheet. **(d)** The skull base was reinforced with bony septum to prevent from protrusion of the fat due to intracranial pressure and pulsation. **(e)** A large mucosal flap was used to cover the skull base. **(f)** A sinus Balloon catheter™ was inserted to confirm mucosal flap attachment to the skull base

The extent of surgical removal, which was evaluated on the basis of postoperative magnetic resonance images (MRIs) obtained in the immediate postoperative period and 3 months later, was classified as total (no residual tumor), subtotal (presence of residual part but removed more than 95%), and partial (removed less than 95%). On postoperative day 3 and after 1 month, the patients underwent endoscopic exploration of the nasal cavities by otolaryngologists to determine cranial base reconstruction effectiveness. Statistical analysis was performed with Welch's t tests and Fisher's exact tests.

RESULTS

The median follow-up period was 23.1 months for the anterior extended approach and 12.6 months for the cavernous approach. The extent of surgical removal was evaluated from postoperative MRI scans obtained 3 months later.

Degree of tumor removal for each type of approach is summarized in Table 1. Among anterior extended approach, 19 of 23 (82.6%) pituitary adenomas, 11 of 16 (62.8%) meningiomas, and 6 of 10 (60.0%) craniopharyngiomas showed more than subtotal removal. Evacuation was performed in three Rathke's cleft cysts, and partial removal was performed in the two cases of optic glioma and one case of dermoid cyst in the frontal base. Among clival approach, five of the six (83.3%) chordomas and the rare echordosis physaliphora were totally removed.^[30] For one patient, the chondroid chordoma extended into the pons and could not be fully resected because of adhesion to the brain parenchyma

and basilar artery. Fibrous dysplasia and plasmacytoma were also removed partially due to wide extension into the sphenoid sinus and the pyramidal bone. In cavernous approach, only two cases of nonfunctioning pituitary adenomas, one meningioma and one dermoid cyst showed more than subtotal removal. Two GH-secreting pituitary adenomas extending into the cavernous sinus and one meningothelial meningioma that developed after stereotactic radiosurgery were too hard to remove because they could not be dissected from the ICA. One chordoma extended into the cavernous sinus and was not fully resected to avoid nerve injury. Representative pre- and postoperative MRI images in which total removal was achieved are shown in Figures 3 and 4.

We analyzed the factors influencing removal rate in three types of tumors treated by anterior extended approach [Table 2]. Among the 23 pituitary adenomas, 3 of 4 (75.0%) tumors that extended to the retrochiasmatic lesion were partially removed. A statistically significant difference was observed between prechiasmatic and retrochiasmatic types of tumors. Pre- and postoperative MRIs of a representative case are shown in Figure 5a and b. For pituitary adenomas extending from the prechiasmatic space to the retrochiasmatic space and compressing the optic chiasm, a portion of the retrochiasmatic part was not removed in order to avoid pituitary stalk injury during resection. Of the 16 frontal base meningiomas, 5 could not be completely removed. Factors that influenced this were hard tumor consistency and intraorbital extension beyond the tuberculum sellae. Although no significant difference was obtained for the average tumor size, one tumor, which was larger than 3 cm in diameter, was not totally removed. Pre- and postoperative MRIs of a representative meningioma case in which the tumor extended over the anterior clinoid process are shown in Figure 5c and d. An analysis of the 10 cases of craniopharyngioma, showed for all 3 cases that harbored multiple cysts in the tumors, the tumors were not completely removed. No significant difference was observed in the average tumor size, retrochiasmatic extension, or surgery timing. Pre- and postoperative MRIs of multi-cystic types of craniopharyngioma are shown in Figure 5e and f.

Preoperative visual deficits were observed in 41 of the 55 (74.5%) cases treated by anterior extended approach and 1 case of fibrous dysplasia that filled the sphenoid sinus. Among them, 37 patients (90.2%) experienced improved postoperative visual function, whereas the remaining 4 patients (2 with optic gliomas, 1 with meningioma extending into the optic canal, and 1 with recurrent pituitary adenoma that developed intratumoral hemorrhage in the remnant tumor) did not show any improvement. Preoperative diplopia manifested in

Table 1: Removal rate in each approach and pathology

Approach	Pathology	No. of cases	No. of >subtotal removal (%)
Anterior extended (n=55)	Pituitary adenoma	23	19 (82.6)
	Meningioma	16	11 (68.8)
	Craniopharyngioma	10	6 (60.0)
	Rathke's cleft cyst	3	0 (0.0)
	Astrocytoma	2	0 (0.0)
	Dermoid cyst	1	0 (0.0)
Clival (n=10)	Chordoma	6	5 (83.3)
	Meningioma	1	0 (0.0)
	Ecchordosis physaliphora	1	1 (100.0)
	Fibrous dysplasia	1	0 (0.0)
	Plasmacytoma	1	0 (0.0)
	Cavernous (n=9)	Pituitary adenoma	4
Meningioma		2	1 (50.0)
Chordoma		1	0 (0.0)
Dermoid cyst		1	1 (100.0)
Adenoid cystic carcinoma		1	0 (0.0)

A. Pituitary adenoma (n=23)

Table 2: Analysis of the factors affected to the removal rate of major tumors operated by the anterior extended approach

A. Pituitary adenoma (n=23)			
	> subtotal n=19	Partial n=4	P
Age	58.7±14.5	58.0±25.7	0.47
Tumor size (mm)	30.1±9.5	47.0±10.8	0.97
Hard consistency (%)	1 (5.2)	2 (50.0)	0.07
Retrochiasmatic extension (%)	1 (5.2)	3 (75.0)	0.008*
Functioning tumor (%)	2 (10.4)	1 (25.0)	0.45
B. Meningioma (n=16)			
	n=11	n=5	P
Age	58.5±16.5	55.4±16.7	0.36
Tumor size (mm)	22.3±6.2	22.4±11.3	0.51
Hard consistency (%)	0 (0.0)	4 (80.0)	0.02*
Extra-tuberculum sellae extension (%)	0 (0.0)	4 (80.0)	0.02*
Malignant histology (%)	1 (9.0)	1 (20.0)	0.54
C. Craniopharyngioma (n=10)			
	n=5	n=5	P
Age	32.3±29.4	47.8±27.8	0.79
Tumor size (mm)	28.7±11.4	34.5±6.4	0.87
Multi-cystic tumor (%)	0 (0.0)	4 (80.0)	0.02*
Retrochiasmatic extension (%)	4 (80.0)	4 (80.0)	0.77
Recurrent tumor (%)	1 (20.0)	4 (80.0)	0.1

Statistical value (P) was evaluated for age and tumor size by Welch's t test and for other factors by Fisher's exact test. Significant difference (P<0.05) was indicated by asterisk (*)

12 cases; of these 8 cases of clival lesions showed complete recovery postoperatively, and 3 cases of cavernous lesion and 1 case of atypical meningioma extending into the superior orbital fissure showed no improvement after surgery. Five patients experienced headache that remitted postoperatively [Table 3].

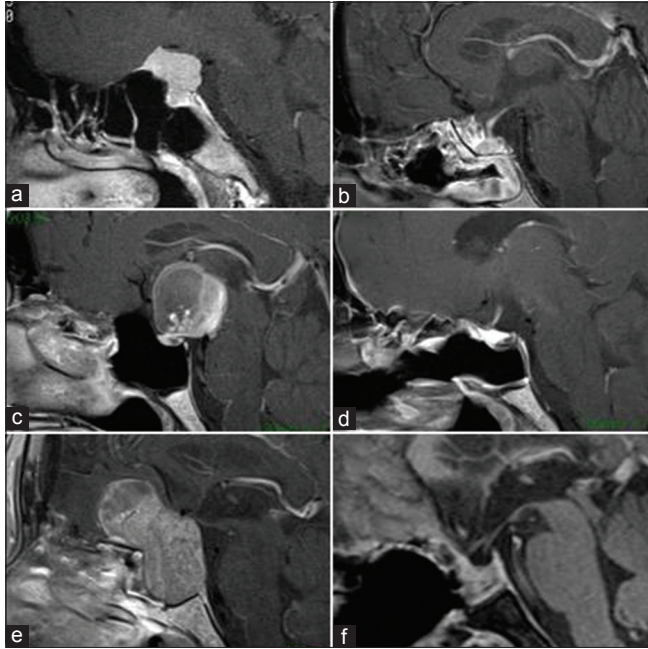


Figure 3: Representative pre- and postoperative MRI of the cases treated with the anterior extended approach. (a, b) A case of tuberculum sellae meningioma. Preoperative MRI revealed a 25-mm meningioma (a). Postoperative MRI shows total removal (b). (c, d) A case of craniopharyngioma. Preoperative MRI showed a cystic mass located in a suprasellar lesion (c). Postoperative MRI revealed total removal (d). (e, f) A case of pituitary adenoma. Preoperative MRI showed a pituitary adenoma located in the sellar to frontal skull base (e). Postoperative MRI demonstrated total removal (f)

The complication rate for each approach is shown in Table 4. No patient died due to surgery. Postoperative CSF leakage was observed in 7 of the 74 (9.5%) patients, including 5 patients that underwent the anterior extended approach. Four cases required reoperations to reinforce the skull base. The CSF leakage were attributable to no mucosal flap in three cases, inadequate mucosal flap size in one case, incomplete adhesion to the skull base in two cases, and infection of reconstruction materials in one case. Reoperation of a wide mucosal flap from the contralateral septum or using fascia in the second operation resolved continuous CSF leakage.

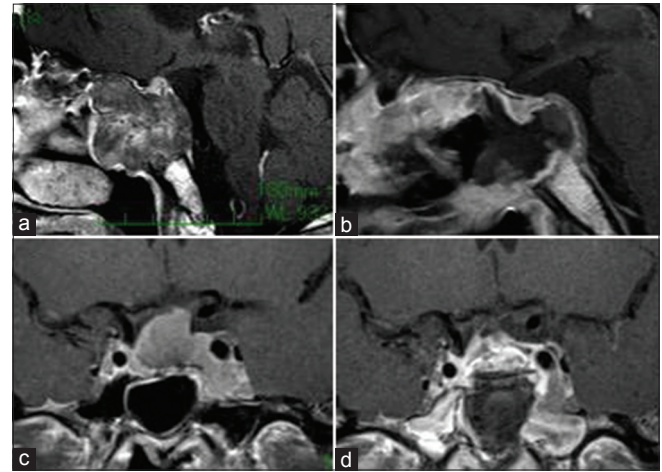


Figure 4: Representative pre- and postoperative MRI of the cases treated with the clival or cavernous approach. (a, b): A case of chordoma. Preoperative Gd-enhanced MRI showed a chordoma located in the sphenoid sinus with destruction of the clivus (a). Postoperative MRI confirmed gross total removal (b). (c and d) A case of pituitary adenoma. Preoperative MRI showed the tumor located in an intrasellar lesion that extended into the cavernous sinus (c). Postoperative MRI revealed a small remnant below the ICA (d)

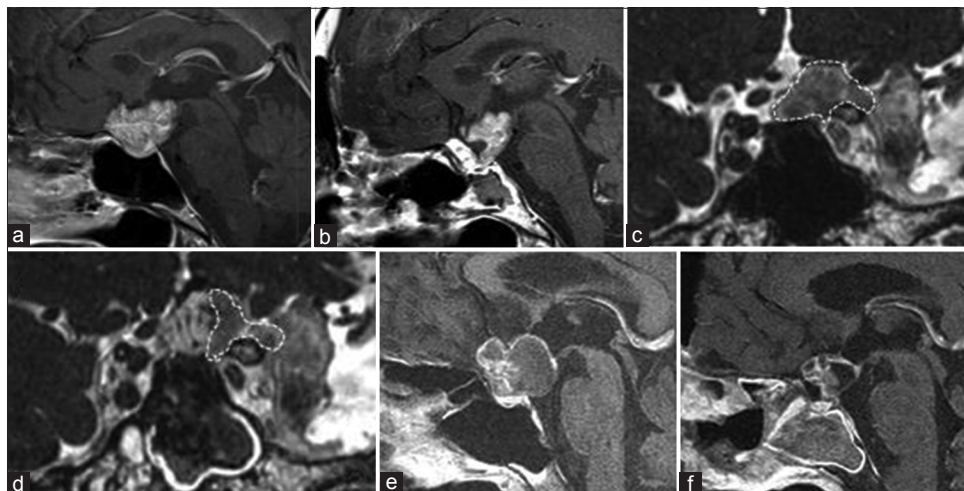


Figure 5: Representative pre- and postoperative MRI of cases with partial removal. (a, b) A case of pituitary adenoma with extension to the retrochiasmatic space (a), which remained in the retrochiasmatic space (b). (c, d) A case of tuberculum meningioma located in the tuberculum sellae that extended over the anterior clinoid process (c). Postoperative MRI showed that the tumor remained around the clinoid process (d). The outline of the tumor surrounded by a dotted line. (e, f) A case of suprasellar craniopharyngioma with multiple cysts (e), which remained in the suprasellar lesion (f)

Table 3: Improvement rate of the preoperative symptoms in each approach and pathology

Approach	Pathology (n)	No. of cases	Visual deficit		Diplopia		Headache	
			Pre	Imp. (%)	Pre	Imp. (%)	Pre	Imp. (%)
Anterior extended (n=55)	Pituitary adenoma	23	18	17 (94.4)				
	Meningioma	16	11	10 (90.9)	1	0 (0.0)	3	3 (100.0)
	Craniopharyngioma	10	7	7 (10.0)				
	Rathke's cleft cyst	3	1	1 (100.0)			1	1 (100.0)
	Astrocytoma	2	2	0 (0.0)				
	Dermoid cyst	1	1	1 (100.0)				
Clival (n=10)	Chordoma	6			6	6		
	Meningioma	1						
	Ecchordosis physaliphora	1			1	1 (100.0)		
	Fibrous dysplasia	1	1	1 (100.0)				
	Plasmacytoma	1			1	1 (100.0)		
Cavernous (n=9)	Pituitary adenoma	4			1	1 (100.0)		
	Meningioma	2					1	1 (100.0)
	Chordoma	1			1	0 (0.0)		
	Dermoid cyst	1						
	Adenoid cystic carcinoma	1			1	0 (0.0)		
	Total	74	41	37 (90.2)	12	8 (66.7)	5	5 (100.0)

Table 4: Complication rate in each approach and pathology

Approach	Pathology (no. of cases)	No. of patients (%)						
		Vascular injury	Neural injury	Delayed deficit	Systemic	Infection	CSF leakage	Endocr. deficit
Anterior extended (n=55)	Pit. adenoma (23)	1 (4.3)		1 (4.3)			1 (4.3)	3 (13.0)
	Meningioma (16)	1 (6.3)		1 (6.3)		1 (6.3)	2 (12.5)	
	Cranio. (10)		1 (10.0)	1 (10.0)		3 (30.0)	2 (20.0)	10 (100.0)
	Others (6)							3 (50.0)
Clival (n=10)	Chordoma (6)		1 (16.7)				1 (16.7)	
	Others (4)							
Cavernous (n=9)	Pit. adenoma (4)		1 (25.0)		1 (25.0)			1 (25.0)
	Meningioma (2)							
	Others (3)						1 (33.3)	
	Total (74)	2 (2.7)	3 (4.1)	3 (4.1)	1 (1.4)	4 (5.4)	7 (9.5)	17 (23.0)

CSF: Cerebrospinal fluid

Three of the seven cases of CSF leakage developed meningitis. Two cases of craniopharyngioma with sinusitis were complicated by postoperative meningitis. Hormonal replacement was required in 17 patients, including 10 with craniopharyngioma, 3 with Rathke's cleft cysts, and 4 with pituitary adenoma. With regard to vascular injury, avulsion of P1 perforator during resection of the tumor capsule was observed in one case of pituitary adenoma. Although bleeding was coagulated by a bipolar forceps, small infarction was observed in left thalamus and the patient suffered from transient arousal disorder. Anterior cerebral artery injury in the A2 segment occurred in one patient with tuberculom sellae meningioma during tumor dissection from the surrounding vessel. Coagulation and vascular clipping were not performed successfully,

so the patient underwent emergency craniotomy to trap the artery. Although small cerebral infarction was observed in the right frontal base, the patient was able to walk by herself in a week. Contusional injury in the left thalamus was observed in the removal of a suprasellar craniopharyngioma. He suffered from transient memory disturbance. Another contusional injury was observed in the pons in the removal of chondroid chordoma extending to brain stem. She suffered from incomplete paralysis of the left extremities for 3 month. Those injuries were seemed to be due to dissection of the tumor from surrounding tissue. Transient abducens nerve palsy was observed in a case of pituitary adenoma extending to the cavernous sinus due to hemorrhage in the residual tumor. Those three cases were classified in neural injuries.

Intratumoral hematoma in the remnant tumor under the optic nerve was observed in a recurrent pituitary adenoma 1 week after removal, and incomplete recovery of a visual deficit was noted. Two cases of hydrocephalus (one meningioma and one craniopharyngioma) were observed about a month after initial surgeries. Those three cases were counted as delayed deficits. One patient developed a subcutaneous hematoma in the abdomen after fat graft preparation, and this was counted as a systemic complication.

DISCUSSION

Surgical approach and indication

The endoscope provides a bright and spacious surgical field, and the surgeon can easily confirm structural details by increasing magnification. Proponents of this method contend that despite the loss of stereoscopic vision, the field of view is better than that achieved with a microscope because the light source and lens are closer to the lesion.^[23] With recent advancements in optical instruments, surgical indications have expanded beyond sellar lesions to lesions in the anterior skull base, cavernous sinus, or clivus.^[2,3,7,19,20] However, this extended approach presents difficulties during the operation, and it can be unclear, which surgical indications warrant this approach; therefore, surgeons need to become skilled in this approach and be aware of improvements in equipment, as well as of the various diseases that can be successfully treated with ETSS.

The anterior extended transsphenoidal approach expands operative exposure beyond the sellar floor by removal of the tuberculum sellae and planum sphenoidale. This approach can be easily modified from the standard endoscopic approach though both the nostrils as we reported previously.^[31] Divitiis *et al.*^[10] reported surgical outcomes in six cases of tuberculum sellae meningiomas. They achieved five gross total resections, but observed death following intraventricular hemorrhage after postoperative CSF leakage in one case and persistent diabetes insipidus in another case. They emphasized the need to establish reliable methods to prevent CSF leakage. Wang *et al.*^[29] performed a similar operation for tuberculum sellae meningioma in seven cases; they achieved total removal in six cases, and visual function was improved without any complications. They concluded that tuberculum sellae meningiomas measuring <4 cm can be removed safely. More recently, Ogawa *et al.*^[24] reported that they were able to totally resect 78.9% of 19 tuberculum sellae meningiomas with a maximum diameter <30 mm. They concluded that tumors with lateral extension over the ICA are less likely to be total removed. The factors resulting in difficult removal of the tumors in our series were retrochiasmatic extension of pituitary adenomas, hard consistency,

lateral or intraorbital extension of meningiomas, and multi-cystic type of craniopharyngiomas; therefore, it is important to carefully analyze preoperative imaging results. Because this approach is sufficient to achieve the minimum purpose of optic nerve decompression, partial removal of the tumor without excessive resection seems to be an option in some elderly patients. On the basis of our experience, we think that small tumors with clinical symptoms are the best indications for employing this approach.

Perfect resection was not achieved for tumors extending into the cavernous sinus.^[6] Although the approach to the extended lateral lesion in the sphenoid sinus was easily performed by removing the bottom part of the middle turbinate and opening the ethmoid bulla, the factors restricting sufficient removal was tumor consistency and the degree of ICA adhesion. Three of our patients had hard tumors that could not be easily extracted with an ultrasonic aspirator. In order to carefully resect a tumor from the ICA, an extraction limit is decided by intraoperative observation of tumor consistency and its adhesion to the artery. However, some soft chordomas and pituitary adenomas can be exposed and extracted from the ICA, so future developments can be expected with the advancement of technology and availability of instruments that increase the ability to operate lateral lesions.

Clival chordoma seems to be a good indication for the endoscopic transsphenoidal approach. Komotor *et al.*^[22] reviewed the benefits and complication rate of this approach compared with traditional microscopic open surgery. Even in the case of lateral extension, successful resection under the endoscope has been reported.^[27] Although we achieved more than subtotal removal in five of six (83.3%) chordomas, one chondroid chordoma with intraparenchymal extension could not be completely removed. That tumor had a very hard consistency and could not be removed with an ultrasonic aspirator. For such a hard and adherent tumor, another approach should be employed after maximum resection to prevent complications.

Complications

Kassam *et al.*^[21] analyzed the incidence of complication for 800 endoscopic skull base surgeries. They classified their operations into five levels and determined that the incidence of complications was proportional to the degree of the surgery. The incidence rate was significantly higher in levels IV (intradural operation) and V (cerebrovascular surgery), which were 19.7% and 14.9%, respectively. For comparison, the incidence rates for levels II and III were 4.7% and 4.3%, respectively. In our series, 7 surgeries were classified as level III (extradural operation) and these resulted in no complications, whereas the remaining 67 surgeries were level IV, and 20 (29.8%) complications

were noted (excluding hormonal deficit). Although our results were obtained from a small number of surgeries, we observed significant differences between the levels. The most prevalent complications in this series were CSF leakage in seven cases (9.5%), infection in four cases (5.4%), neural injuries in three cases, and vascular injury in two cases (2.7%).

Postoperative CSF leakage was the most common complication; previous reports have described rates of 20 - 30% for craniopharyngioma surgery^[9,15] and of 33% for tuberculum sellae meningioma surgery^[11] using an endoscopic skull base approach. Recently, skull base reconstruction with vascularized nasoseptal flap was reported effective, and the incidence rate of CSF leakage was reduced from 58% to 5.56%.^[17,25] In our experiences, seven cases (9.5%) showed postoperative CSF leakage. Three cases were early in our experience, and we did not apply nasoseptal flaps. The nasoseptal flap was too small in one case, had incomplete contact with the skull base in two cases, and became infected with methicillin-resistant *Staphylococcus aureus* (MRSA) in one case. After preparing for the wide mucosal flap, we have not observed CSF leakage due to incomplete adhesion of the flap except one MRSA infection case. We used sinus balloon to reinforce the contact of mucosal flap in all cases. Indeed sinus balloon may cause incomplete attach to whole flap and result in loosening the pressure at the peripheral part and on the contrary, balloon pressure setting too high may cause flap necrosis. To avoid these disadvantages of the sinus balloon, we filled the gap in sphenoid sinus with fat, then covered mucosal flap with enough amount of fibrin glue and subjected to sufficient pressure to prevent falling the mucosal flap by filling with 5-8 ml of distilled water. By using such a method, we have not experienced flap necrosis nor incomplete attach to the skull base as long as we prepared wide mucosal flap. Because reparation of a wide mucosal flap from the contralateral septum or usage of the fascia in the second operation resolved continuous CSF leakage, preparing a sufficiently wide nasoseptal flap with good blood supply and confirming complete contact of the flap with the skull base are important factors for preventing CSF leakage.

Postoperative infection is a concern for intradural skull base surgery because of large amount of intraoperative CSF leakage. Although the incidence rates of meningitis after resection of pituitary adenomas extending to suprasellar lesions were reported from 0.7% to 1%,^[1,12] traditional skull base surgeries reported higher rates, such as 17.2%^[26] to 30.7%.^[14] For the endoscopic skull base approach for intradural tumors, one group reported that 6.7% of patients developed postoperative infection, and one patient died due to *Escherichia coli* infection.^[21] In our series, four patients (5.4%) developed postoperative meningitis,

including three patients with craniopharyngiomas (two of whom had postoperative CSF leakage). The other two patients had sinusitis without CSF leakage. One developed a postoperative MRSA infection postoperatively with severe tissue damage. A high complication rate of meningitis (10%) was reported for craniopharyngiomas,^[15] and some factors might cause meningitis in patients with these tumors, which are different from meningiomas or pituitary adenomas. To prevent postoperative infection, prediction of MRSA carriers, the existence of sinusitis prior to the surgery, and prevention of intraoperative leakage of cyst content might be important factors.

The incidence of intraoperative neural injury reported was 2.2-33%,^[11] which were low when compared with conventional microscopic skull base surgery.^[21] Three patients (4.1%) of 74 cases suffered transient neural injury in our series. In the cases of craniopharyngioma and chondroid chordoma, contusional injuries occurred in the thalamus during removal of the tumor capsule from the third ventricular floor or in the pons during internal decompression of the tumor by ultrasonic aspiration, respectively. Intracavernous hematoma caused incomplete abducens nerve palsy in the removal of pituitary adenoma extended into cavernous sinus. Upon intratumoral decompression for deep tumors, if it is difficult to determine the depth with the endoscope, then ultrasonic aspirator use should be avoided.

Vascular injury is the most dangerous complications. Although the overall incidence rate is low (1.1-2%),^[13,21] complication rates of 9.1% for anterior skull base lesion^[14] and 10% for craniopharyngiomas by endoscopic surgery^[9] were reported. Our incidence rate of 2.7% (two cases) was similar to previous reports. One case had avulsion of A2 segment of anterior carotid artery during resection of tuberculum sellae meningioma and another had avulsion of P1 perforator during peeling off the capsule of pituitary adenoma extended over the dorsum sellae. What was common to both vascular injuries was an incomplete view of the interface between the tumor and surrounding tissue. Pulling or incision of the tumor prior to complete observation should be avoided.

In this series, there were no instances of ICA injury because we did not perform aggressive extractions for paramedian lesions. Kassam *et al.*^[21] described that it should not be a contraindication for endoscopic skull base surgery because treatment is expected to be necessary for cases with vascular complications. However, we consider that it may be challenging to treat vascular lesion with the endoscopic skull base approach, unless ready the instruments for hemostasis such as clip forceps or bipolar coagulator specially developed for endoscopic skull base surgery and the sufficiently skilled technique of hemostasis.

CONCLUSION

This study summarizes our initial experiences using the endoscopic skull base approach for midline lesions. Although there was obvious learning curve in these procedures, symptom improvement was high, and the complication rate was low; moreover, it seemed to be minimally invasive compared with conventional skull base surgery, especially for anterior skull base and clival lesions. The factors that reduced the successful resection rate in this series were consistency, extension, and adhesion of the tumor. It is important for the operators to expect these factors by preoperative imaging as much as possible and to keep in mind that they may be risk factors, which will be helpful to avoid complications such as CSF leakage, infection, and vascular injury. Ultimately, the surgical approach should be chosen with the ultimate goal of improving patient symptoms and minimizing risk.

REFERENCES

- Cappabianca P, Cavallo LM, Colao A, de Divitiis E. Surgical complications associated with the endoscopic endonasal transsphenoidal approach for pituitary adenomas. *J Neurosurg* 2002;97:293-8.
- Cappabianca P, Cavallo LM, Esposito F, De Divitiis O, Messina A, De Divitiis E. Extended endoscopic endonasal approach to the midline skull base: The evolving role of transsphenoidal surgery. *Adv Tech Stand Neurosurg* 2008;33:151-199.
- Cavallo LM, de Divitiis O, Aydin S, Messina A, Esposito F, Iaconetta G, et al. Extended endoscopic endonasal transsphenoidal approach to the suprasellar area: Anatomic considerations--part I. *Neurosurgery* 2007;61(3 Suppl):24-33.
- Cavallo LM, Messina A, Esposito F, de Divitiis O, Dal Fabbro M, de Divitiis E, et al. Skull base reconstruction in the extended endoscopic transsphenoidal approach for suprasellar lesions. *J Neurosurg* 2007;107:713-20.
- Cavallo LM, Prevedello DM, Solari D, Gardner PA, Esposito F, Snyderman CH, et al. Extended endoscopic endonasal transsphenoidal approach for residual or recurrent craniopharyngiomas. *J Neurosurg* 2009;111:578-89.
- Ceylan S, Koc K, Anik I. Endoscopic endonasal transsphenoidal approach for pituitary adenomas invading the cavernous sinus. *J Neurosurg* 2010;112:99-107.
- Ceylan S, Koc K, Anik I. Extended endoscopic approaches for midline skull-base lesions. *Neurosurg Rev* 2009;32:309-19.
- de Divitiis E, Cappabianca P, Cavallo LM. Endoscopic transsphenoidal approach: Adaptability of the procedure to different sellar lesions. *Neurosurgery* 2002;51:699-705.
- de Divitiis E, Cappabianca P, Cavallo LM, Esposito F, de Divitiis O, Messina A. Extended endoscopic transsphenoidal approach for extrasellar craniopharyngiomas. *Neurosurgery* 2007;61(5 Suppl 2):S219-27.
- de Divitiis E, Cavallo LM, Esposito F, Stella L, Messina A. Extended endoscopic transsphenoidal approach for tuberculum sellae meningiomas. *Neurosurgery* 2007;61(5 Suppl 2):S229-37.
- 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* 2008;62:556-63.
- Dehdashti AR, Ganna A, Karabatsou K, Gentili F. Pure endoscopic endonasal approach for pituitary adenomas: Early surgical results in 200 patients and comparison with previous microsurgical series. *Neurosurgery* 2008;62:1006-15.
- Fatemi N, Dusick JR, de Paiva Neto MA, Kelly DF. The endonasal microscopic approach for pituitary adenomas and other parasellar tumors: A 10-year experience. *Neurosurgery* 2008;63(4 Suppl 2):S244-56.
- Feiz-Erfan I, Han PP, Spetzler RF, Horn EM, Klopfenstein JD, Porter RW, et al. The radical transbasal approach for resection of anterior and midline skull base lesions. *J Neurosurg* 2005;103:485-90.
- Frank G, Pasquini E, Doglietto F, Mazzatenta D, Sciarretta V, Farneti G, et al. The endoscopic extended transsphenoidal approach for craniopharyngiomas. *Neurosurgery* 2006;59(1 Suppl 1):ONS75-83.
- Frank G, Sciarretta V, Calbucci F, Farneti G, Mazzatenta D, Pasquini E. The endoscopic transnasal transsphenoidal approach for the treatment of cranial base chordomas and chondrosarcomas. *Neurosurgery* 2006;59(1 Suppl 1):ONS50-57.
- Gardner PA, Kassam AB, Snyderman CH, Carrau RL, Mintz AH, Grahovac S, et al. Outcomes following endoscopic, expanded endonasal resection of suprasellar craniopharyngiomas: A case series. *J Neurosurg* 2008;109:6-16.
- Holzmann D, Reisch R, Krayenbuhl N, Hug E, Bernays RL. The transnasal transclival approach for clivus chordoma. *Minim Invasive Neurosurg* 2010;53:211-7.
- 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.
- Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: The rostrocaudal axis. Part II. Posterior clinoids to the foramen magnum. *Neurosurg Focus* 2005;19:E4.
- Kassam AB, Prevedello DM, Carrau RL, Snyderman CH, Thomas A, Gardner P, et al. Endoscopic endonasal skull base surgery: Analysis of complications in the authors' initial 800 patients. *J Neurosurg* 2011;114:1544-68.
- Komotar RJ, Starke RM, Raper DM, Anand VK, Schwartz TH. The endoscope-assisted ventral approach compared with open microscope-assisted surgery for clival chordomas. *World Neurosurg* 2011;76:318-27.
- Laufer I, Anand VK, Schwartz TH. Endoscopic, endonasal extended transsphenoidal, transplanum transtuberulum approach for resection of suprasellar lesions. *J Neurosurg* 2007;106:400-6.
- Ogawa Y, Nakagawa A, Takayama K, Tominaga T. Pulsed laser-induced liquid jet for skull base tumor removal with vascular preservation through the transsphenoidal approach: A clinical investigation. *Acta Neurochir (Wien)* 2011;153:823-30.
- Rutka JT. Endonasal resection of craniopharyngiomas. *J Neurosurg* 2008;109:1.
- Sen C, Triana A. Cranial chordomas: Results of radical excision. *Neurosurg Focus* 2001;10:E3.
- Taniguchi M, Kohmura E. Endoscopic endonasal removal of laterally extended clival chordoma using side-viewing scopes. *Acta Neurochir (Wien)* 2012;154:627-32.
- Wang Q, Lan Q, Lu XJ. Extended endoscopic endonasal transsphenoidal approach to the suprasellar region: Anatomic study and clinical considerations. *J Clin Neurosci* 2010;17:342-6.
- 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* 2009;16:889-93.
- Yamamoto T, Yano S, Hide T, Kuratsu J. A case of echordosis physaliphora presenting with an abducens nerve palsy: A rare symptomatic case managed with endoscopic endonasal transsphenoidal surgery. *Surg Neurol Int* 2013;4:13.
- Yano S, Kawano T, Kudo M, Makino K, Nakamura H, Kai Y, et al. Endoscopic endonasal transsphenoidal approach through the bilateral nostrils for pituitary adenomas. *Neurol Med Chir (Tokyo)* 2009;49:1-7.
- Yano S, Tsubaki H, Kudo M, Kai Y, Morioka M, Takeshima H, et al. Sellar repair with resorbable polyglactin acid sheet and fibrin glue in endoscopic endonasal transsphenoidal surgery. *Surg Neurol* 2007;67:59-64.