

Submucosal Inferior Turbinectomy to Widen the Surgical Corridor for Endoscopic Endonasal Skull Base Surgery

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Abstract

The nasal cavity is the exclusive surgical corridor for endoscopic endonasal surgery; however, it is sometimes too narrow to allow extensive surgical maneuvering. Here we show the technique of submucosal inferior turbinectomy (SIT) to widen this surgical corridor. Its effectiveness is evaluated quantitatively by comparing pre- and intraoperative magnetic resonance images. Between March 2015 and October 2018, we performed endoscopic endonasal resection of 57 skull base tumors with 3T intraoperative magnetic resonance imaging (iMRI). Among these resections, cases with previous endonasal surgery and cases for which the iMRI did not cover the entire nasal cavity were excluded. Finally, six cases with and 19 cases without SIT were included in the subsequent retrospective analysis. We measured the dimensions of the narrowest area in inferior nasal cavity on pre- and intraoperative coronal plane gadolinium (Gd)-enhanced T1-weighted MR images using dedicated software, and compared them. The incidence rates of postoperative nasal complaints at outpatient clinics were also compared. Considerable widening of the inferior nasal cavity could be achieved with the SIT, which was statistically significant compared with those without the SIT ($111.1 \pm 56.5\%$ vs. $39.4 \pm 59.4\%$, respectively; $P = 0.0093$). In terms of the incidence rate of postoperative nasal complaints at 6 months, there was no statistical difference between the groups (33.3% vs. 15.8% , respectively; $P = 0.35$). SIT is effective for widening the surgical corridor while keeping nasal function and is especially helpful for lower clivus and laterally extended skull base lesions.

Key words: submucosal inferior turbinectomy, endoscopic endonasal approach, skull base tumors

Introduction

With the development and advancement of surgical techniques, the endoscopic endonasal approach (EEA) has been applied increasingly to the various skull base tumors. The nasal cavity is the exclusive surgical corridor, which is sometimes too narrow to allow extensive surgical maneuvering. To widen this surgical corridor, several methods have been so far introduced, such as superior and middle turbinectomy, posterior ethmoidectomy and posterior septectomy, all of which create changes in the nasal physiological environment.^{1–9)} In this study, we

demonstrate the technique of submucosal inferior turbinectomy (SIT) to widen the surgical corridor while preserving nasal physiological function. Its effectiveness is also evaluated quantitatively by measuring the narrowest area of the inferior nasal cavity in pre- and intraoperative MR images, and comparing the rate of changes between cases with or without SIT.

Materials and Methods

Patient population

Between March 2015 and October 2018, we performed endoscopic endonasal resection of 57 skull base tumors with 3T intraoperative magnetic resonance imaging (iMRI) (Magnetom Skyra; Siemens AG, Munich, Germany). Among these resections, cases with previous EEA and cases for which the

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iMRI did not cover the entire nasal cavity were excluded. Finally, six cases with and 19 cases without SIT were included in the subsequent retrospective analysis of medical records and radiological data. Opt-out methods of consent were used. The study was approved by the local ethics committee of Kobe university hospital (No. 180138).

Patient setup and surgical procedures

After induction of general anesthesia, each patient's head was fixed to a rigid frame. Navigational guidance (Curve; Brainlab AG, Munich, Germany) was performed in all cases. The binostril endoscopic transseptal approach was performed. The surgery was performed by a single surgeon (M.T.). Bayonet-style rigid lens scopes with a 4.0-mm diameter and 0°, 30°, and 70° viewing directions were used. The scopes were attached to a pneumatically driven holding system (EndoArm; Olympus Co., Tokyo, Japan). Nasal manipulations were performed through both nostrils. The septal mucosa in the nares were cut vertically in both sides, and dissected subperiosteally to the vomer bone. The septal bone was fractured and removed. The wide sphenoidotomy was performed to expose the vidian canal and paraclival carotid artery on the side toward which the tumor demonstrated lateral extension. A micro-Doppler probe was used for accurate identification of the carotid artery. The major compartment of the tumor along the midline was removed with regular

surgical instrumentation. For laterally extended tumor compartments, the surgical maneuver was performed under the guidance of a side-viewing endoscope using various instruments with malleable/steerable tips.¹⁰⁾

Submucosal inferior turbinectomy

Submucosal inferior turbinectomy was performed in patients with laterally extended lesions at the middle to lower clivus, in whom gain of space at lower nasal cavity was considered beneficial (Fig. 1A). It was also performed in patient with growth hormone secreting pituitary adenoma with hypertrophy of the turbinates. The mucosa at the anterior pole of the inferior turbinate was incised about 5 mm on the side where widening of the surgical field was considered necessary (Fig. 1B). The bony turbinate was dissected sub-mucously and removed with a rongeur (Fig. 1C). A drill with a 3-mm diameter diamond burr was also used if necessary. To widen the surgical field sufficiently, removal of the pedicle attached to the maxilla was essential. During the procedure, care was taken to preserve the inferior turbinate mucosa as much as possible to maintain nasal physiological environment (Fig. 1D).

Intraoperative MR scanning

After a certain amount of the tumor had been resected, iMRI was performed. The sequences included precontrast axial T1- and T2-images, postcontrast axial,

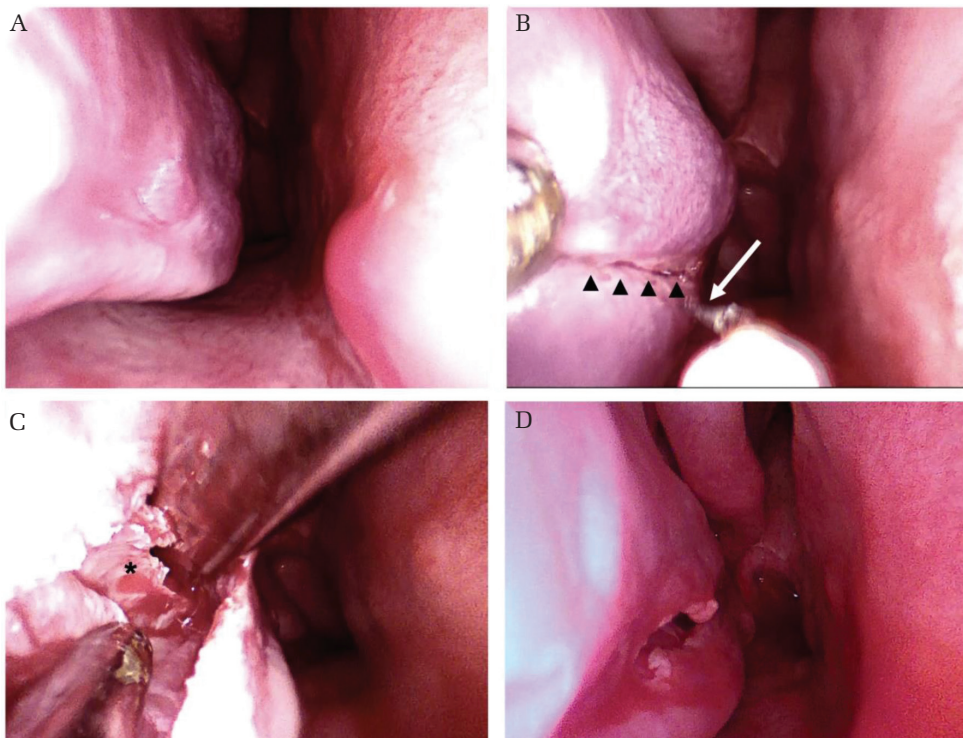


Fig. 1 Submucosal inferior turbinectomy (SIT). (A) In this case, where the intra-nasal surgical corridor was deemed to be insufficient SIT was performed. (B) The mucosa at the anterior pole of the inferior turbinate was incised about 5 mm. *Black arrowheads* indicate the incision line and the *white arrow* indicates the tip of the monopolar coagulator. (C) The bony turbinate (*asterisk*) was dissected submucously and removed. (D) After the SIT, the choana and middle turbinate can be clearly seen, which were obscured before the SIT. During the procedure, care was taken to preserve the inferior turbinate mucosa.

coronal and sagittal T1-images and coronal constructive interference in the steady state images depending on the presenting pattern of the lesion on preoperative MRI. When a residual tumor was identified, it was also resected.

Reconstruction

After tumor removal, the sella was filled with fat tissue harvested from the abdomen,¹¹⁾ the dura was sutured roughly with a 6-0 absorbable suture, and the sellar floor was reconstructed with the bony nasal septum. Reconstruction with the nasoseptal flap was performed in extended cases where a large defect of skull base and a robust outflow of the cerebrospinal fluid (CSF) were encountered. After reconstruction of the sellar floor, septal mucosa that had not been used for skull base reconstruction was replaced in its original position and the nasal turbinate was rectified to its original configuration. Chitin coated gauzes (Beschitin-F, Unitika, Co. Ltd., Aichi, Japan) were placed bilaterally in the common nasal meatus for 2 days to prevent synechia.

Postoperative nasal physiological check-ups at outpatient clinics

The patients' noses were cleaned regularly by an otorhinolaryngologist. Nasal complaints and physiological function, such as nasal obstruction, increased nasal discharge and changes in smell were checked in the neurosurgical outpatient clinic at 1, 3 and 6 months postoperatively.

Quantitative analysis of areal changes of the inferior nasal cavity

We measured the dimensions of the narrowest area of the inferior nasal cavity on pre- and intraoperative coronal plane gadolinium (Gd)-enhanced T1-weighted MR images (slice thickness: 0.5–0.9 mm) using dedicated software (iPlan; Brainlab AG, Munich, Germany). The preoperative MR images were obtained with the 3T MRI (Achieva 3T or Ingenia 3T Philips Medical Systems, Best, The Netherlands). The inferior nasal cavity was defined as the space below the inferior edge of the middle turbinate (red area; Fig. 2A). Both the pre- and intraoperative images were imported into the iPlan and merged. The narrowest part of the inferior nasal cavity was determined by tracing its contour on the preoperative coronal postcontrast T1-weighted MR image (yellow area; Fig. 2B), and its dimensions were calculated automatically. Subsequently, the same area was measured on the intraoperative images and compared with the preoperative images.

Statistical analysis

The χ^2 and Fisher exact tests were used for paired data to test for differences in the distribution between the groups. The Mann–Whitney test was used to compare nonparametric data. All these data were expressed as means \pm standard deviation.

P-values <0.05 were considered statistically significant for comparison between two groups. All analyses were performed using a commercially available statistical software package (Prism 8 v8.1.1; GraphPad Software Inc., San Diego, CA, USA).

Results

Six cases with SIT and 19 cases without SIT were included in this study. There were no differences in the sex, age, pathology, total surgical time, amount of blood loss, tumor removal rate or complication rate between the groups (Table 1). No complications related to SIT were encountered. Locations of tumors in each group is shown in Fig. 3. The location of six tumors resected with SIT were in clivus, petrosal bone and sella turcica (Fig. 3A). All but one of these six tumors demonstrated lateral extension. One case with growth hormone secreting pituitary microadenoma required SIT, because his nasal cavity was narrowed due to hyperplasia of nasal mucosa and bony inferior turbinate. The location of 19 tumors resected without SIT were in orbit, sella turcica, sphenoid wing, posterior clinoid and petro-clivus (Fig. 3B). One case with granuloma located in clivus was treated with partial removal of the midline compartment for biopsy (vi, gray area; Fig. 3B). Among these 19 cases without SIT, there was no case in which the laterally extended tumor compartment was resected.

Comparison of the amount of change at the narrowest area of inferior nasal cavity using preoperative and intraoperative MR images

The summary of the individual areal changes at the narrowest part of the inferior nasal cavity between pre- and intraoperative MR images is shown in Fig. 2C. There was no statistical difference between the mean area at the narrowest part of the inferior nasal cavity of preoperative MR images with SIT ($n = 6$) and without SIT ($n = 19$) (47.3 ± 20.3 mm² vs. 47.9 ± 19.9 mm², respectively; $P = 0.94$). In some cases without SIT, the area at the narrowest part of the inferior nasal cavity was increased on the intraoperative MR image compared with the preoperative MR image. However, there were five cases without SIT in which the area was decreased at the narrowest part of the inferior nasal cavity

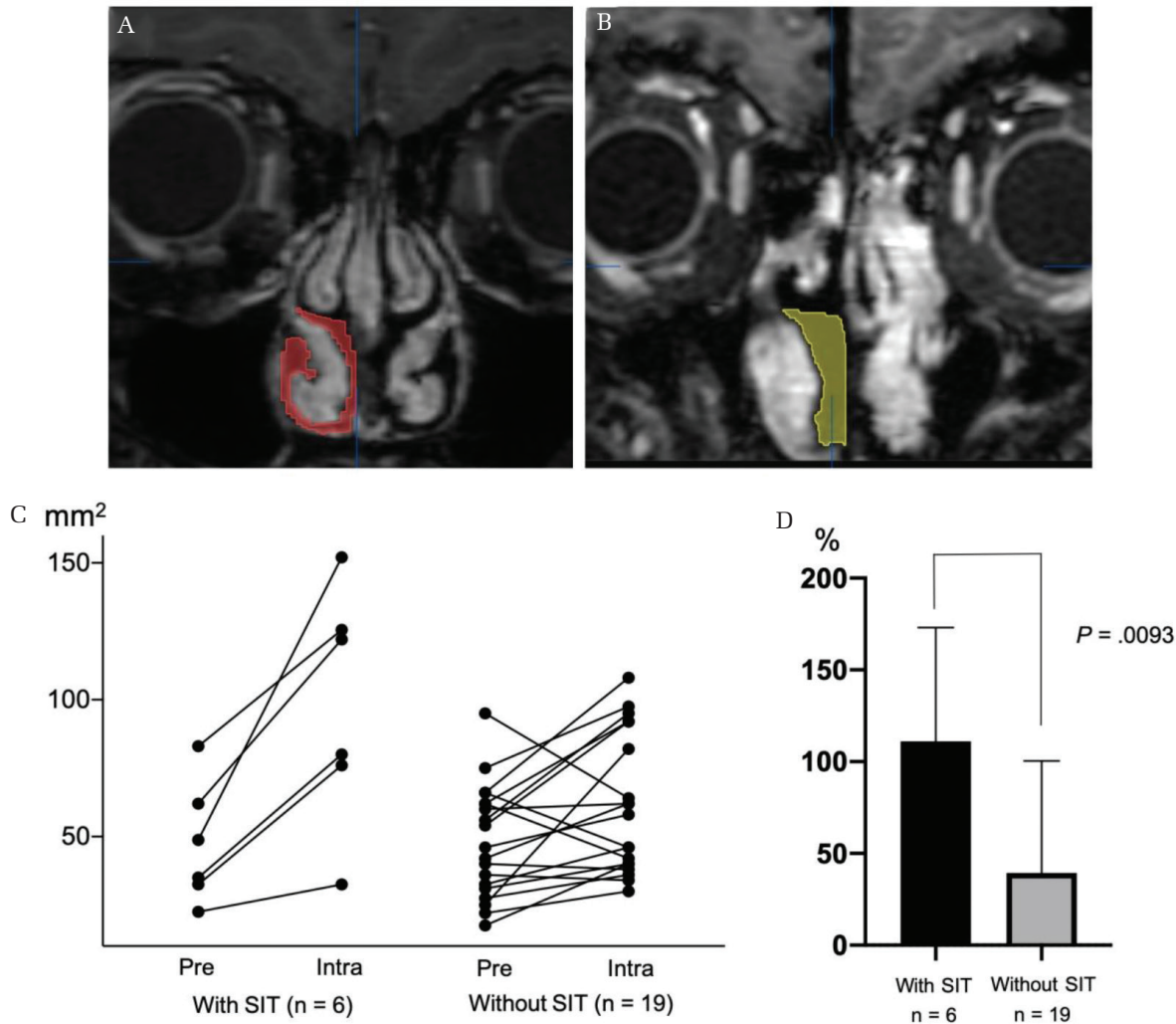


Fig. 2 Dimensions of the narrowest area in inferior nasal cavity on pre- and intraoperative coronal plane MR images, summary of the individual areal changes and mean of the areal changes at the narrowest part of the inferior nasal cavity between pre- and intraoperative MR images. (A) The inferior nasal cavity was defined as the space below the inferior edge of the middle turbinate (*red area*). Both the pre- and intraoperative images were imported into iPlan and merged. (B) The narrowest part of the inferior nasal cavity was determined by tracing its contour on preoperative coronal post-contrast T1-weighted MR image (*yellow area*). (C) Preoperative (Pre) and intraoperative (Intra) areas at the narrowest part of the inferior nasal cavity. (D) Mean of the areal changes at the narrowest part of the inferior nasal cavity between pre- and intraoperative MR images. SIT: submucosal inferior turbinectomy.

on intraoperative MR image compared with the preoperative MR image. On the contrary, all six cases with SIT increased the area at the narrowest part of the inferior nasal cavity on the intraoperative MR image compared with the preoperative MR image.

The mean of the areal changes at the narrowest part of the inferior nasal cavity between pre- and intraoperative MR images are shown in Fig. 2D. Considerable widening of the inferior nasal cavity could be achieved with the SIT, which was statistically significant compared with those without the

SIT ($111.1 \pm 56.5\%$ vs. $39.4 \pm 59.4\%$, respectively; $P = 0.0093$).

Postoperative nasal complaints and physiological function

One patient with SIT suffered from nasal airway dryness and another from changes in smell. Three patients without SIT suffered from nasal obstruction (two patients) and changes in smell (two patients), with one patient complaining of both symptoms. In terms of the incidence rate of postoperative nasal

Table 1 Patients' summary

Group	With SIT, n = 6	Without SIT, n = 19	P-value
Mean age (years old)	41.3 ± 20.7	55.5 ± 9.5	0.24
Gender (Male:Female)	1:1	6:13	0.57
Pathology (cases)			
Pituitary adenoma	1	9	0.51
Craniopharyngioma	1	1	
Meningioma	1	1	
Chordoma	1	2	
Chondrosarcoma	1	0	
Granuloma	1	2	
Rathke's cleft cyst	0	2	
Hemangioma	0	1	
Hypophysitis	0	1	
Mean total surgical time (min)	590.0 ± 186.4	517 ± 129.4	0.35
Mean amount of blood loss (mL)	200.0 ± 197.2	280.5 ± 404.3	0.50
Gross total resected cases	3 (50.0%)	8 (42.1%)	0.73
Postoperative complication cases	2 [†] (33.3%)	2 [‡] (10.5%)	0.18

[†]Cerebrospinal fluid leak, abducens nerve palsy in one patient each. [‡]Abdominal subcutaneous bleeding, visual impairment in one patient each. SIT: submucosal inferior turbinectomy.

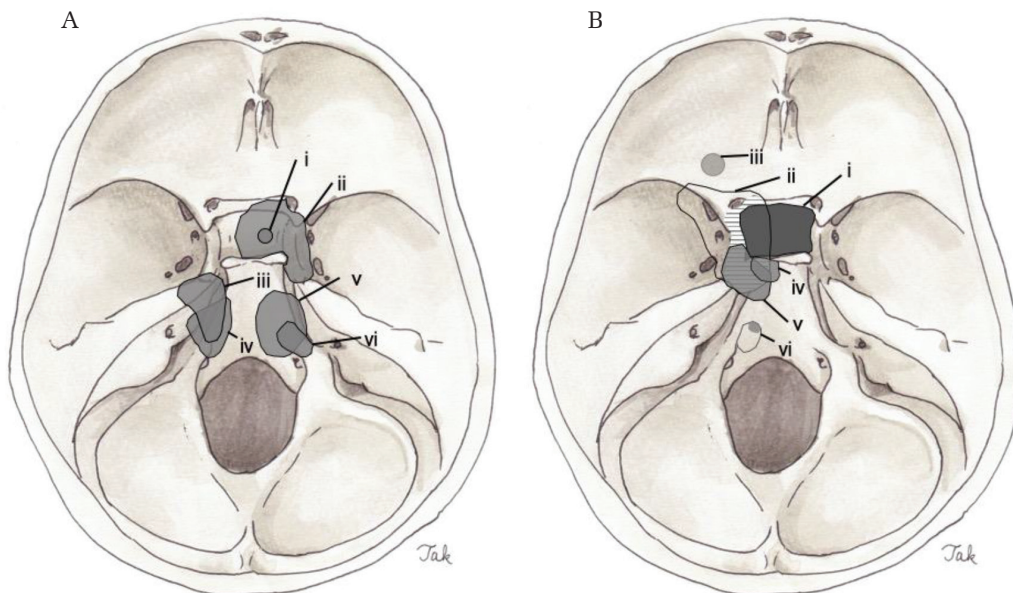


Fig. 3 Schematic drawings of tumor locations. (A) Location of tumors resected with submucosal inferior turbinectomy (SIT). One growth hormone secreting pituitary microadenoma with hyperplasia of nasal mucosa and bony inferior turbinate was located in sella turcica (i). One recurrent craniopharyngioma was extended to cavernous sinus (ii). One chordoma (iii), one recurrent chondrosarcoma (iv), one meningioma (v) and one granuloma (vi) were located in middle to lower clivus with and lateral extension. (B) Location of 19 tumors resected without SIT. Fourteen tumors were located in sella turcica (i). One sphenoid wing meningioma with visual impairment was resected only intrasellar part (ii, *gray borderline area*). One hemangioma was located in orbit (iii). One chordoma was located in posterior clinoid (iv) and the other was in petro-clivus (v). One case with granuloma located in clivus was treated with partial removal of the midline compartment for biopsy (vi, *gray area*).

complaints and changes in physiological function at 6 months, there was no statistical difference between the groups (33.3% vs. 15.8%, respectively; $P = 0.35$).

Case presentation: illustrative case with SIT

A 49-year-old-woman suffered diplopia for 1 year due to right abducens nerve palsy. An outpatient MRI showed a 2-cm extra-axial mass located in right lower clivus that extended to the right Dorello's canal (Figs. 4A and 4B). The patient underwent endoscopic endonasal resection of the tumor. Because her intranasal surgical corridor was too narrow to perform extensive surgical maneuvering, SIT was

performed. Owing to SIT, we were able to achieve laterally extended tumor resection while avoiding interference with the endoscope and surgical instruments (Figs. 4C and 4D). Postoperative MRI showed subtotal resection of the tumor with a small remnant located laterally of the lower cranial nerves (Figs. 4E and 4F).

Discussion

With the evolution of the endoscopic endonasal technique, various midline and para-median skull base lesions are now treated with this technique.

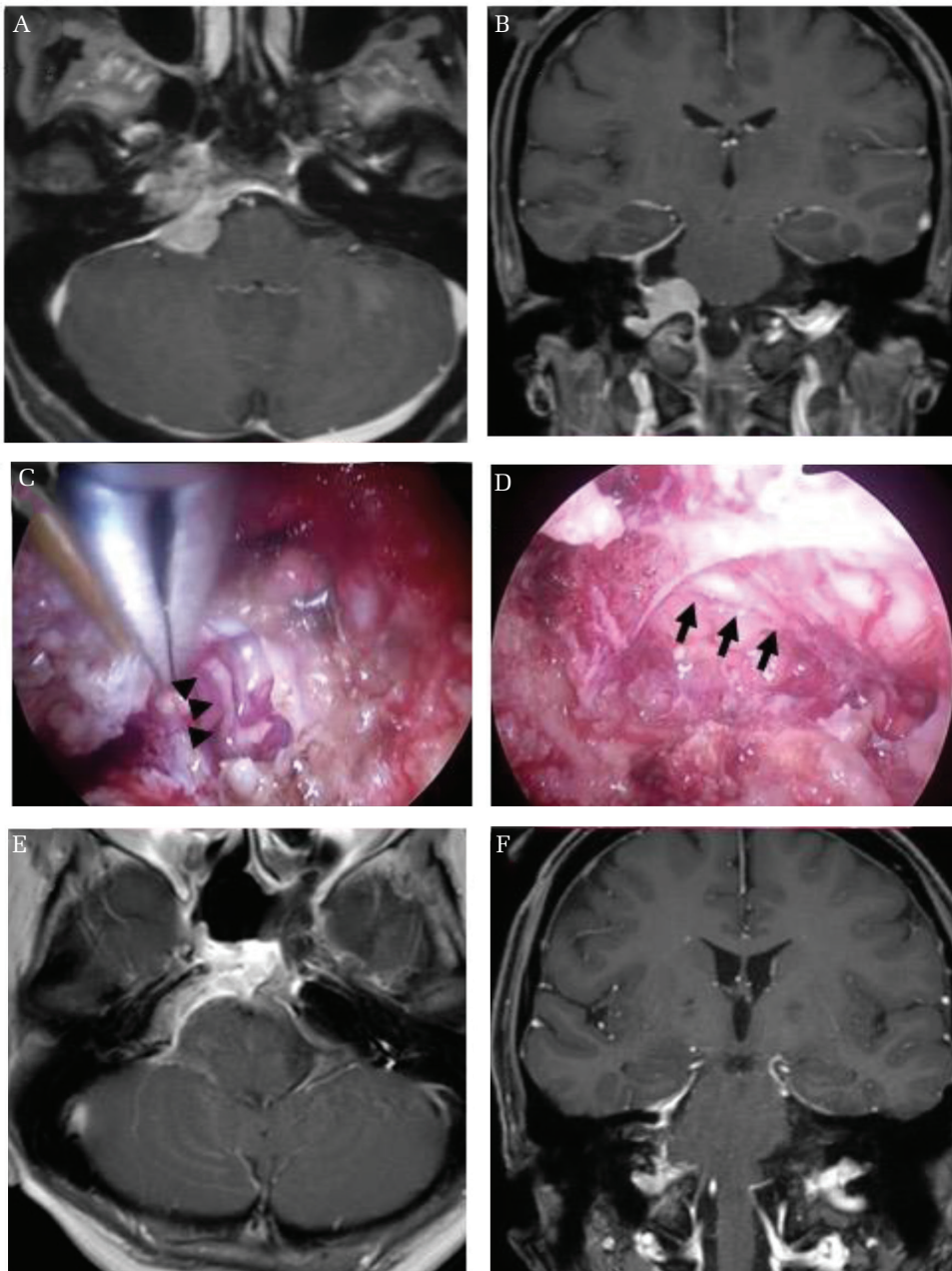


Fig. 4 Illustrative case presentation. A 49-year-old-woman suffered diplopia due to right abducens nerve palsy. (A and B) An outpatient MRI showed a 2-cm extra-axial mass located in the right lower clivus that extended to the right Dorello's canal. Because her intranasal surgical corridor was too narrow, submucosal inferior turbinectomy (SIT) was performed. Using the space provided by SIT, the intradural tumor compartment was removed. (C) After the dural opening, the right abducens nerve, which had been compressed by tumor, was identified (*black arrowheads*). (D) After tumor removal, the right facial nerve was identified (*black arrows*). (E and F) Postoperative MRI showed subtotal resection of tumor with small remnant located laterally of the lower cranial nerves.

Our basic strategy was to approach the site of tumor origin at initial stage of the surgery, and remove the tumor by retracting it back to its origin, thereby preventing the tumor being removed through the narrow space between the vital structures such as the cranial nerves. As such, EEA was used instead of open transcranial approach, though some tumors in the present series exhibited lateral extension.

Several methods for widening the surgical corridor of EEA were introduced by other literatures. Posterior ethmoidectomy with or without superior turbinectomy is effective for approaching midline skull base, optic canal and anterior skull base.^{1,2,5,8)} Middle turbinectomy is commonly recommended for extended EEA including anterior skull base and cavernous sinus.^{3,5,6,8)} Posterior septostomy is effective for EEA to the cranio-cervical junction.^{4,9)} To the best of our knowledge, there are only two reports about inferior turbinectomy to widen the surgical corridor for EEA.^{12,13)} Both reports described EEA to the ventral craniocervical junction without detailed description of the surgical procedure.

We demonstrated our technique of SIT to widen the surgical corridor while preserving nasal physiological function. As the inferior turbinate is the largest, its volume reduction was effective in expanding the transnasal surgical corridor. This was especially true, if laterally extended lesion at the middle to lower clivus had to be approached, compared with the middle turbinectomy, which is more suited for parasellar lesions at upper clivus level. In fact, in the present series, the SIT was mainly indicated for patients with lesions at middle to lower clivus level, and only exception was a case with growth hormone secreting pituitary adenoma, in whom the preoperative nasal cavity was narrow due to the hypertrophy of the turbinates. Although gross total removal was not achieved in half of the cases in the present series, the surgical maneuverability and comfort of the surgeon could be enhanced.

In terms of the incidence of postoperative nasal complaints and changes in physiological functions, there was no statistical difference between the groups with and without SIT. As the SIT is an established surgical procedure for treatment of nasal obstruction, its safety is proven historically.^{14–16)} Given that the inferior turbinate serves a vital role in nasal physiology,¹⁷⁾ preservation of mucosa is important for maintenance of its function and for prevention of empty nose syndrome, atrophic rhinitis or hypoamia/anosmia.¹⁸⁾

We also evaluated the effectiveness of SIT quantitatively by measuring the narrowest area of the inferior nasal cavity in pre- and intraoperative MR images, and compared the amount of change between the cases

with and without SIT. Measurement of the narrowest area of the inferior nasal cavity was performed with the gadolinium (Gd)-enhanced T1-weighted images. As nasal cavity was contaminated with irrigation saline and blood during the surgery making accurate distinction of nasal cavity from other intranasal structures difficult, the pre-contrast axial T1- and T2-images were not suited for this purpose. All six cases with SIT increased the area at the narrowest part of inferior nasal cavity in intraoperative images compared with preoperative MR images. There was a significant difference in the mean of the areal changes between patients with and without SIT. To the best of our knowledge, this is the first study in which the effectiveness of SIT for widening the nostril was evaluated quantitatively. An angled endoscope enables visualization of lesions around corners. However, surgical instruments sometimes cannot reach the corners of the lesions without widening the surgical corridor. A small increase in the entrance of the long surgical corridor with SIT extended the reach of the surgical instruments to the corners of lesions. As such, the SIT becomes helpful, especially for lower clivus and laterally extended skull base lesions, for operating without interference from the endoscope and surgical instruments.

Conclusion

The SIT is effective for widening the surgical corridor when the nasal cavity is insufficient to allow extensive surgical maneuvering. This is especially true for laterally extended lesions at the middle to lower clivus.

Conflicts of Interest Disclosure

The authors declare that they have no conflicts of interest. All the authors have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

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