Neuroendoscopic Transnasal Surgery for Skull Base Tumors: Basic Approaches, Avoidance of Pitfalls, and Recent Innovations

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Abstract

Since the introduction of endoscopic technology in the neurosurgical field, the role of transnasal surgery has been dramatically enlarged. With this technique, we can approach the anterior cranial base, parasellar region, clivus, cavernous sinus, and craniovertebral junction, less invasively than with conventional microsurgery. This review describes the two major approach methods in endoscopic skull base surgery, the endonasal approach and the transseptal approach. The endonasal approach uses two nostrils without nasal specula and the mucosa on the sphenoid rostrum and the posterior margin of the nasal septum are removed. In the transseptal approach, only a single nostril is available, but using the nasal speculum, sufficient surgical field can be obtained with only a small incision on the septum. In either approach method, it is very important to avoid excessive mucosal damage and to select the appropriate approach for each patient. The endoscopic skull base approach is one of the least invasive surgical procedures, which is a very promising therapeutic choice with potential for further advances. For better surgical outcomes and further progress, cooperation with rhinolaryngologists who have much more knowledge and experience about nasal surgery than neurosurgeons is essential. We believe this article will contribute to the development of safe and effective surgical procedures, and to the benefit of the patients suffering from intractable skull base lesions.

Key words: endoscopy, skull base tumor, endonasal approach, transseptal approach, transsphenoidal surgery

Introduction

In the past decade, endoscopic technology has been introduced into the neurosurgical field, and the role of transnasal surgery, which had been applied mainly for pituitary lesions, has been dramatically enlarged. In this approach, the surgical field is visualized from inside the cranium, so the corridor can be smaller than the conventional microsurgical approach, although large enough to pass surgical manipulation devices. The transnasal route allows safe approach to the anterior cranial base, suprasellar region, clivus, cavernous sinus, and craniovertebral junction, without requiring external incisions (Fig. 1). Endoscopic skull base approaches are less invasive and easier to master than the conventional microsurgical skull base approaches, but neurosurgeons using this approach must become familiar with working under endoscopic vision and understand the neurosurgical anatomy in the skull base region and the otolaryngological basics of nasal surgery.

In this article, we present our basic techniques of endoscopic skull base surgery to reduce the steep learning curve of neuroendoscopic skull base surgery, to increase the safety as well as efficacy of this technique.
Surgical Equipments Specific for Endoscopic Surgery

I. Endoscope systems

The essential components of endoscopic skull base surgery are the endoscope, camera with cable, fiberoptic cable, xenon cold light source, monitor, and digital video recording systems. We use the rigid endoscopes of 175–180 mm length (Machida Endoscope Co., Ltd., Tokyo; or Karl Storz Endoscopy Japan, Tokyo). Endoscopes with 4-mm diameter and 0° or 30° lenses are mainly used, and 70° lenses are used for inspection of the lateral regions. Endoscopes with 2.7-mm diameter are used to guide the nasal speculum, inserted between the blades as a “guiding sheath.” A bayonet-shaped endoscope (Olympus Medical System Co., Ltd., Tokyo) is used if navigation system guidance is used to avoid conflict of the endoscopic camera with the recognition part of the navigation probe. Antifog liquid is applied to all endoscopes before use. The three-CCD camera with optical zoom function is essential to provide surgical images with better resolution than the digital zoom camera. Consequently, the monitor must have resolution high enough to support the quality of the camera. A cathode-ray tube-based display or liquid-crystal display with the highest resolution is recommended. The quality of the surgical procedure partly depends on the quality of these equipments, and the quality of the intraoperative images is affected by the single item of equipment with the worst quality. Therefore, the best examples of the each equipment must be chosen and well maintained.

II. Surgical instruments

When we first started using this procedure, few surgical instruments were available for use in the narrow nasal cavity. Therefore, we modified surgical tools for conventional sublabial approaches and designed most of the instruments especially for the endoscopic transnasal procedure (Fujita Medical Instruments, Co., Ltd., Tokyo). For transnasal surgery, surgical equipments are inserted along the long narrow corridor on the same axis as the endoscopic systems. To avoid conflict of the surgeons' hands with the endoscopic cameras outside the patients' nasal cavity, curved or bayonet-shaped surgical equipments are used. Concurrently, to avoid conflict of the instruments with the distal lens inside the deep surgical field, and to allow the instruments to reach suprasellar tumors or tumors invading the cavernous sinus, the tips of the instruments are also designed to be curved in various degrees. The suction tube with irrigating function is one of the essential surgical tools for this procedure. The suction tube can clear the endoscopic lens if clouded by mucus or blood, which saves space in the narrow nasal corridor, comparing to the conventional cleaning-irrigation system mounted on the endoscope, and also surgical time to avoid repeated entrances and exits from the nostril to wipe off the distal lens. Narrow-shaft bipolar cauterizing and various malleable dissecting or curettling devices, specially developed for this procedure, are simultaneously used. The high frequency radiosurgical device with a sharp malleable tip (Surgitron®; Ellman International Inc., Oceanside, New York, USA) is used to cut the nasal mucosa, which allows bloodless incision and earlier postoperative repair of the nasal mucosa. To remove the septal bone or the posterior vomer in a block, a drill system (eMax drill; The Anspach Effort, Palm
Beach Gardens, Florida, USA) with a diamond bar for the long and slightly curved shaft is used.

### III. Patient positioning and preparation for transnasal surgery

The patient is placed in the supine position with the head raised by 5° to 15° and fixed with the Mayfield 3-point head holder, slightly rotated to the operator’s side. The head holder should be fixed above the level of sellar turcica because of the necessity of intraoperative angiography using C-arm fluoroscopy for inadvertent injury of the internal carotid artery (ICA). After both nasal cavities are sterilized with 0.025% benzethonium chloride solution, nasal pledgets soaked with 0.02% epinephrine solution are placed on the nasal mucosa and the patient is covered in sterile drapes. Then, the neuronavigation system is positioned.

### IV. Arrangement of the operating room

The endoscope system and the monitor of the navigation system are positioned at the rostral side of the patient’s head, with the monitor and light source facing the operator (Fig. 2). The nurse is positioned next to the operator at the right side of the patient to facilitate delivery of surgical tools to surgeon’s right hand, and the anesthetist is positioned on contralateral side of the patient to the operator. In general, there are largely 2 methods to stabilize the scope in the operative field, holding with the assistant’s hand or using mechanical holding devices. If the endoscope is held by the assistant’s hand, the endoscopic lens dynamically moves to the ideal position, which makes the surgical procedure easier for the operator. The assistant holding the endoscope must be well accustomed to handling of the endoscope, and usually a co-working rhinolaryngologist acts as navigator of the surgical field. In contrast, if the holding device is used, the image remains clear and stable, and the surgery is closer to the conventional microsurgical procedure. This surgery is usually performed by a single neurosurgeon, so the assistant is not always necessary, but can act as the second operator as necessary. The position of the endoscopic lens must be carefully selected to avoid conflict of surgical equipments and endoscopic lens. We prefer using the robotic holding device (Point Setter; Mitaka Kohki Co., Ltd., Mitaka, Tokyo). The endoscope holder is fixed to the operating table at the anesthetist’s side, and the endoscope is introduced from the direction of 12 o’clock to prevent hampering of bimanual surgery.

### Surgical Procedures

#### I. Endonasal approach and transseptal approach

Endoscopic skull base surgery through the nostril allows 2 major approach methods, the endonasal approach and the transseptal approach.

The endonasal approach uses both nostrils to reach skull base lesions (Fig. 3). The mucosa on the sphenoid rostrum and the posterior margin of the nasal septum are removed, and the sphenoid sinus can be exposed without using the nasal specula. In this approach method, a wide range of ventral skull base regions including the anterior skull base and far lateral regions like the pterygopalatine fossa can be reached. Also, nasal packing is not necessary after the surgery, and the hospitalization is shorter than by the other method. The endonasal approach is very simple, but in patients with congestive nasal mucosa and prominent septal tubercle, the approach route is not always large enough to insert the surgical equipments. Over surgical time, adequate surgical approach routes become more and more difficult to maintain, and damage to the nasal mucosa is gradually anticipated. **18**

The transseptal approach uses only a single nostril. The approach side is determined depending on the tumor localization, diagonally through a contralateral nostril. At the level of the anterior end of the middle nasal concha, the mucosa on the nasal septum of unilateral side is perpendicularly cauterized in a linear fashion using a high frequency radiosurgical device, and the mucosa is separated from the septum and the anterior aspects of the

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sphenoid bone. The septal bone is removed and the nasal mucosa contralateral to the approach side is dissected in the submucosal layer from the anterior aspects of the sphenoid bone. The nasal speculum for transnasal surgery is inserted beneath the bilateral mucosa of the nasal septum, and the posterior vomer is drilled and removed to the maximum extent. In this approach, the mucosa on the sphenoid rostrum can be preserved with a small incision on the septum. The disadvantage of this method is that the size of the entrance on the approach route depends on the size of the nostril. In Asian women and small children, the size of the nostril is sometimes not large enough to approach from a single nostril and may restrict the surgical performance.

II. Approach to sellar and clival lesions

Insertion of a 0° endoscope along the middle nasal meatus allows observation of the bilateral inferior, middle, and superior nasal conchae. The middle nasal conchae are dislocated laterally and, if necessary, the posterior ethmoidal air cells are collapsed with a blunt dissector. The sphenoid rostrum is removed en bloc and the opening of the sphenoid sinus is enlarged with a drill. The sella is identified and the clival indentation is revealed below. The prominences of the ICA are observed at the lateral margins of the sellar floor, and the eminence of the optic canal can be observed on the rostral aspects of the sphenoid sinus using a 30° endoscope (Fig. 1D). Then, the mucosa overlying the sellar floor is carefully cauterized with bipolar coagulation and removed in the area between the carotid prominences. The middle part of the sellar floor is removed with a drill, and the dura mater is sufficiently dissected from the sellar floor bone with a dissector. The opening of the sellar floor is extended with Kerrison punches, disclosing the dura mater of the sella. ICA injury during transsphenoidal surgery is reported to most frequently occur during dural incision of the sella floor. The inner margin of the cavernous sinus and location of the ICA must be confirmed using the navigation system together with the micro-Doppler probe before dural incision. The clivus is observed just beneath the sella turcica and between the

Fig. 3 Appearance of nostrils during surgery and schematic drawings of the two major approach methods, the endonasal approach (A, C) and the transseptal approach (B, D). In the endonasal approach, we can use two nostrils without nasal specula (A, C) and the mucosa on the sphenoid rostrum and the posterior margin of the nasal septum are removed (C). In the transseptal approach, only the single nostril is available (B), but using the nasal speculum, we can retain sufficient surgical field with only a small incision on the septum (D).

Fig. 4 A, B: Axial (A) and coronal (B) T₁-weighted magnetic resonance (MR) images with contrast medium showing a clival chordoma. C: The tumor was approached through the transsphenoidal routes (sphenoid rostrum). D, E: After entering the sphenoid sinus, the tumor was exposed (D) and completely removed, and normal anatomy of the clivus (cl), pituitary dura mater (pd), and internal carotid artery (ICA) was observed under the 0° scope (E). F: The lower clivus was observed with the 30° scope. G, H: The tumor was completely removed but recurred at the petrous apex in the left side (G, arrow), which was successfully removed at the second surgery (H: surgical view of the left petrous apex under the 30° scope). I: Postoperative axial MR image.
ICA eminences (Fig. 1D, E). Opening of the sphenoïd rostrum will expose clival tumors under the mucosa in the sphenoïd sinus. Chordoma is one of most common clival tumors, which often proliferates in various directions with osteolytic changes of the surrounding bones.\(^7,17\) Even if the tumor invades into the upper clivus, lower clivus, petrous apex, and jugular bulb, these regions can be accessed under direct vision using a 30° endoscope (Fig. 4).

### III. Approach to the craniovertebral junction

Insertion of a 0° rigid endoscope along the space between the middle and inferior nasal meatus allows observation of the upper pharynx between the tori tubarius through the choana (Fig. 1G, H). Removal of the posterior part of the vomer and the lower part of the sphenoid bone can gain more working space, which facilitates the approach to this deep area (Fig. 1I). To reach the lower clivus or the craniovertebral junction, the pharyngeal mucosa and the prevertebral muscle must be removed. Since these structures are important to prevent nasal regurgitation of liquids from the mouth, this function is transiently impaired after this approach, but will fully recover after a few weeks due to compensation by other palatal muscles in all patients. In any approach to the lateral lesions, care must be taken not to injure the eustachian tubes, damage to which can cause exudative otitis media and hearing deterioration. Furthermore, the ICA sometimes runs closely behind the eustachian tube and at the lateral margin on the prevertebral muscles (Fig. 5).

### IV. Reconstruction of the sellar floor and nasal mucosa

Gelfoam is placed in the cavity after tumor removal, and the preserved bone of the sphenoid rostrum is inserted to close the sellar floor. If cerebrospinal fluid (CSF) leakage occurs from any small laceration of the diaphragma sellae, the adipose tissue is harvested and attached to the tear of the diaphragm with fibrin glue. In the transnasal approach, the reconstructed sellar floor is finally covered with nasal mucosa, and nasal pledges are placed for 1 to 3 days in the approach side of the nose. If the defect of the diaphragma sellae is relatively large and continuous flow of the CSF is observed, the adipose tissue and the abdominal fascia are harvested and are placed to cover the sellar floor in two layers, inside and outside the sellar floor, and fixed with fibrin glue. If the third ventricle or the prepontine cistern is approached with removal of the arachnoid membrane, very active and strong pulsatile CSF flow can be expected, so pedicled nasoseptal flap or suture of the inlay fascia lata to the dural margin has to be considered.\(^12\)

### Discussion

Here, we presented our experience of endoscopic approach for skull base lesions. Two major approach methods for endoscopic skull base surgery are widely used at present, the endonasal approach and the transseptal approach. Each approach has pros and cons, so neither can be recommended as superior. The most important attitude is to understand the differences and select the appropriate approach in each patient. In fact, any difference is very subtle for most pituitary lesions and midline clival lesions, so the approach is selected depending on the proficiency of the surgeons. When the neuroendoscopic skull base surgery is developed based on the rhinolaryngological techniques, the surgeons...
tend to prefer the endonasal approach. In contrast, when it is developed from conventional sublabial transsphenoidal surgery, they tend to prefer the transnasal approach. In either approach method, the surgical procedure with bimanual handling of the surgical equipment is essential, and performance of “fine transsphenoidal surgery” under endoscopic vision involves a steep learning curve at the beginning, requiring certain experience to get used to manipulation of endoscopes and surgical procedures under video monitoring.

In our hospital, we started endoscopic transnasal pituitary surgery in 1998 and, during the early period, the endoscope was mainly used to assist in the microsurgical transseptal approach. With the nasal speculum, we can swiftly switch between the endoscopic procedure and the microsurgical procedure and vice versa, helping to smoothly shift from microsurgery to only endoscopic surgery. Therefore, our method is based on the surgical techniques of the microscopic sublabial transsphenoidal approach and we are used to the transseptal approach. However, when we approach the superficial anterior cranial base, periorbital regions, and far lateral regions such as the pterygopalatine fossa or subtemporal areas, the nasal speculum may hamper the approach routes without certain benefits, and the direct endonasal approach is selected.

The endoscopic skull base approach is a relatively new method, which means that standard surgical procedure based on the long-term outcomes has not yet been established. In other words, endoscopic skull base surgery is still one of the developing fields in neurosurgery, and the indication is rapidly enlarging. In recent years, along with the increased incidence of complex skull base lesions, we developed the binositr transseptal approach, which is now under evaluation for efficacy and safety. We believe that development of such new techniques and also new technologies for the surgical tools and the quality of the endoscope will improve the surgical outcomes with lesser invasiveness for the patients. From this point of view, cooperation with the rhinolaryngologists is essential. The rhinolaryngologists have much more knowledge and experience of nasal surgery than neurosurgeons, and they have much to teach about the physiological function of the nasal cavity and the paranasal sinus, and management to optimize preservation of the structures and functions. The chief function of the nasal cavity and the mucosa is to warm and moisten the inspired air, so optimal distribution over the nasal turbinates with intimate contact of the air to the moist mucosal surface is essential.8) Thus, any new transnasal approach must reduce the patients’ discomfort after surgery and to avoid excessive mucosal damages and preserve the nasal conchas as far as possible.3,8,15)

In conclusion, we emphasize that the endoscopic skull base approach is one of the least invasive surgical procedures, and represents a very promising therapeutic choice with great potential for further advances. This approach is less invasive than the conventional skull base approaches, but the associated complications can be quite serious. Thus, surgeons have to be aware of the potential risks and take adequate countermeasures. We believe this article will contribute to pursuit of safe and effective surgical procedures of endoscopic skull base procedures and finally to the benefits of the patients suffering with intractable skull base lesions.

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