Transcranial Combined Neurorhinological Approach to the Paranasal Sinuses for Anterior Skull Base Malignancies

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ABSTRACT

Objective: Various transcranial and transfacial approaches have been described and each claims to provide the best exposure to the anterior skull base. Similarly, each approach claims the best outcomes following the resection of anterior skull base malignancies. We have always advocated a combined neurorhinological approach for the management of paranasal sinus malignancies that infiltrate the skull base, such as esthesioneuroblastomas. **Materials and methods:** At the outset, the technique was developed on cadaver specimens, imitating the limitations that might be imposed in the real-life situation when undertaking endoscopic sinus surgery. Additional exposure of the anterior cerebral fossa was achieved using a classical bifrontal approach. Starting with endoscopic or microscopic unroofing of the ethmoids, all relevant landmarks were identified. The frontal, sphenoid, and maxillary sinuses were then opened using endoscopic techniques. **Results:** The dissections proved that a broad exposure of the anterior skull base could be combined with clear endoscopic visualization of the nasal cavity and of all the paranasal sinuses from above. This facilitated complete eradication of lesions from the sinuses cavities, their walls, and the intracranial tumor. **Discussion:** The combined neurorhinological transcranial approach to the anterior skull base and nasal and paranasal sinuses, avoiding trans-facial approaches, enables a multidisciplinary team to resect malignant tumors of the anterior skull base directly without unnecessary destruction of facial structures. It appears to provide better access than other more destructive methods like midfacial degloving or subfrontal approaches. Our single-stage approach also facilitates safe and effective reconstruction of the skull base. The technique can be employed for tumors of all sizes and is also used for orbital resections and decompression of the optic nerve and chiasma.

KEYWORDS: Transcranial, paranasal sinus, skull base, rhinosurgery

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The successful complete surgical ablation of malignant tumors from the anterior skull base, mostly of paranasal origin, has become one of the significant oncologic achievements of the recent past. Several new techniques have been proposed as alternatives to the classic craniotomy approach. These were reviewed in 2004 by Har-El.¹ These are largely combinations of transcranial exposures with transnasal/transfacial access,¹⁻⁷ or strictly transfacial approaches with no retraction of the frontal lobes.⁸⁻¹⁴ Also, endoscopic sinus surgery has been integrated into these combined neurorhinosurgical procedures.¹⁵⁻¹⁷ However, it is apparent that endoscopy in this context has only been used to control the efficacy of the transcranial tumor ablation. When strictly transnasal endoscopic approaches to the anterior skull base have been described,^{18,19} its limitations for the resection of suprabasal structures have been stressed.

In contrast, we have developed a systematic endoscopic tumor debulking and radical removal from the sub-basal compartment via a transcranial exposure of the skull base. Two previous publications in 1992 and 1995 in which a combined neurorhinosurgical approach was employed lacked a detailed description.^{20,21} Its particular advantage was and continues to be total avoidance of any transfacial access route, thus preserving both the facial skin and skeleton. Our clinical results with this approach are contained in a comprehensive retrospective analysis of the outcome of 26 patients with olfactory neuroblastomas treated between 1975 and 2000 at the University of Erlangen-Nuernberg.²² To clarify the principles of this method, its description is illustrated in this article using photographic documentation of the surgical and endoscopic steps on a cadaver specimen. It must be stressed that the transbasal endoscopic exposure of the nasal and paranasal compartments was used not only as a visual control for the transbasal resections, but also to facilitate endoscopic removal of tumor and to secure a safe margin.

MATERIALS AND METHODS

Surgical Technique

For demonstration of the microendoscopic procedure, several formalin- or alcohol-fixed cadaver heads were acquired from the Institute of Anatomy. Another fresh specimen that had been frozen was also used. The dissection was performed in a step-wise fashion as would be employed in live surgery.

First, a typical endonasal-endoscopic pansinus operation was undertaken which included total ethmoidectomy, with exposure of the frontal, maxillary, and sphenoid cavities. Then, the specimen was fixed in a semireclined position, imitating the neurosurgical setting.

STEP 1 EXPOSURE OF THE ANTERIOR CEREBRAL FOSSA

A bitemporal coronal skin incision was made (Fig. 1A), following which the scalp was elevated forward to the superior orbital ridges and the nasal root. The exit of the supraorbital nerves (Fig. 1B) was identified. The underlying galeal-periosteum flap was raised. This was more difficult in a fixed cadaver than on vital textures. It is important to develop an intact, anteriorly pedicled flap for use in later reconstruction of the skull base. A classic frontoparietal bone flap is then raised using sharp cutting burrs or a Gigli saw. The internal periosteal dural layer should be preserved to act as a cover for the frontal lobes, which are now gently lifted and retracted backward. Tributaries to the sagittal sinus, dural attachments to the crista galli, and the olfactory bulbs must be transected to expose the olfactory groove (Fig. 2).

At this point, the anterior skull base becomes very thin and translucent as a result of underlying ethmoid air cells. A tract of cells, ~5 to 10 mm in breadth, can be identified between the posterior wall of the frontal sinus anteriorly and the harder bone of the sphenoid plate posteriorly. In most cases, the frontal sinus cavity will automatically be opened by the craniotomy. Particular attention must be paid to the identification of the upper insertion of the nasal septum, as it is an important

Figure 1 Transcranial exposure of the anterior skull base in a specimen. (A) The bicoronal skin incision. (B) Decollement of the frontal skull. The galea-periosteal flap is retracted anteriorly to the nasal root and exits the supraorbital nerves. (C) Exposure of the anterior cerebral lobes in their dura mater envelope after excision of a frontoparietal bone flap, particularly great for training reasons.

landmark. Its sagittal position does not always correspond to the cranial midline, and it must not be confused with the bases of the middle and upper turbinates. The anterior and posterior ethmoid arteries can be identified now or left until later. The olfactory grooves on both sides of the midline are clearly visualized with residual elements of the olfactory nerves. The lateral borders of the translucent ethmoid mark the medial border of the orbital roof. The olfactory groove, the orbitoethmoidal border, and the rostral margin of the hard sphenoidal bone, the sphenothmoidal border, are important landmarks for transbasal paranasal surgery.

STEP 2 EXPOSURE OF THE NASAL AND ETHMOIDAL CAVITIES FROM ABOVE

After the anatomical midline has been defined by identification of the superior insertion of the nasal septum, flanked on both sides by the upper edges of

the sagittal ground lamellae of the middle and upper turbinates, the ethmoids are opened from above with sharp forceps and punches over their entire length (Fig. 2C). Likewise the roof of the nasal cavity is incised and resected, that is the cleft between the ground lamellae and the nasal septum. The middle and upper turbinates are isolated and fixed only by their rostral and dorsal insertions. Exenteration of the ethmoids and development of safe margins can best be executed under microscopic control. However, precise inspection of the inferior compartments of the nasal cavity and ethmoids is better undertaken with direct or angled endoscopes.

STEP 3 INSPECTION OF THE FRONTAL SINUS FROM BEHIND

If the frontal sinus was not opened during the craniotomy, it is simple to open it at this stage by perforating the posterior wall of the sinus at the

Figure 2 Anterior skull base. (A) The rhinobasis between the frontal bone (anteriorly) and sphenoid (posteriorly) with the olfactory bulbs (o.b.) in position. (B) The olfactory grooves after removal of the olfactory bulbs and resection of the crista galli. Midline: Upper insertion of the nasal septum (s). Lateral of the grooves: upper insertion of the middle and upper turbinates (t). Lateral of these crest the translucent roofs of the ethmoids. (C) Exposure of the exenterated right ethmoid from above between the turbinates (t) (medial) and orbital wall (o) (lateral).

rostral end of the ethmoids. Further extension can be made according to individual needs. As a training exercise, one may follow the infundibulum down to the nasofrontal duct and agger nasi cells. In neurosurgical procedures the resection of the posterior frontal sinus wall with removal of the mucosa is

Figure 3 Anterior segment of the anterior cerebral fossa after removal of the calvarian block. After resection of their dorsal walls both frontal sinuses can be inspected down to the infundibula (arrows).

routine; this is called “cranialization” of the frontal sinus (Fig. 3).

STEP 4 CONTROL OF THE MAXILLARY SINUS FROM ABOVE

While the medial wall of the maxillary cavity can be inspected from above using a microscope, its lateral compartments and the prelacrimal recess require the use of rigid, angled endoscopes at 25 and 90 degrees (Fig. 4). By this means, all parts of the operative cavity can be inspected. The endoscope can be introduced obliquely to facilitate the use of other instruments or drills for bone removal. It is also useful for a transeptal inspection of the contralateral side in case of a unilateral craniotomy.

STEP 5 EXPOSURE OF THE SPHENOID CAVITY AND BIFURCATION

Transcranial endoscopy of the sphenoid sinus from above is the most delicate maneuver in live surgery

Figure 4 Endoscopic exposure of the right maxillary sinus from above. (A) The medial wall with a large supraorbital nasooantroscopy (*). (B) Lateral view to the zymatic recess (z.r.) through a 70-degree optic. The channel of the infraorbital nerve (i.n.) entering the anterior wall can be identified.

as it is necessary to minimize retraction of the frontal lobes. A rigid endoscope with at least a 70-degree angulation is mandatory for inspection of the posterior and upper walls of the sphenoid sinus (Fig. 5). Parallel introduction of curved forceps is comparatively easy. When removing the roof of the posterior ethmoid and the planum sphenoidale, care must be taken not to destroy too much of the anterior wall of the sella turcica, otherwise the pituitary gland may be compromised. *In those cases*

with considerable lateral extension of the sphenoid cavity, endoscopic inspection and manipulation may become difficult.

STEP 6 CLOSURE OF THE SURGICAL FIELD

After completing the dissection of the anterior skull base from above together with the nasal and paranasal cavities (Fig. 6), an exploration of the orbit and optic chiasma may be added for exercise. The management of these compartments, however, is

Figure 5 Endoscopic exposure of both sphenoid sinuses from above. (A) A vertical penetration behind the right (r) ethmoid led into the left (l) cavity. Asymmetric development with dextroposition of the intersphenoidal septum (*). (B) Endoscopic inspection of the left sphenoid cavity via a 70°-degree angled optic looking backward to the dorsal wall. With this inverse visualization the convexity of the sella turcica (s.t.) lies at the bottom.

Figure 6 Comprehensive exposure of the central portion of the anterior skull base after exenteration of the nasal and paranasal cavities and resection of the middle and upper turbinates. The midline is marked by the rudiment of the nasal septum (s) after a two-third resection of its upper segments. On both sides the posterior ends of the inferior turbinates (c.i.) are visible. Bottom: The broadly exposed recesses of the sphenoidal cavities (s.c.). Anteriorly: The remnant block of the frontal bone (*).

not the subject of this article. The surgical field is then closed as *in vivo* by retrograde placement of the anteriorly pedicled periosteal flap into the sphenoid (Fig. 7). Here it is fixed to the bone by sutures and/or fibrin glue. This interposed tissue must be intact to form a watertight seal. If not stable enough, it can be reinforced by interposition of a free fascia lata, cartilage, or bone grafts. The frontal bone flap is then replaced.

RESULTS

Five patients with esthesioneuroblastomas of the Kadish stages B and C underwent surgery between 1975 and 2000 by the technique described above. The resections were planned as one-stage procedures aiming to achieve a safe resection with minimal sacrifice of healthy structures. The preceding description of a dissection on cadaver specimens makes the feasibility and flexibility of this technique quite obvious. Three patients were alive without disease after follow-up intervals of 18, 13, and 194 months after surgery²². In the other two cases an initial rhinosurgical ablation was followed by a secondary neurosurgical intervention with adjuvant radiotherapy. Both had died of the disease after 8 and 27 months respectively, the first patient after surgery plus radiotherapy, the second after surgical monotherapy.

DISCUSSION

There is consensus in the literature that the therapeutic method of choice for the management of nasal and paranasal malignancies that involve the anterior skull base is radical surgery followed by adjuvant radiotherapy.^{18,23–26} A large number of techniques have been described. These range from purely rhinological approaches in which transnasal

Figure 7 Closure of the skull base defect. (A) The defect after transcranial sinus surgery from above. (B) The galeoperiosteal flap (*) extended between bone and dura mater.

endomicroscopic ablations, including resections of the skull base, are undertaken from below, to transfacial exposures of the anterior skull base via subfrontal or transglabellar approaches or by midfacial degloving in combination with various neurosurgical transcranial approaches (reviewed in 2004 by Har-El¹).

Since the majority of craniobasal carcinomas and esthesioneuroblastomas have their origin in the nasal cavity and paranasal sinuses, primary neurosurgical ablation has to be followed by a meticulous removal of the sub-basal compartments, that is, the paranasal sinuses and nasal cavity. Similarly, incomplete rhinological surgery requires subsequent neurosurgical revision of the suprabasal structures, the meninges, and the frontal lobes. It would seem prudent to combine both approaches in a simultaneous one-stage procedure if the preoperative imaging suggests infra and suprabasal tumor growth. With the intention of minimizing destruction of unaffected areas in the approach to the lesion, and to preserve healthy facial and nasal structures, the development of an endoscopic technique appeared to be a logical step. In comparison to the midfacial degloving techniques or subfrontal resections, this combined neuro-rhinological approach respects all uninvolved maxillofacial structures to a much higher degree and provides a one-stage procedure. We have demonstrated by analysis of our long-term results²² that the method has proved valuable in clinical practice.

Some details of the dissection deserve a few comments. Working on formalin-fixed heads is difficult because the tissues are unnaturally hardened. Fresh specimens are definitely more useful for training purposes. A unilateral transcranial approach, as practiced in neurosurgery, may be attempted on cadavers but is less realistic than real life. Most also require a juxta-midline exposure of the olfactory groove. The introduction of rigid endoscopes and instruments into the contralateral sinuses is difficult and may endanger the overlying blood vessels. The bifrontoparietal craniotomy is, therefore, more often practiced.

Trainees should be particularly careful and continuously check the degree of frontal lobe retraction while working on the sphenoid compartments. They should learn to orient themselves using anatomical landmarks and take care to avoid damaging arteries and the optic nerves. It is profitable to extend these topographic studies into the middle cranial fossa and the orbit. In addition, trainees should practice operating with grasping instruments through an inverted visual field, using 70-degree angled endoscopes from unfamiliar directions.

CONCLUSIONS

This article describes and illustrates a one-stage neuro-rhinological combined approach to the anterior skull base and nasal and paranasal cavities. It can be recommended for the surgical treatment of several nasal and paranasal neoplasms that invade the suprabasal space, and also of other neoplasias above the frontal skull base. It has the advantage of preservation of uninvolved facial and nasal structures while allowing broad exposure of the anterior skull base between the frontal sinus, sphenoid cavity, and paranasal sinuses from above. Its disadvantage lies in the obligatory transection of the olfactory fibers on the affected side, which is irrelevant for esthesioneuroblastomas and most of the suprabasal malignancies. This technique was successfully applied in several patients, among whom were five patients with esthesioneuroblastomas of the skull base that have been followed for periods that ranged from 18 to 194 months. The procedure, described and illustrated in this cadaver study, requires an intimate knowledge of the related topographical anatomy and skillful practice of endoscopic surgery.

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