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Recent Advances

Extended applications of endoscopic sinus surgery and its reference to cranial base and pituitary fossa

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Abstract Sinus surgery has the potential of allowing ENT surgeons to encroach the boundaries of our colleagues in ophthalmology and neurosurgery. The advent of nasal endoscope and lately powered instrumentation and computer-assisted navigational systems has avoided the use of the conventional and more radical approaches by the ENT surgeon for the treatment of inflammatory pathology or tumors of the orbit and skull base. As rhinologists have gained more experience in endoscopic surgery, more areas related to the orbit and the anterior skull base are accessible and surgery is safer.

Keywords Endoscopic sinus surgery · Extended applications cranial base · Pituitary fossa · Powered instrumentation

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Introduction

In the past 20 years, there has been significant transformation from external headlight sinus surgery to endoscopic sinus surgery (ESS). This surgery was pioneered by Messenklinger, who has shown that the sinuses had a predetermined mucociliary clearance pattern towards the natural ostium irrespective of additional openings into sinuses. This philosophy of opening the natural ostium of the diseased sinus was then popularized by Stammberger and Kennedy. ESS is now accepted as the surgical management of choice for chronic sinusitis. In addition, as our knowledge of the anatomy of the sinuses has improved, other anciliary surgeries such as endoscopic lacrimal surgery, orbital decompression, approaches from the sphenoid/sella extending to the cribriform, parasellar and clival region have developed. Further development in instrumentation has led to the acceptance of endoscopic management of benign endonasal tumors and more recently, literature data on endoscopic management of malignant tumors of the nose and sinuses. This significant and rapid development of new surgical techniques in ESS could not have occurred without significant instrument development.

The current interest in ESS stems from several developments. The first is the advent of compact, multiangled telescopes that allow excellent visualization of the nasal cavity for examination and of the sinuses during procedures, including such areas as the maxillary ostia and the frontal recess. Secondly, is the acceptance and appreciation of the great work of Messerklinger (1967) demonstrating that the anterior ethmoids are usually the key to persistent sinusitis. Thirdly, is the advent in radiological imaging. Endoscopic diagnostic examinations in conjunction with modern imaging methods, particularly CT scan, have proven to be an ideal combination in recent years and have been accepted as the "Standard of Care" for sinus disease in many parts of the world. The CT scan has shown clearly what the plain sinus X-rays could not, that is the anterior ethmoids are usually diseased when the condition would appear to be only maxillary and frontal sinus involvement. These developments make it possible to diagnose more accurately and treat sinusitis refractory to non-invasive therapy.

The technique of ESS was developed in Europe by Messerklinger and Wigand, who had two different goals. They are designed for different extremes of disease and there is considerable blurring of distinctions for intermediate disease. The Messerklinger technique (1985) is an anterior to posterior approach which involves only the anterior ethmoids and the maxillary sinus ostium. This technique can be extended into the posterior ethmoids, sphenoid and the frontal sinus anteriorly if necessary. Thus, the Messerklinger technique is ideal for patient with anterior ethmoid disease with or without maxillary or frontal sinus disease. On the other hand, the Wigand approach (1978) is posterior-to-anterior and routinely involves all the sinuses on the ipsilateral side. Thus, the technique used should fit the disease. The Wigand technique is ideal for patient with pan-sinusitis who has or is apt to fail the more limited Messerklinger approach.

Both techniques are based on the assumption that the sinus mucosa is most likely reversibly diseased and will return to normal once ventilation has been established. No attempt is made to eradicate the sinus mucous membrane, as in the Caldwell-Luc procedure, but rather to re-establish drainage so the mucosa can return to normal and restore its proper function.

The World Congress for Endoscopic Surgery of the Brain, Skull Base and Spine in October 2005 in Pittsburgh, pioneered new frontiers and challenges to the budding rhinolaryngologist and neurosurgeons of the future. As a joint team effort, this extended applications beyond the sphenoid sinus/sella needs a lot of surgical skills, planning and coordination for proper patient selection and optimal care. The incidence of tumor recurrence will be very much reduced with this minimally invasive ventral skull base technique. The use of powered instruments with navigational fusion imaging is most beneficial especially in revision cases.

A significant development for soft-tissue removal was the development of "through-cutting" instrumentation. Powered instrumentation using soft tissue shavers offer another significant advancement to the endoscopic sinus surgeon. These devices may seem recent to most otolaryngologists, but a similar device based on similar principles was used for arthroscopy by the orthopedic surgeons in the 1970s. In 1994, Setliff and Parsons were the first to report the use of soft-tissue shavers in ESS [1]. Powered instrumentation has become more useful for "non-functional application" to the orbit and skull base to reduce morbidity and hospital stay, whilst achieving comparable results to conventional techniques. ESS with its minimally invasive technique often reduces pain, bleeding and length of hospital stay and avoids external incision and thus reduces surgical cost compared to conventional techniques. Endoscopic surgery cannot replace every conventional external approach and we should never be embarrassed to employ or convert to these conventional approaches when necessary. However, not all cases are suitable for an endoscopic approach and the surgeon must be experienced in the full range of surgical options, the pathophysiology and natural history of disease processes, if optimum results are to be achieved. This is particularly true in the controversial area of sinonasal neoplasia. The various extended ESS techniques performed preferably under general anesthesia are detailed below.

Choanal atresia surgery

Choanal atresia is secondary to the unilateral or bilateral persistance of the buccopharyngeal membrane. It can be membranous or bony. It is essential to define how thick the bony stenosis is and study the anatomy of neighboring structures such as the carotid artery.

A newborn infant relies on its nasal airway. It is particularly compromised during suckling. Bilateral choanal atresia is an emergency condition. Rapid assessment and correction are needed to provide a nasal airway, and an oropharyngeal airway needs to be restored immediately. Bilateral choanal atresia is often associated with other congenital abnormalities (the CHARGE syndrome) that need to be investigated. Initially, an attempt to pass a fine nasogastric tube into the nasopharynx should be made to help confirm the diagnosis. An axial CT scan should be performed, but only after decongesting the mucosa and sucking any mucus. A unilateral atresia often presents later in the early teens when the patient realizes that they cannot breathe through one side. They can also present with a unilateral mucoid discharge.

Unilateral nasal obstruction in adolescents and young adults may go undetected and only becomes apparent on careful nasal endoscopy and axial CT scan. Obligate nasal respiration in the neonate rapidly uncovers bilateral choanal atresia. The atretic area is usually a combination of fibrous tissue and bone. Powered instrumentation has demonstrated utility in choanal atresia repair [2]. The presence of suction at the drill site seems to clear debris away more quickly and has allowed improved visualization at this small operative site. Randall, Kang and Mohs [3] report favorable results from the application of a 3.5 mm mini-arthroscopic drill system via a transnasal endoscopic approach in three cases of choanal atresia. Even the small nostrils of neonates were able to accommodate the mini-arthroscopic drill and the 0 degree, 2.7 mm endoscope. Both the atretic plate and a portion of the posterior nasal septum should be removed using an endoscopic drill with cutting burrs and/or strong bone punches [4]. Stenting should be avoided if possible.

Pituitary surgery

Pituitary tumors occur in 9 in 100,000 people and comprise 10% of intracranial tumors. The commonest pituitary tumors in patients under 35 years secrete prolactin and adrenocorticotropin, whereas after 35–50 years they generally secrete growth hormone. After 50s onwards, non-secreting tumors are more common. Symptoms can be caused by pressure on the anterior pituitary and hypopituitarism, or by an extrasellar growth that can produce headaches, pressure on the optic chiasm or brain.

The degree of pneumatization of the sphenoid sinus varies and influences how prominent structures are in its lateral wall. Pneumatization can extend to the clivus, the lesser wing and the root of the pterygoid process. Agenesis of the sphenoid sinus occurs in 0.7% of patients.

The concept of transsphenoidal pituitary surgery is well established as a joint rhinosurgical procedure by the otolaryngologist and neurosurgeon [5]. Several modifications of this approach to the sphenoid sinus were subsequently described [6]. The sublabial, transseptal, transsphenoidal approach was favored over other approaches because it was midline approach and was safer and provided equal access to both sides of the sphenoid sinus and sella. Pituitary surgery has been routinely performed with endoscopic endonasal approach at our referral center since 1990 [7].

Surgery for pituitary disease must be based on an assessment of the patient by a multidisciplinary team. The medical management of many pituitary tumors has reduced the frequency of the need for surgery in many patients. Medical management is rarely of use in tumors that extend into the suprasellar region and extend above the diaphragm sellae. Hour-glass tumors cannot readily be dealt with using an inferior approach alone unless only partial debulking of the tumor and/or biopsy is required.

Since most pituitary tumors are in the midline, a transseptal sphenoidotomy (TSS) provides direct access to the sella [8]. The approach is fairly straightforward, utilizing only a hemitransfixation incision or transcolumellar approach. A speculum may be inserted to provide wide exposure to the anterior face of the sphenoid sinus. If exposure to the sella tursica is necessary, the sinus mucosa, intersinus septum and posterior sinus wall are resected to expose the pituitary tumor. This technique is minimally invasive and obviates the need for sublabial incision combined with a transfixation incision, which might result in dental injury or numbness of the lips. In addition to the excellent illumination, magnification and a panoramic view of operative field, angled endoscopes provide the opportunity to examine the sella for any residual tumor. The surgery has been particularly successful for microadenomas. This minimally invasive technique has resulted in decreased morbidity and shorter hospital stay for patients, reducing the overall cost of the surgery.

Whatever approach is used to the sphenoid sinus and pituitary fossa, the endoscope gives excellent visibility within the sphenoid sinus and with a 45 degree endoscope, it is possible to see more detail within the pituitary fossa than with the microscope. The advantages of the transnasal, transseptal or lower buccal approach is that it avoids an external scar and by removing the posterior part of the septum, vomer and anterior wall of the sphenoid, this approach allows wide access. In the transnasal approach, mucosal preservation is an added advantage. All these techniques, allow the two nostrils and four hand technique advocated by Prof. Stammberger. This is valuable in the occasional case when there is moderate or severe bleeding as this situation is then controlled more readily. It is difficult to deal with bleeding if the only access has been endoscopically through a unilateral sphenoidotomy, even if two experienced endoscopists are working together with one holding the endoscope to allow the other surgeon the use of both hands. An external ethmoidectomy approach produces a scar and has the potential to cause stenosis of the frontal recess.

The vomer consistently joins the sphenoid in the midline and this is a very reliable landmark. The sphenoid intersinus septum is often asymmetric (more than 75%) and the preoperative CT scans should be reviewed before operating. The degree of pneumatization of the sphenoid also varies a great deal [9]. The natural sphenoid ostium is relatively high in the posterior wall of the sphenoid and is often placed at the level of the superior turbinate. It may be readily visible after gentle lateralization of the middle turbinate. The bony anterior wall of the sphenoid sinus is often thin or deficient 1–1.5 cm above the posterior choana. The lateral wall of the sphenoid sinus has indentations from various structures. In its upper third, the optic nerve can indent its surface and can be dehiscence in 8% cases. The carotid artery bulges into its lower lateral wall and it can be dehiscent in up to 30% of the patients. The vidian nerve can bulge into its floor.

A transnasal sphenoidotomy (TNS) starts by widening the sphenoid opening on the side of the tumor or when it is in the midline opening, the side where the sinus is larger. The sphenotic ostia is endoscopically visualized in the sphenoethmoidal recess and entered inferomedially. The sphenoidotomy is opened up to the level of the skull base using a sphenoid punch. Suction diathermy will be needed to stop bleeding from the posterior branch of the sphenopalatine artery when extending to the sphenoidotomy inferiorly. After carefully examining the CT scan and endoscopically inspecting the sphenoid sinus to check on the proximity of the lateral structures, the lateral aspect of its anterior wall can be removed if necessary. A Kerrison antrum punch is preferably used as its small diameter means that the bone can be removed in small pieces with good visibility. If more space is needed across the midline, the vomer can be fractured across or it can be incised 1 cm in front of the sphenoid and removed. As the vomer joins the sphenoid, it can be very thick but it rarely needs drilling. The pituitary often bulges into the roof of the sphenoid and the bone may be very thin. If the bone is thick, a coarse diamond burr should be used to thin it. A diathermy point is useful to open the dura by making a cross-shaped incision through it. A 45 degrees endoscope gives excellent visibility and helps to avoid going through the diaphragm sellae. A Hajek punch helps to remove the bone over the pituitary.

In the transethmoid sphenoidotomy (TES) initially, a maxillary antrostomy and total ethmoidectomy are performed [10]. The anterior wall of the sphenoid sinus is then visualized. The sphenoid sinus is safely entered through the inferomedial triangle thus avoiding the optic nerve and carotid artery in the superolateral region of the sinus.

The transmaxillary sphenoidotomy (TMS) is the most lateral endoscopic approach. A large maxillary antrostomy is created through the posterior fontanelle and the medial aspect of the posterior maxillary sinus wall is removed exposing the pterygopalatine fossa. The SPA is identified, ligated and divided. Dissection through the remaining soft tissue exposes the lateral pterygoid plate and sphenoid sinus wall, which are removed with an oval burr. This approach can also be utilized to remove benign tumors limited to the infratemporal fossa.

The tumor is often grey in color but occasionally it can be vascular and ooze moderately. The pituitary fossa can be closed at the end of the procedure with septal bone placed in the bony defect. If there is a cerebrospinal fluid (CSF) leak, fascia and fat may also be needed to stop it.

The other alternative surgical techniques are transbuccal-septal-sphenoid, external transethmoidectomy and craniotomy approach.

Transbuccal-septal-sphenoid approach

This approach involves no external scar but is directed toward the roof of the sphenoid and gives good visibility of the pituitary. It is a longer distance or tunnel to work through than other approaches. Much of the nasal septum is removed to allow access but it is vital to preserve the anterior 0.5 cm from where the septum is attached to the spine to avoid loss of tip support. It is advisable to electively remove the necessary segment of the intact cartilage so that it can be readily be inserted at the end of the procedure to minimize the risk of a perforation as septal tears often occur during the procedure.

External transethmoidectomy approach

The disadvantage of this approach is that there is an external scar and there is a possibility of producing stenosis of the frontal recess. This approach allows the microscope to be used and the sphenoid can be opened in a plane directly along the axis wall of the sphenoid.

Craniotomy

This approach is for lesions with significant suprasellar extension.

Dacrocystorhinostomy

Dacrocystorhinostomy (DCR) is a procedure performed to drain the lacrimal sac in instances of nasolacrimal-duct obstruction. Traditionally, ophthalmologists perform this procedure using an external incision. Recently, there has been renewed interest in intranasal DCR due to the advent of endoscopic instrumentation for sinus surgery. Endoscopes provide the surgeon with excellent intranasal visualization and access to the lacrimal sac. One of the most important aspect of this surgery is to make sure that the primary pathology is due to the distal obstruction of the nasolacrimal system. If there is proximal obstruction, then surgery will fail. Distal nasolacrimal obstruction can also occur secondary to ESS if back-bitters used to remove the uncinate process are used too far forward. A dacryocystogram is indicated if there is any mass within the sac. Scintigraphy helps to define a functional problem.

An endonasal approach has been advocated to overcome obstruction of the distal nasolacrimal system [11]. Endoscopic DCR allows drainage of an obstructed lacrimal sac without the need for skin incision. The exact position of the sac can be readily determined by a fiberoptic light fiber passed through one of the canaliculi. The medial wall of the canal is removed by a Hajek rongeur, drill or laser [12]. It is essential to expose the fornix of the nasolacrimal sac to have maximum exposure prior to incising the sac. It is important to note the relationship of the agger nasi cell and frontal recess to the nasolacrimal sac. The use of stents may not be necessary when marsupialization of the sac is wide. In experience hands, the success rate of endoscopic DCR is comparable to the conventional external approach. A contraindication to DCR is the presence of a benign or malignant tumor in the lacrimal system or the surrounding tissues and active Wegener granulomatosis.

Repair of CSF leak

The bone tightly adheres to the dura at the anterior skull base and therefore it is at a greater risk of developing a fistula. The risk of meningitis, which may develop even after a leak appears to close spontaneously, may be as high as 10%. The overall risk of meningitis in untreated cases of CSF leak is up to 25%.

The thinnest area of the skull base is adjacent to where the anterior ethmoidal artery enters the anterior skull base at the lateral lamella of the cribriform plate. The next most common area where CSF leak occurs is where the middle third of the middle turbinate starts to attach more laterally from the skull base to the lateral nasal wall. It is here that it can inadvertently be grasped, twisted or pulled and a defect created. The skull base tends to angle inferiorly as the surgeon works posteriorly and the height of the posterior ethmoid sinuses varies. One need to have a good reason to be in the posterior ethmoid sinuses especially when there is severe polyposis with or without purulent disease. Before starting any surgery, it is worth flexing the head on the neck as this will place the skull base in a more vertical plane. This is particularly worthwhile as, following intubation, the patient is often positioned on the operating table with the head extended, making it more likely that the surgeon will enter the skull base if one goes straight backward.

Clear fluid may be seen emanating from a skull base defect. It looks like a clear stream in a pool of blood and it often pulsates. The edges of the bony defect should be defined. Numerous graft materials have been used, ranging from a “bath plug” fat graft for small leaks [13] to a free turbinate or chonchal cartilage graft for larger defects [14]. It is preferable to place the graft above the defect so that it underlays the defect. This is then overlaid by the free mucosal graft from the inferior turbinate. A lumbar drain may not be necessary. The graft is supported by gelfoam to avoid it sticking to the nasal pack. Both preoperative and postoperative prophylactic antibiotics are given for 10 days. The patient is nursed 30 degrees or more head-up and asked not to strain. Patients are discharged home after about 3 days.

The commonest site of a spontaneous CSF leak is the area of the cribriform plate where dura around the olfactory nerves appears to have extended through the cribriform plate and ruptured. The next most common leak is from a very well pneumatized sphenoid sinus. A high pressure system may be a contributing factor in these cases and a shunt or ventriculostomy may be required.

Post-traumatic CSF leaks commonly originate from the cribriform plate, the fovea ethmoidalis and the posterior wall of the frontal sinus or sphenoid sinus. Leaks of the anterior and middle cranial fossa occurring after neurosurgical procedures most commonly follow pituitary surgery. Postneurosurgical leaks also come from the posterior wall of the frontal sinus when it has not been cranialized and more likely if a pericranial flap has not been used to repair any dural defect.

It is vital to localize the site of the leak [14]. It is essential to consider whether there is an underlying high-pressure system. Successful closure depends on defining the exact site of any defect. The site of any defect should be defined using high-resolution coronal CT. If CT fails to define the site of the defect, T2-weighted MRI may help [15]. This has superseded CT cisternography. In a small proportion of patients, the site of the leak is uncertain. Under these circumstances, a diagnostic or preoperative fluorescein lumbar puncture will help define the source of the leak. It is vital to ensure that there is a free flow of CSF before proceeding to inject any fluorescein. This minimizes the chance of entering the surrounding space and causing arachnoiditis. It is important to aspirate 10 ml of CSF and dilute the fluorescein with it before the fluid is slowly re-injected. Only 1 ml of 5% sodium fluorescein specifically for intrathecal use should be diluted with CSF before it is re-injected. The ideal time for fluorescein to be injected is 1 hour beforehand. Preferably, the patient is placed in a 10 degrees head-down position. The fluid will appear bright yellow, unless a blue filter is used when it appears fluorescent green.

A variety of intracranial, extracranial and transnasal approaches have been utilized for surgical repair of CSF fistulas. Recently, endoscopes have been used to repair CSF leaks in the anterior skull base [13, 16]. Endoscopes permit precise localization of the area of dehiscence and enable direct repair with minimal morbidity. The use of intrathecal sodium fluorescein may be helpful in localizing a small dehiscence that may not be demonstrated by CT or magnetic resonance imaging (MRI) [13, 16, 17]. The etiology of CSF leak could be spontaneous from the cribriform plate or from a sphenoid meningocele, iatrogenic or traumatic. In general, autologous materials are preferable to artificial materials. There is no risk of infectious transmission or rejection. Bone grafts are not necessary unless there is a large bony defect. The precise positioning of the graft material over the defect is more important. The author’s preference is a free mucosal graft from the middle turbinate or the “bath plug technique” held in place with gelfoam and fibrin glue [17]. The postoperative use of lumbar drains are only indicated in profuse leaks of long-standing to decompress the system whilst the arachnoid granulations recover their ability to reabsorb CSF. The endoscopic technique is not recommended for leaks associated with high-pressure conditions, brain injury, frontal sinus leaks, CSF leaks with large bony defects or sphenoid leaks in which there is extensive sphenoid pneumatization.

Repair of orbital blow-out fractures

Compression of the orbital contents leads to fracture along lines of weakness resulting in the classical blow-out of the floor in the region of the infraorbital nerve through which the orbital fat extrudes and becomes trapped. Often in association with a blow-out of the floor, the laminae papyracea may fracture increasing enophthalmos. As in orbital decompression there are technical limits to assessing the lateral orbital floor endoscopically, but to improve enophthalmos the medial orbital wall may be readily repositioned via an endoscopic approach through ethmoid labyrinth. This can be combined with one of a variety of external approaches where appropriate.

Orbital decompression

Removing one or more of the bony walls that make up its surrounding can decompress the contents of the orbit. The largest potential amount of decompression is obtained by removing the medial wall of the orbit, next its floor and then its lateral wall.

The primary indication for this procedure is dysthyroid eye disease, either for cosmetic reasons or when vision is deteriorating and steroids and radiotherapy have not controlled this. In experienced hands, it is possible to obtain better access to the orbital apex and even to decompress the optic nerve endoscopically [18]. Hypertrophy of the extraocular muscles and orbital fat in thyroid eye disease is one of the commonest causes of proptosis. Surgical decompression may be required to relieve compression of the optic nerve at the orbital apex, exposure keratopathy and occasionally sublaxation of the globe in severe cases. An endonasal endoscopic approach allows precise removal of the entire medial orbital wall with ease as far posteriorly as the ethmosphenoidal junction together with the medial portion of the floor of the orbit [19]. Adequate removal of the floor of the orbit can only be achieved through a very large middle meatal antrostomy.

Optic nerve decompression

Optic nerve decompression is an extension of orbital decompression when the optic nerve in the lateral wall of the sphenoid is decompressed. The indications for this are limited. All too often, damage to the optic nerve is recognized days after the trauma that caused it. Under these circumstances, it may be inappropriate for the patient to undergo surgery, particularly if they have a Glasgow coma scale score of <8 [20]. If there is a skull base fracture included in the sphenoid and there is evidence of an afferent defect, then further investigations, including visual evoked potentials [21] or usually a swinging light test [21], should be done. If these are abnormal, then the question remains when it is appropriate to decompress the optic nerve. Literature review suggests that with retro-orbital hemorrhage, decompression of the orbit needs to be done in <1 hour [21]. However, where there is no hemorrhage, it is less clear under what circumstances it is beneficial to decompress the nerve pathway.

High-dose steroids are the primary treatment of choice in traumatic optic neuropathy [22]. However, if the optic nerve function is deteriorating in spite of these, it would seem reasonable to intervene [23]. If there is an anatomical constriction on CT scans affecting the course of the optic nerve and the patient is fit for anesthesia, then it seems reasonable to remove the bone pressing on the nerve.

Optic nerve decompression is probably best performed endoscopically using drills [24]. In cases where traumatic visual loss secondary to blunt trauma does not improve with high dose steroids, the bone may be removed from the optic canal with a diamond burr under excellent visualization of 180 degrees or more.

The endoscopic approach obviously avoids a facial scar, carries a much smaller risk to the nasolacrimal system and infraorbital nerve. It is important that patients clearly appreciate the potential complications, particularly the inevitable postoperative diplopia which in selected cases may require muscle surgery. This should not be undertaken until at least 3 months have elapsed.

Tumors of the anterior and ventral skull base

The management of tumors of the skull base should be done as part of a multidisciplinary team and the surgeon should be able to change to an external approach if necessary and know how to deal with the majority of possible complications. The following principles apply to the planning of endoscopic procedures at the skull base:

- An understanding of the pathology of any lesion at the skull base is important in its management
- Peers from other relevant disciplines should be involved in making a treatment plan
- An extended range of equipment should be available to do this type of surgery
- Imaging should be performed to define the extent of any tumor and angiography with or without embolization may be necessary
- Preoperative counseling is essential.

We are not advocating that the majority of the lesions in and around the skull base should be resected endonasally, but we believe that the endoscope can provide improved access and visibility in specific circumstances without compromising tumor resection. Examples of endoscopic tumor resections are:

- Encephaloceles
- Benign tumors
  - Inverted papilloma
  - Osteoma
  - Mucoceles
  - Hemangioma

Angiofibroma
Schwannoma
Chordoma
Chondroma
Pleomorhic adenoma
- Malignant tumors
  Olfactory neuroblastoma
  Plasmacytoma
- Malignant melanoma

Encephaloceles

An encephalocele is a herniation of a part of the intracranial contents through a defect in the skull base. Basal encephaloces can be classified on the basis of their location into: transethmoidal, transsphenoidal, frontosphenoidal or rarely basiocciptal-nasophryngeal. Encephaloceles may be congenital in origin. Acquired encephaloceles may be post-traumatic or follow neurosurgery or sinonasal surgery.

Inverted papilloma

The aggressive and recurrent nature of inverted papilloma is well known and there is approximately 10% risk of development of malignant transformation. Traditional surgical management involves lateral rhinotomy and ipsilateral medial maxillectomy.

It is important to exclude any coexistant malignancy or atypia present at diagnosis as these occur in 8–15% of cases on presentation and these justify an enbloc resection with possible radiotherapy, depe nding on the histology and degree of invasion. It is important that all macroscopically diseased tissue is examined in order to avoid malignancy being missed. A review of the literature shows that while malignant transformation does occur, it is very unusual [25]. Perhaps a reduction in tumor antigen load in these patients after surgery may help eradicate any residual disease. Smaller lesions may not only be more readily excised but may represent better host immunity.

Recurrence rates are often quoted as being over 30% and this of course represents residual disease. The most difficult areas of excision are the frontal sinus, the anterior wall of the maxilla and the nasolacrimal system. According to the literature report, there was no incidence of recurrence when endoscopy was clear for 3 years and 90% who are disease free after a mean of 10 years following endoscopic medial maxillectomy [26].

More recently, endoscopic removal of inverted papillomas have become the treatment of choice in situations in which the lesion is small and can be easily removed with a margin of normal tissue. With skull base involvement in the area of the ethmoid or sphenoid sinuses, the endoscopic approach allows the tumor to be resected as completely as any approach except the more massive craniofacial operation which most surgeons feel is not required for this benign lesion. The medial wall of the maxillary sinus can be removed by retrograde uncinectomy using back-bitting forceps to create an opening that extends inferiorly to the floor of the nose, anteriorly to the nasolacrimal duct and posteriorly to the pterygoid plate. Attachment of the tumor within the frontal sinus is a contraindication of the endoscopic approach. A retrospective evaluation revealed that 17% of patients treated endoscopically experienced recurrence while 19% who were treated extranasally experienced recurrence [27]. In the author's experience however, the endoscopically managed tumors tended to be smaller.

Osteoma

Earwacker (1993) reported a 3% incidence of people having paranasal sinus osteomas. Majority of osteomas are found incidentally and are blamed for causing headaches and excision is recommended before they cause symptoms [28]. Osteomas rarely cause any problems other than cosmetic. If they cause symptoms by obstructing the frontal recess, the history should include symptoms that are worse after respiratory tract infections and there should be endoscopic and CT scan signs of mucosal disease.

The removal of osteomas depends on how accessible they are. The endoscope can be used to shell out the osteoma and then its walls can be removed or fractured inwards. As the most symptomatic ones are in the frontal recess, it is important to reconstruct the mucosal lining with a septal flap or a free mucosal graft or to combine their removal with a median drainage procedure.

Mucoceles

Mucocele is a chronic, expansive, benign cystic lesion limited by the mucosa of the paranasal sinus, with thick, translucent mucous secretions. Although considered a benign lesion, the expansive character of the mucoceles promotes slow erosion of the adjacent bone via compression and consequent bone absorption. It is believed that this disease is secondary to obstruction to sinus drainage, leading to stagnation of the secretion within the cavity. The predisposing factors can be fractures, mucosal edema, polyps, tumors, surgical trauma and chronic sinusitis. Mucoceles are classified according to the sinus of origin. The frontal sinus is the most common site, followed by the ethmoid, maxillary and sphenoid sinuses.

Fronto-ethmoidal sphenoidal and the rare maxillary sinus mucoceles are ideal cases for endoscopic approach provided wide marsupilization can be achieved [29]. Mucoceles accessible with the endoscope should be opened as widely as possible using through cutting forceps in order to minimize the amount of scar tissue that forms around the edges and which might lead to recurrence. Coronal CT scan is helpful to show whether the lesion can be approached via the nasal cavity and whether the lesion is uni or multilocular. Abnormally thick bone as in Paget's disease, fibrous dysplasia and those mucoceles secondary to malignancy may not be suitable for an endoscopic approach [30]. In the frontal sinus, a small mucocele may be drained via the endoscopic approach but mucoceles with lateral extension may be difficult to access via the nose. In this cases, an external and endoscopic approach can be usefully combined, preserving lateral support of the frontal recess and avoiding a stent.

The majority of mucoceles can be marsupialized endoscopically with minimal morbidity and with long-term results that are as good as if not better than, those done by the conventional external approach. The wider the mucocele is marsupilized, the better the result. Once a frontal and/or ethmoid mucocele has been marsupilized, the expanded "shell" of bone that remains can often be pushed manually in order to correct any bony swelling that may cause a cosmetic defect or displacement of the orbit.

Hemangioma

Most hemangiomas that appear in childhood involute spontaneously and no intervention is required. Occasionally they can enlarge, endangering vital structures. Here, steroids or interferon-2 have a role [31]. Later in life, smaller capillary, venous or cavernous hemangiomas can present, often with epistaxis. They can originate from the septum or the turbinates and alarm the patient and the primary care physician, who may suspect malignancy. They can emulate pyogenic granulomas, which is due to a florid reaction as a result of local trauma, typically in the third trimester of pregnancy. Outpatient endoscopic examination along with gentle palpation with a round ended probe will help make the diagnosis. All these tumors are readily removed endoscopically after infilteration and by taking a margin of tissue around the lesion. More extensive hemangioma should not be removed surgically unless imaging, including angiography has shown that resection and vascular control are possible. Therefore, these lesions often require major surgery, occasionally preoperative embolization and are not suitable for endoscopic resection. Their blood vessels do not contract and the bleeding that can occur with their removal can be life-threatening.

Angiofibroma

Angiofibromas originate from the sphenopalatine foramen at the junction of the sphenoid process of the palatine bone and the pterygoid process of the sphenoid. Whether endoscopic excision of an engiofibroma is possible depends on its size, blood supply and on whether it can be embolized safely. It is not possible to excise them endoscopically without preoperative embolization. Total removal depends on accessability and control of its blood supply. The conventional approaches are via a lateral rhinotomy and medial maxillectomy, mid-facial deglowing [32] or transpalatally [33]. Larger lesions require the addition of a lateral infratemporal approach.

Angiofibromas at stage Ia, IIa or IIb according to Fisch may be suitable for endoscopic excision [34]. These lesions comprise only a fifth of all angiofibromas [35]. It is essential that any surgeon embarking on an endoscopic resection should be able to convert to an open approach as bleeding can necessitate this. It is necessary to have blood saved and at least six units of blood cross-matched and to have access to fresh frozen plasma.

Endoscopic resection consists of type III maxillary sinustomy, an ethmoidectomy and removal of the posterior wall of the maxillary sinus to define and clip the terminal branches of the maxillary artery and its sphenopalatine branches. Invariably, sphenoidectomy is performed and the tumor removed. The aim is to remove the whole lesion in one piece, but is often removed in several pieces. It is often necessary to pack and apply pressure to the area temporarily to reduce bleeding before the next attempt is made to remove any remnant. Large suckers are helpful to remove enough blood quickly and allow the lateral wall to be visualized. A suction catheter passed through the other nostril into the nasopharynx also reduces the reservoir of blood in the nasopharynx and helps visibility. The main problem area is removing disease that goes behind and lateral to the pterygoid plates and clivus. The 45 degrees endoscope helps visualize this area. It is helpful to have one surgeon holding the endoscope while the other has two hands free.

Schwannoma

Unusual isolated lesions can occasionally be resected endoscopically but their suitability for this approach depends on their extent and size.

Chordoma

Chordomas often present with late neurological or ophthalmological symptoms but occasionally present earlier with nasal symptoms of obstruction or epistaxis.

Radiological imaging (CT scanning and MRI) are important in assessing their extent. Biopsy must differentiate it from chondrosarcoma. Large lesions often require a sublabial/transfacial approach, access via a Le Fort l osteotomy or lower lesions by mandibular split. Some lesions based on the anterior aspect of the sphenoid can largely be removed endoscopically. It involves a bilateral sphenoid sinusotomy type III when the sphenoidotomy is extended to the floor of the sinus and laterally to the vital structures. The carotid arteries and optic nerves can almost be skeletonized using a long-shanked drill and a well-irrigated coarse diamond drill.

Chordomas are moderately radiosensitive and radiotherapy is often performed in conjunction with surgery. Cure is rare as recurrence is common and while the long-term prognosis is poor, they often grow slowly and patients can live for several years.

Chondroma

Chondromas can be localized to the ethmoid sinuses, maxilla or septum and can be removed endoscopically. If it is large and spread beyond the paranasal sinuses, they may need to be excised via a lateral rhinotomy or midfacial deglowing.

Pleomorphic adenoma

It can involve the septum and can be excised endoscopically with a small but macroscopically clear margin to leave a perforation. This can be inspected for recurrence and reconstructed after disease free interval. It is essential to have a clear margin and remove it in one piece meal, otherwise recurrence is likely.

Other benign pathological lesions

Almost every type of benign lesion has been reported in the paranasl sinuses [36]. Surgical management depends usually on the anatomical location.

The role of endonasal surgery in resection of malignant tumors

Only a small minority of cases are suitable for endoscopic resection for malignancy involving the paranasal sinuses [37]. While the endoscope has the potential to help visualize the paranasal sinuses and reduce the morbidity associated with the resection of the lesion in this area, it is vital that the surgical resection and its margin are not compromised by the use of these techniques. Usually the endoscope is used to assist in defining the intranasal extent of the tumor in conjunction with a craniofacial resection [38]. While more recent techniques have extended what can be resected, such as lesions involving the cavernous sinus but there is no evidence that these increase life expectancy or reduce morbidity [39]. An understanding of the pathology of tumor in this region and formulation of the treatment plan with an oncological team are important. Moreover, the management of all malignant lesions should be performed in conjunction with a multidisciplinary team.

The surgeons main aim is the enbloc resection of the malignant tumors. However, this is not always possible and in some circumstances where tumor is abutting the internal carotid artery, the optic nerve or cavernous sinus, removal without a clear margin or incomplete removal, will occur. Additional treatment such as radiotherapy or chemotherapy is often given, depending on the pathology, the patient's condition and the relative benefit compared to the morbidity these may produce. Longer term follow-up is currently available and comparative trials are needed before the endoscopic resection of malignant tumors can be advocated.

Endoscopic-assisted craniofacial resection (EACR)

The main use of the endoscope is to help obtain a clear inferior margin. Preoperatively, the radiographs and the endoscopic appearance need to be studied to estimate the extent of the lesion. When the margin of the tumor is not clear, it is advisable to take endoscopic biopsies at the commencement of the procedure and send this for frozen section. The craniofacial resection can then proceed and the wait for the pathologist's reply will not prolong the procedure.

A through fronto-sphenoethmoidectomy can be performed away from the tumor margin, if possible to add to the margin of the resection. The septum can be divided endoscopically to help the specimen be delivered enbloc via the craniotomy. If the tumor extends to involve the medial wall of the orbit, this can be removed via the craniotomy and the endoscope can help in ensuring that its inferior margin are cleared.

Endoscopic resection of malignant skull base tumors

Craniofacial enbloc resection remains the gold standard that has in creased life expectancy in skull base tumors [40]. The integrity of the dura is critical in the management of this condition. A tumor invading the dura is associated with a poor prognosis. The endoscopic resection of malignant skull base lesions may have a role in small tumors where a margin of resection is possible. However, it is often necessary to debulk a tumor hanging into the airway in order to improve the visibility of its margins and the roof of the sinuses. Powered instrumentation helps but all material must be collected in a trap for histological examination.

Olfactory neuroblastoma

Endoscopic resection has been advocated for tumors of Kadish stage A or B with no evidence of intracranial extension. Endoscopically, it is possible to resect the cribriform plate, the crista galli, the olfactory bulbs and their surrounding dura along with the top of the septum and the middle turbinates where they are attached to the skull base [41]. The primary determining factor affecting prognosis is the degree of differentiation. Since poorly differentiated tumors usually metastasize and it is best to minimize surgical morbidity and mortality by endoscopic resection. Craniofacial resection have a complication rate of almost one in four [42].

Plasmacytoma

Granuloma, pseudolymphoma, reactive plasmacytic hyperplasia, olfactory neuroblastoma, lymphoma, anaplastic carcinoma and metastatic tumors all have a similar appearance to plasmacytoma. The management of these lesions depends on the understanding of their pathology, since their behavior and management differ. Therefore, biopsy is important. The diagnostic classification of plasma cell neoplastic disorders includes:

- Solitary plasmacytoma
- Extramedullary plasmacytoma
- Myelomatosis
- Plama cell leukemia.

Solitary plasmacytoma of bone commonly presents as single large osteolytic lesion, often with multicystic areas of rarefaction. Moreover, almost 50% of solitary plasmacytomas will convert to multiple myeloma [43]. It is essential to look for evidence of systemic involvement and the presence of paraprotein. Solitary lesions can be excised but since they are highly radiosensitive, they should be only removed if it can be performed with minimum morbidity. Radiotherapy is the treatment of choice. Adjuvant chemotherapy is occasionally indicated in an attempt to delay conversion to myeloma. Extramedullary plasmacytomas present as sessile, pedunculated or polypoid masses with a pale yellow hue and fewer patients convert to multiple myeloma.

Malignant melanoma

An enbloc resection with radiotherapy is associated with a lower recurrence rate and metastatic rate in spite of its relatively low radiosensitivity. However, the prognosis is poor with approximately only one in four surviving 5 years. The endoscope is useful for examining the nasal lining for evidence of satellite lesions although about one-third are amelanotic.

Other malignant skull base tumors

There is no much evidence to suggest that the endoscope is of benefit in resecting other malignant tumors affecting the skull base or paranasal sinuses namely adenocarcinoma, squamous cell carcinoma, nasopharyngeal carcinoma, neuroendocrine tumors other than olfactory neuroblastoma, lymphoma [44], undifferentiated carcinoma, small cell carcinoma, adenoid cystic carcinoma, sarcomas and metastases. However, some malignant tumors can be resected with a wide margin as can be obtained using other techniques in the hands of an experienced endonasal surgeon. This should be only be performed in conjunction with a multidisciplinary team.

Recurrent or residual malignant disease

The endoscopic debulking of tumor can sometimes help in palliation by providing a nasal airway. The potassium, titanyl phosphate (KTP) laser is particularly useful in debulking hemorrhagic lesions.

Expanded endonasal approaches to ventral skull base

There is an ongoing revolution in multiple surgical specialities with the introduction of minimally invasive techniques. In rhinology, ESS has become the new standard for the treatment of inflammatory as well as neoplastic disease. A natural extension of ESS has been the application of endoscopic techniques for the surgical treatment of pathologic conditions of the cranial base. This has been driven by the ongoing development of endoscopic technology. Moreover, it has been driven by consumer demand. Furthermore, as the limits of ESS is tested, the possibilities for cranial base surgery are expanded. Truly, it is a maximally invasive endoscopic surgery than minimally invasive surgery.

The expanded endonasal approach (EEA) to the ventral skull base provides endoscopic access from the frontal sinus to the second cervical vertebra in the sagittal plane and from the midline to the jugular foramen, internal acoustic canal (IAC) and lateral mass of C 2 in the coronal plane. Anatomical modules can be combined to tailor the approach to the location and extent of the pathology. Potential advantages of the EEA not only includes improved cosmesis but more importantly, the potential for much less neurovascular manipulation in well selected cases. In pediatric patients, preservation of facial skeleton avoids disruption of growth centers and development of facial asymmetry with further growth. In contrast to an intracranial approach, an endonasal approach avoids the need for any brain retraction and may result in less damage to brain tissue. Improved visualization and better access to difficult sites may result in improved oncological outcomes.

Advances in cranial base surgery over the last two decades have only been possible with the collaboration of multiple surgical specialities [45]. This is more obvious with endoscopic skull base surgery. Rather than working sequentially as is often done with open approaches, surgeons from different speciality work together simultaneously as a team: one person maintaining a view with the endoscope and the other working bimanually to dissect the tissues. The benefits of the two team surgery include improved visualization, increased efficiency and the ability to deal with a crisis such as vascular injury. There is added value of having a 'co-pilot' for problem solving, avoiding complications and modulating enthusiasm.

The primary advantage of the endoscope compared to other methods is improved visualization. Improved visualization results in increased access to difficult to reach areas and may facilitate complete tumor resection and avoidance of complications due to poor visualization. Other potential benefits of endoscopic surgery include improved cosmesis and decreased morbidity from tissue trauma and manipulation of vessels and nerves. The consequences of decreased morbidity are a faster recovery, shortened hospitalization and decreased cost of medical care.

Familiarity with endoscopic anatomy, proper instrumentation, an experienced surgical team and adherence to endoscopic surgical principles are essential ingrediants for avoiding severe complications. The basic principle of endoscopic cranial base surgery is internal debulking of tumor to allow extracapsular dissection of tumor margin with early identification of neural and vascular structures. This principle is the same for open neurosurgical procedures and sharp dissection of tumor margins is performed without pulling on tumor. Adherence to these fundamental principles minimizers the risk of neural or vascular injury.

In the late 1980s and early 1990s, the combined effort between the otolaryngologist and neurosurgeons worldwide, made significant strides in the surgical removal of tumors at the base of the skull and brain. These procedures were however disfiguring and painful for the patient. Furthermore, patients encountered long recovery periods and significant risk of complications because the procedures involved large incisions in the face and scalp and removal of parts of the skull to reach the abnormality at the cranial base.

In 1998, a group ofotolaryngologist and neurosurgeons at UPMC in Pittsburgh, USA initiated the first systemic approach to using the nose as a minimally invasive passageway to the brain. They began the extensive process of mapping anatomy and in collaboration with the medical device manufacturers, designed new instruments to make this idea a reality.

By 2000, the Pittsburgh team of doctors had developed the necessary tools and techniques to access tumors located inside the skull by the way of the nose known as EEA. In EEA, the surgeons use endoscopes with light source as well as other instruments especially designed, to treat various types of brain and spinal abnormality. Hence, today surgeons can take out baseball-sized growths without pulling on the brain or touching the normal tissue. This continued refinement of EEA now allows access to an expanded region of the brain, skull base and spine.

The successful evolution of EEA can be directly attributed to the unique collaboration between surgeons with different areas of specialization, both in research laboratory and the operating room. The collaborative effort has put the otolaryngologist and the neurosurgeon to work closely via the nose using the two hole and four hand technique performing the operation simultaneously which never happened in this manner before. The two nostril and four hand technique was first advocated by Prof. Dr. Heinz Stammberger from Graz, Austria for endoscopic cranial base surgery.

As rhinologist has gained more experienced in endoscopic surgery, more areas in the anterior skull base are accessible and surgery is safe. EACR is the standard approach for benign or malignant tumors involving the paranasal sinuses and extending to the skull base. Endoscopes have been successfully used in the management of benign lesions of the paranasal sinuses that extend to the skull base and orbit namely inverted papilloma, fibro-osseous lesions, juvenile nasopharyngeal angiofibroma, sella, parasellar and clival lesions, etc. minimally invasive endoscopic approach to skull base offers the advantages of avoiding facial incisions, osteotomy, tracheostomy and less mobidity and short hospital stay.

As a joint team effort, this extended application beyond the sphenoid sinus and sella region needs a lot of anatomical surgical skills, planning and coordination for proper patient selection and optimal care. The incidence of tumor recurrence will be very much reduced with this minimally invasive cranial base surgery. The use of powered instruments with navigational fusion imaging is most beneficial in the anterior and ventral skull base lesions especially in revision cases.

Standardization of training and the adoption of modular, incremental training program are expected to facilitate the gradual training of endonasal surgeons in otolaryngology and neurosurgical disciplines. Stages of training are established for both surgical speciality based on level of technical difficulty, potential risk of vascular and neural injury and unfamiliar endoscopic anatomy. Mastery of each level is recommended before attempting procedures at higher level. Adherence to such a program during the growth phase of endoscopic skull base surgery may decrease the risk of complications as the surgeon's knowledge and surgical expertise develop [46].

Complications of EEA are the same as open approaches: neural and vascular injury, infection and CSF leak. Literature report of neural and vascular injury are fortunately rare accounting for 1% incidence. These can be avoided with attention to anatomical landmarks and proper dissection techniques. An experienced team can effectively control venous bleeding from the cavernous sinus or basilar plexus. Inadvertent laceration of a large arteriole can be catastrophic unless the team can maintain an endoscopic view and control the bleeding with bipolar electrocaurtery or focal packing. Injury to internal carotid artery usually requires subsequent sacrifice using endovascular techniques. Despite bacterial contamination of the nasal portal, infectious complications are exceedingly rare. Perioperative antibiotic prophylaxis, multilayered repair of dural defects and aggressive management of postoperative CSF leaks are contributing factors. One of the biggest remaining challenges is repair of large dural defects and prevention of postoperative leaks. With the advent of the septal mucosal flap, the Pittsburgh groups suggest an incidence of 6% of CSF leak. Developments that have decreased the incidence of postoperative CSF leaks include a multilayered closure, direct suturing of grafts to dural edges, use of biological glues, coverage with vascularized septal mucosal flap and supporting the reconstruction with an intranasal balloon catheter.

Conclusion

The advent of nasal endoscope and lately powered instrumentation and computer-assisted navigational systems has avoided the use of conventional and more radical approaches by the otorhinolaryngologist for the treatment of "non-functional application" of sinonasal inflammatory pathology involving orbit and skull base.

The minimally invasive endoscopic surgery of the cranial base and the pituitary fossa is an interactive real-time live surgical team effort. For many tumors involving the ventral skull base, the most direct approach is through the nasal cavity. The collaborative effort between the otolaryngologists and the neurosurgeon is critical and valuable in effectively managing pituitary fossa and cranial base tumors with minimal morbidity and avoidance of medico-legal implications. ESS with its minimally invasive technique often reduces pain, bleeding and length of hospital stay and avoids external incision and thus reduces surgical cost compared to conventional techniques. Endoscopic surgery cannot replace every conventional external approach and we should never be embarrassed to employ or convert to these conventional approaches when necessary.

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