Endoscopic Skull Base Surgery – Development of a Sub-specialty in Otolaryngology

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Introduction

The introduction of functional endoscopic sinus surgery (FESS) in 1985 has revolutionised the surgical treatment of sinonasal disorders[1,2]. Almost all inflammatory conditions and benign sinonasal tumours are now exclusively treated using an endonasal approach. Endoscopic sinus surgery is not confined to the domain of otolaryngology but has also spread to ophthalmology and neurosurgery. Ophthalmic conditions such as lacrimal duct obstruction and thyroid orbitopathy can be treated with endoscopic dacrocystorhinostomy and orbital decompression respectively. In neurosurgery, endoscopic resection of pituitary tumours is becoming commonplace.

With increasing experience gained with the treatment of cranial base lesions such as cerebrospinal fluid (CSF) leak and pituitary tumours, the limits of endoscopic sinus surgery are constantly being redrawn and the surgical indications have expanded. The whole of the ventral skull base is now entirely accessible using an endonasal approach. The term "expanded endonasal approach' (EEA) was coined to describe approaches that access the anterior, middle and posterior cranial fossa[3].

Technological developments

Over the past decade, renowned skull base centres such as the University of Pittsburgh Medical Center (UPMC) have spearheaded the development of endoscopic skull base surgery to deal with pathologies involving the whole skull base. This is made possible with a better understanding of the skull base anatomy from the endonasal perspective and advances in innovative technologies.

Improvements in the optics of the rod-lens endoscope, high-resolution cameras and high-definition monitors have greatly enhanced the quality of the visual display. This improved visualisation is vital during dissection of the tumour from the surrounding neurovascular structures. Another area of interest is the development of a three-dimensional scope to overcome the lack of depth perception[4]. Current three-dimensional systems, however, lack high definition and future ones will likely address this shortcoming.

Intra-operative navigation is essential for all endoscopic skull base surgery, as it defines anatomical landmarks, tumour boundaries and important neurovascular structures. Refinements of these systems have further improved accuracy and precision. Though it is no substitute for anatomical knowledge, image guidance has helped expand the limits of the expanded endonasal approach. Image fusion capability, combining both computed tomography (CT) and magnetic resonance imaging (MRI) scans, has also evolved[5]. This allows the unique features of each component imaging modality to be used at different stages of the surgery. Intra-operative CT or MRI scanners have also been employed to allow the surgeon to assess the completeness of resection.

Extended instrumentations specific for endonasal skull base surgeries have also been developed. These include the high-speed drill, as removal of thick and dense bone is a hallmark of skull base surgery. A hybrid or coarse diamond drill bit is preferred as it combines the advantages of haemostasis with rapid and yet precise bone removal.

Although not universally available, neurophysiological monitoring can be an aid during surgery. These include somatosensory evoked potentials (SSEPs), cranial nerve electromyography and acoustic doppler ultrasonography[6]. SSEPs monitors cortical responses to simultaneous stimulation of the peripheral nerves of the upper (median nerve)) and lower (tibial nerve) extremities. Changes in the cortical responses due to inadequate cerebral blood flow can be detected earlier than changes in other physiologic parameters. It provides an early alert to a developing complication such as intracranial hemorrhage or parenchyma edema and is recommended in cases where there is potential for such injury. Electromyography is useful to identify and alert against injury to specific cranial nerves during the dissection of a tumour, while acoustic doppler sonography helps to identify important vessels such as the internal carotid artery that may be obscured or displaced by a tumour, or, to identify the viability of the pedicle of a reconstructive flap.

Another major area of concern is haemostasis during endonasal surgery. Bleeding impedes visualisation by soiling the lens and by obscuring the surgical field; it prevents complete tumour excision and increases the risk of neurovascular injury. Warm saline (40° C) irrigation coupled with endoscopic bipolar electrocautery and new hemostatic agents helps to provide a 'dry' and clear surgical field. Absorbable gelatin powder, sponge oxidised regenerated cellulose, microfibrillar collagen, fibrin or synthetic sealants are all effective haemostatic agents available now. The addition of thrombin to gelatin powder facilitates its delivery and improves haemostasis.

Endoscopic endonasal approach

The endoscopic endonasal approach (EEA) consists of modules that are oriented in the sagittal and coronal planes. The sphenoid sinus is often used as the starting point for the modules. Key anatomical structures such as the optic nerve and internal carotid arteries can be identified here and then followed to other areas of the skull base. The sagittal plane extends from the frontal sinus to the second cervical vertebrae (Figure 1) while the coronal plane subdivides into anterior, middle and posterior planes according to the corresponding cranial fossae [8].The lateral limit of the coronal modules is limited by critical neurovascular structures such as the optic nerve and carotid artery. This is the basic tenet of endoscopic skull base surgery. Lesions medial to these neurovascular structures can be safely resected without the need for brain retraction and there is also minimal manipulation of these neurovascular structures. Conversely, lesions lateral to these structures are best dealt with via an open approach.

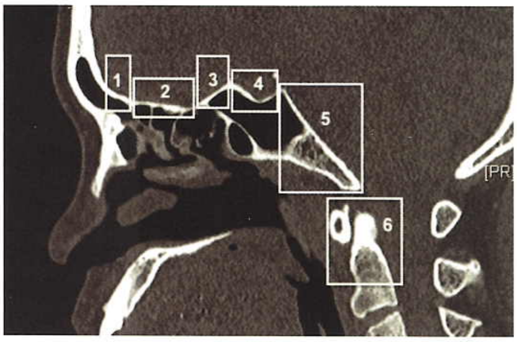
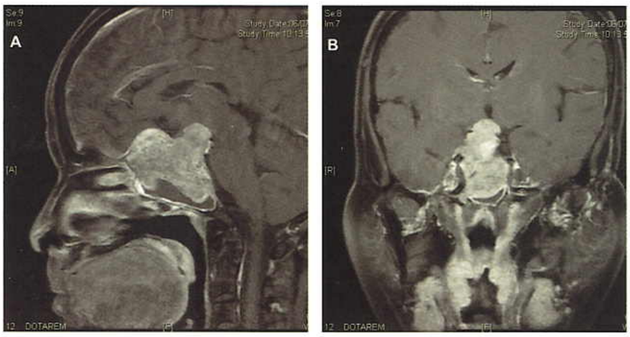


Fig. 1. Schematic depiction of the sagittal plane module on a computed-tomography (CT) scan of the skull base. They are numbered as follows: (1) transfrontal, (2) transcribriform, (3) transplanum, (4) transsellar, (5) tranclival and (6) transodontoid

Some common approaches used in EEA are briefly described here. The transfrontal module provides access to the posterior wall and floor of the frontal sinus. Examples of lesion in this area include mucocoele, osteomas and dermoids. Transcribriform module extends from the crista galli to the planum sphenoidales (roof of the sphenoid sinus) and across the ethmoid roof to the mid-orbital roof. Lesions in this area include sinonasal malignancies with skull base involvement such as olfactory neuroblastoma and olfactory meningiomas.

Transsellar approach is the standard approach for pituitary tumours but may need to be extended to the planum (transplanum approach) for those pituitary tumours with suprasellar extension (Figure 2) and craniopharyngioma. Transclival approach deals with pathology of the clivus such as chorodma, but, in the local setting, it is the standard approach used for resection of recurrent nasopharyngeal carcinoma.



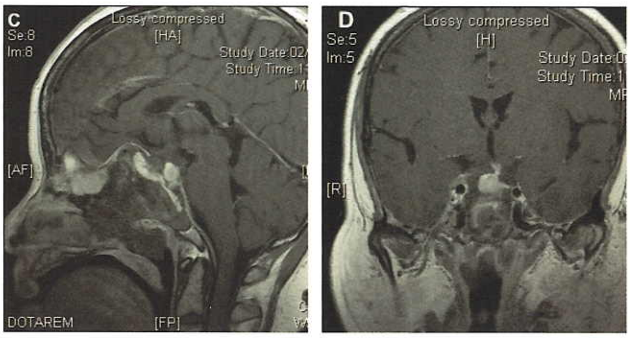


Fig. 2. Magnetic resonance imaging (MRI) of a large pituitary tumour with suprasellar extension. An endonasal transsellar and transplanum approach is used to remove the tumor. Figures A and B are the pre-operative scans and Figures C and D are the post-operative scans.

Principles of oncological resection

Evolving from an endoscopic assisted approach, it is feasible now to completely resect malignant sinonasal and skull base tumours endoscopically. One of the major criticisms of endoscopic resection of sinonasal tumours is that en-bloc resection cannot be achieved. It has been shown when properly performed, piece-meal resection of the tumour does not compromise results as long as the final margins are clear[8,9]. Although sinonasal tumours often fill up the whole of sinonasal cavity, its involvement of the skull base is often more confined. In the case of esthesioneuroblastoma, the intranasal component is debulked towards its attachment at the skull base. This exposed the whole anterior skull base from the floor of the frontal sinuses anteriorly, medial orbit and fovea ethmoidalis (roof of ethmoid) laterally and planum sphenoidale posteriorly. The dura is then incised around the periphery of the tumour and the tumour dissected free from the surface of the brain with inclusion of the olfactory bulbs and tracts (Figure 3A). Thus, the area of skull base involvement is removed en bloc and clear margins are then confirmed with frozen section analysis.

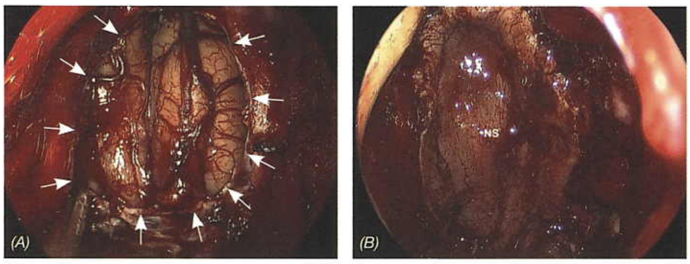


Fig 3. Endoscopic view (A) of the surgical dural defect (delineated by white arrows) following an endoscopic transcrifbriform resection of an esthesioneuroblasma. The ventral surface of the frontal lobe and the cut end of the olfactory tracts are seen. Reconstruction of the defect is performed using a nasoseptal flap (NS) (B).

Following resection, there is a need to re-establish the separation between the nasal cavity and the brain. This is one of the greatest challenges in endonasal skull base surgery. Previously, this has been attempted using multiple non-vascularised 'sandwich' graft such as cartilage, bone, mucosa or artificial graft. However, this still results in a fairly high incidence of cerebrospinal fluid leak (30%)[10]. The introduction of the vascularised nasoseptal flap is one of the most significant advances in skull base reconstruction in the pass decade[11,12]. This vascularised flap is based on the posterior septal branch of the sphenopalatine artery and can provide complete coverage of the defect from the frontal sinuses to the planum sphenoidale and from orbit to orbit (Figure 3B). It has dramatically decreased the incidence of post-operative cerebrospinal fluid leak following skull base reconstruction to about 6%[13]. If this flap is unavailable, then a pericranial or temporoparietal fascial flap can also be used.

As this technique is relatively new, there are not many long-term studies on its outcome compared to open approach. Nevertheless, early reports appear to suggest that the short-term outcome for endoscopic skull base resection are at least equivalent compared to traditional approaches[6].

Team

Unlike other team surgeries that employ sequential teams of surgeons, endonasal skull base surgery involves participation of two skull base surgeons (usually an otolaryngologist and neurosurgeon) simultaneously during the surgery. This is also described as binarial surgery where 2 instruments are introduced through each nostril (Figure 4). The benefits of a team surgery approach include dynamic visualisation, increased operative efficiency and improved decision making and problem solving. These benefits become more apparent during a vascular emergency where time is of essence.

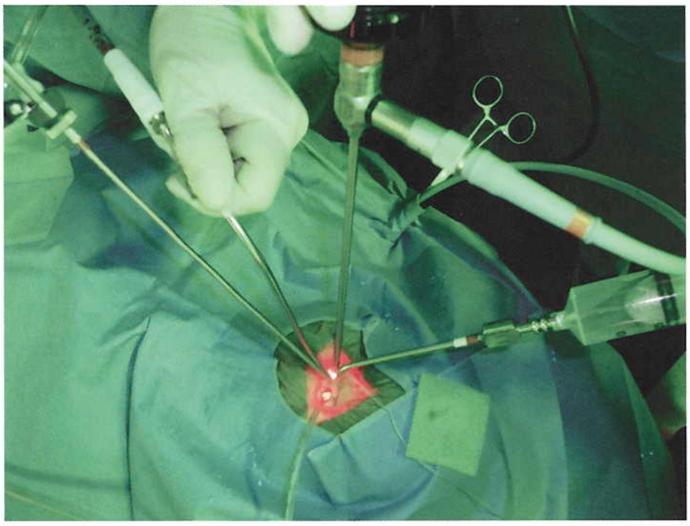


Fig. 4. A 2-surgeon binarial approach in a 5-year-old child with 5 instruments in both nasal cavities.

Advantages

Advantages of an endonasal approach include the avoidance of a facial incision, craniotomies, decreased pain, faster recovery and better patient acceptance. The avoidance of brain retraction from an open craniotomy also reduces the possibility of brain contusion, edema and eventual encephalomalacia. The use of the endonasal approach is becoming more appropriate in select situations. Below are two examples.

Recurrent nasopharyngeal carcinoma

Current treatment options for recurrent nasopharyngeal carcinoma options are mainly re-irradiation and/or surgery. Re-irradiation, due to its high cumulative radiation dose, may result in late and morbid complications such as multiple cranial nerve palsies, temporal lobe necrosis, osteoradionecrosis, trismus, hearing and visual impairment and even carotid rupture. Alternatively, surgery presents a reasonable choice when the recurrent tumour is resectable. It gives satisfactory local control and there is less morbidity than re-irradiation[14].

Surgical resection is traditionally achieved with an open approach. As access to the nasopharynx is difficult, these approaches are often complex and may result in considerable morbidity such as facial scarring, trismus, dental malocclusion, and injury to cranial nerves among others. An endonasal approach to the nasopharynx, on the other hand, avoids these morbidities. In fact, endoscopic nasopharyngectomy should be considered as the first option if the tumour is resectable (Figure 5). Current evidence suggests that it is safe and feasible for early recurrences (rT1 and some rT2 tumours)[14]. For advanced tumours such as those involving internal carotid artery or with intracranial invasion, concurrent chemoirradiation should still be considered first.

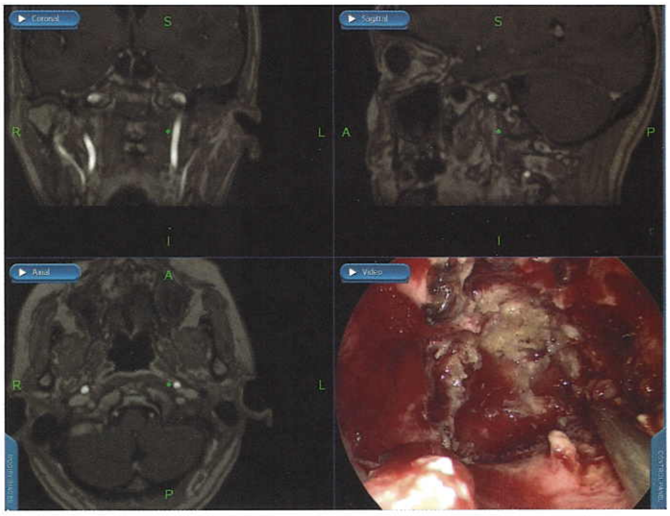


Fig. 5. A 60 year-old patient with recurrent nasopharyngeal carcinoma involving the left fossa of rosenmulla. An endoscopic nasoharyngectomy is carried out. The figure showed the lateral extent of the dissection being limited by the internal carotid artery.

Paediatric population

The use of an endonasal approach in a child may also potentially avoid craniofacial growth abnormalities as it does not disrupt the facial growth centres. This makes it especially suitable for paediatric population. The smaller nares and nasal cavities in young children do not preclude endonasal surgery. An 8-month-old old girl recently underwent endoscopic assisted decompression of her right optic nerve without making any external incisions.

Applications of EEA in the paediatric population include biopsy for diagnosis, and treatment of neoplasms such as juvenile nasopharyngeal angiofibroma and rhadomyosarcoma. An example is illustrated in Figure 6.

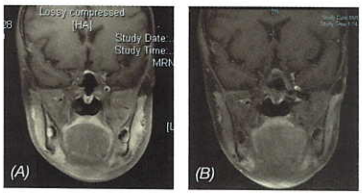


Fig. 6. MRI scan (A) showed enhancement of the left infraorbital (*), trigmeninal nerve, trigeminal ganglion and infratemporal region. A post-surgery MRI scan (B) 3 months later did not reveal any recurrence.

This is a 9-year-old child with rhadomyosarcoma involving the left infratemporal fossa, parotid gland (with left facial nerve palsy) and paramengingeal involvement of the left trigeminal ganglion. He subsequently underwent chemo-irradiation followed by surgical extirpation. Post chemoradiation MRI scan (Figure 6A) showed persistent enhancement of the left infraorbital, trigmeninal nerve, trigeminal ganglion and infratemporal region. Resection of the tumour was performed via a combined approach. An open parotidectomy was performed to approach the infratemporal fossa laterally while the medial infratemporal fossa was approached endoscopically (transmaxillary). The resected parotid tissue and the left infraorbital nerve did not reveal any residual tumour. The trigmeninal nerve was also explored and did not reveal any evidence of tumour involvement. As a result, there was no further escalation of his chemotherapy regime. A post-surgery MRI scan (Figure 6B) 3 months after surgery did not reveal any recurrence.

Conclusion

Setting up a skull base team requires a team of surgeons who are committed and interested in working collaboratively. At the National University Hospital, Singapore, we have assembled a team of both neurosurgeons and otolaryngologists that have undergone training in this area and have worked well as a team in complex cases. Being a tertiary hospital also means that there is sufficient surgical volume to maintain our expertise. This will continue to grow and it will ultimately benefit our patients.

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