Endoscopic Tumour Surgery – Current Limits and Future Possibilities

a report by

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Brain tumours represent a major focus of research in chemotherapy, radiotherapy and neurosurgery. The principle that guides all of these disciplines is: be effective on the tumour with fewer effects on normal brain tissue. In surgical sciences this concept has become known as 'minimally invasive surgery'. The development of endoscopic techniques has had a revolutionary impact in several disciplines such as urological, gastrointestinal and thoracic surgery. In neurosurgery, the use of the endoscope was initially limited to the treatment of hydrocephalus. Only during the last few decades have the indications for endoscopy – which has been driven by global technological progress, leading to the development of image-guided surgery, intra-operative-imaging-dedicated surgical instruments and increasingly efficient endoscopes – been extended to other pathologies such as aneurysms and tumours.

Historical Background

Until the 1960s, neurosurgical procedures for brain tumours were performed with the naked eye and head-mounted lights or glasses with magnifying lenses. The introduction of the surgical microscope in neurosurgical practice provided magnification and coaxial illumination, even in the depth of the brain. This new standard of vision and the evolution of instruments and techniques of haemostasis allowed the development of less invasive surgical approaches through smaller craniotomies. However, the microsurgical operative field is limited to structures directly in line with the microscope, which can be angled to a limited degree to uncover hidden corners and craniotomies. Despite limitations of microscopes *per se*, in the 1960s Guiot performed endoscopic explorations of the ventricular cavities and of the sellar area,[1] and in the 1970s Apuzzo instigated the use of a side-viewing telescope during conventional microsurgical procedures to highlight hidden intracranial structures.[2] A new dimension in the field of intra-operative visualisation had unfolded. However, at that time the concept of multimodality imaging was in its infancy and, due to technical limitations, was performed by only a few neurosurgeons. Consequently, this exciting field of research was developed and superior optical systems provided superior illumination and image quality.

The 1980s saw the dawn of a new era in diagnostic imaging: computed tomography (CT) and magnetic resonance imaging (MRI), which could encounter smaller lesions and better differentiate between tissues, thus encouraging the reduction of the conventional surgical approaches to their essential parts. Indeed, the term 'minimally invasive neurosurgery' refers to the technique of exposing the surgical target with minimal exposure and manipulation of the surrounding brain tissue, which can also include a keyhole craniotomy. Perneczky made major contributions to this concept, which would guide further developments until the present day. In the 1990s, profound changes took place: the limits of microscopic visualisation were overcome when Perneczky proposed the endoscope as a further visualising tool during microsurgical procedures and reported encouraging early results of endoscope-assisted approaches to intracranial lesions.[3,4] The introduction of the endoscope through limited surgical corridors enhances the visualisation of structures that otherwise would be hidden by the operating microscope (endoscope-assisted technique); alternatively, the endoscope can be be used as the sole visualising tool during the whole procedure (endoscope-controlled technique). Since the 1980s, several ear, nose and throat (ENT) surgeons have pioneered functional endoscopic sinus surgery,[5–7] thus encouraging the pure endoscopic endonasal approach to the sella. Jho and Carrau developed this technique,[8] followed by another team.[9] These experiences supported a continued structured evolution of the endoscopic technique: new skills have been transferred across subspecialities,[9] new instruments have been designed,[10] new image-guidance systems have been developed[11,12] and new surgical corridors have been defined,[13] thus revealing the way to the pure endoscopic approach to lesions affecting the skull base, the cerebellopontine angle and the ventricular and paraventricular area.

The Endoscopic Technique

The endoscope has become part of the equipment in all neurosurgical operating theatres and the surgeon can rely on low-profile endoscopes with straight or variably angled views, xenon light source, irrigation sheaths for cleaning the lenses inside the operating field and endoscope holders to perform bimanual dissection, as in microsurgery. Nevertheless, the endoscope is far from being commonly applied as a visualising tool during microsurgical procedures: the endoscope-assisted technique is devoted to surgery for aneurysms and cerebellopontine tumours. The reasons for this lie in the marked differences between the two imaging modalities. Despite the fact that several systems integration strategies have been applied,[3] the two devices tend to exclude each other. Pure endoscopic approaches are becoming commonplace in everyday practice, and are the standard of care for various tumour types and locations. Meanwhile, new frontiers are being gained in some referral centres. It is hoped that this new neurosurgical technique will bring with it the highest degrees of knowledge, skill, expertise and practice possible to maximise the endoscopic techniques. The endoscopic approaches are flexible and safe in well-selected cases. The wide

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panoramic, multi-angled and close-up view of the anatomical structures expresses its best properties in deep and narrow spaces such as the mid-line skull base, the third ventricle and the cerebellopontine angle. This constantly evolving research environment requires rigorous control since each endoscopic technique may represent evolution from the standard procedure, rather than the first stage of a surgical research project. Therefore, to be accepted as the new standard of care, each endoscopic technique should be evaluated through proper outcome measures. Controlled studies have demonstrated that several endoscopic techniques are superior, or at least equal, to the conventional approach, and their application is of real benefit to the patient. The ongoing reporting of short-term outcomes allows surgeons to develop an evidence-based approach to the indications, advantages and drawbacks of each endoscopic procedure.

Nowadays, the surgical armamentarium in the treatment of cranial tumours is supported by an increasing number of attractive and pure endoscopic procedures such as the endonasal trans-sphenoidal approach to pituitary adenomas, extended endonasal approaches to the skull base and to the cerebellopontine angle, the endoscopic supraorbital approach and ventricular endoscopy. Some of the techniques we reviewed can be applied using basic endoscopic skills, i.e. the endoscopic endonasal approach to the sella turcica and the endoscope-assisted approach to the ventricular cavity, whereas others require significant experience and can be applied only in referral centres, i.e. endoscopic endonasal extended approaches and endoscope-assisted and -controlled approaches to the cerebellopontine angle.

Pituitary Surgery

Pituitary adenomas are the third most common primary intracranial tumours, surpassed only by gliomas and meningiomas. The majority of these tumours are managed surgically and the endoscopic endonasal trans-sphenoidal approach is becoming the procedure of choice.[14–17] This approach is safe and effective, with surgical results and a complication rate at least similar, if not better, to those reported in the main microsurgical series.[14,18–20] Furthermore, patient compliance is improved.[14] A rigid endoscope, without a working channel, is inserted into one nostril with the instruments running contiguous to it. The virtual surgical corridor between the nasal septum and the middle turbinate is enlarged by laterally pushing the middle turbinate; consequently, the anterior wall of the sphenoid sinus and the sellar floor are opened, thus exposing the lesion. After tumour removal, the sellar floor is repaired, when required, and the middle turbinate is put back medially, without packing the nasal cavity. The endoscopic approach offers several advantages to the patient: less nasal trauma and post-operative pain, no nasal packing, shorter post-operative hospital stay and a quicker return to daily activities. This technique also has several advantages for both surgeons (wider and more manoeuvrable view of the surgical field, easier treatment of recurrences, increase of scientific activity and interdisciplinary co-operation) and institutions (shorter post-operative hospital stay and increase of the case load). Due to its characteristics, this technique found wide acceptance. The learning curve for the endoscopic endonasal approach can be reduced by working with ENT surgeons. Furthermore, the neurosurgeon will easily adapt to the bi-dimensional endoscopic vision and learn to manage the complications of the trans-sphenoidal route through the endoscopic vision.

Extended Endonasal Approaches to the Skull Base

In recent times, the promising results of the endoscopic endonasal trans-sphenoidal approach to the sella[18] and the utilisation of additional tools (dedicated instruments, image-guided systems, micro-Doppler probes) has contributed to the development of extended endonasal approaches – either the endoscope-assisted or purely endoscopic techniques. Some authors already experienced in endoscopic pituitary surgery have chosen this strategy to face lesions located over the mid-line skull base, from the frontal sinus to the cranio-vertebral junction, such as meningiomas, craniopharyngiomas and chordomas.[21–30] These approaches expose the skull base through an endonasal extracranial route, thus avoiding manipulation of the brain and neurovascular structures. The idea behind all of the endonasal approaches is to remove an intracranial tumour surrounded by structures passing through an endonasal extracranial corridor, thus gaining direct access to the target with minimal action on the intracranial structures. In appropriately selected patients, preliminary reports have demonstrated that the extended trans-sphenoidal approach represents an encouraging addition to the armamentarium used for cranial base surgery. Through this 'low route', the lesion is unlocked following its direction of growth, avoiding brain retraction and optic apparatus manipulation. Furthermore, using the endoscope the surgeon can interchange a panoramic multi-angled view and a close-up insight view. This possibility allows the surgeon to distinguish the limits and relationships of the tumour. Anterior skull-base meningiomas can be devascularised early and completely removed, together with the dura and bone involved.[23] The suprasellar and intraventricular craniopharyngiomas can be unlocked through this extracerebral route; the close-up view facilitates the identification of the pituitary stalk, which can be preserved, if not infiltrated, during tumour dissection from the inferior aspect of the chiasm, and allows a careful dissection of the tumour from and the lateral walls of the third ventricle.[21]

Concerning clival chordomas, the endoscope-assisted and the pure endoscopic endonasal approaches are less invasive than sublabial or mid-face de-gloving trans-sphenoidal or transmaxillary approaches. The endoscopic technique maximises tumour removal as well as tumour extension. Furthermore, the removal rate of these locally invasive tumours correlates with responses to radiotherapy. The neuronavigation, the Doppler probe and the endoscopic close-up view maximise tumour removal, and removal rate is comparable to that of the endoscope-assisted approach.

Endoscopic Retrosigmoid and Supraorbital Approaches

Over the last 10 years there has been an increase in the use of the endoscope to approach tumours through the supraorbital and the retrosigmoid routes.[31–34] When performing a traditional microsurgical approach, the introduction of the endoscope gives the procedure a new, dynamic dimension and makes surgery more reliable and safe.[31,33] Recently, the endoscope has been used as the sole visualising tool during the removal of middle cranial fossa meningiomas,[35] vestibular schwannomas[36,37] and epidermoids.[38] The pure endoscopic approach is also used in patients complaining of trigeminal neuralgia or hemifacial spasm to recognise the offending vessel and to perform a safe and reliable decompression.[39] Based on these experiences, the retrosigmoid and supraorbital routes have many advantages over the endoscope-assisted technique.

During the endoscope-assisted technique, the endoscopy can be performed intra-operatively before, during and after tumour removal, to identify important microanatomical details not seen or not well seen

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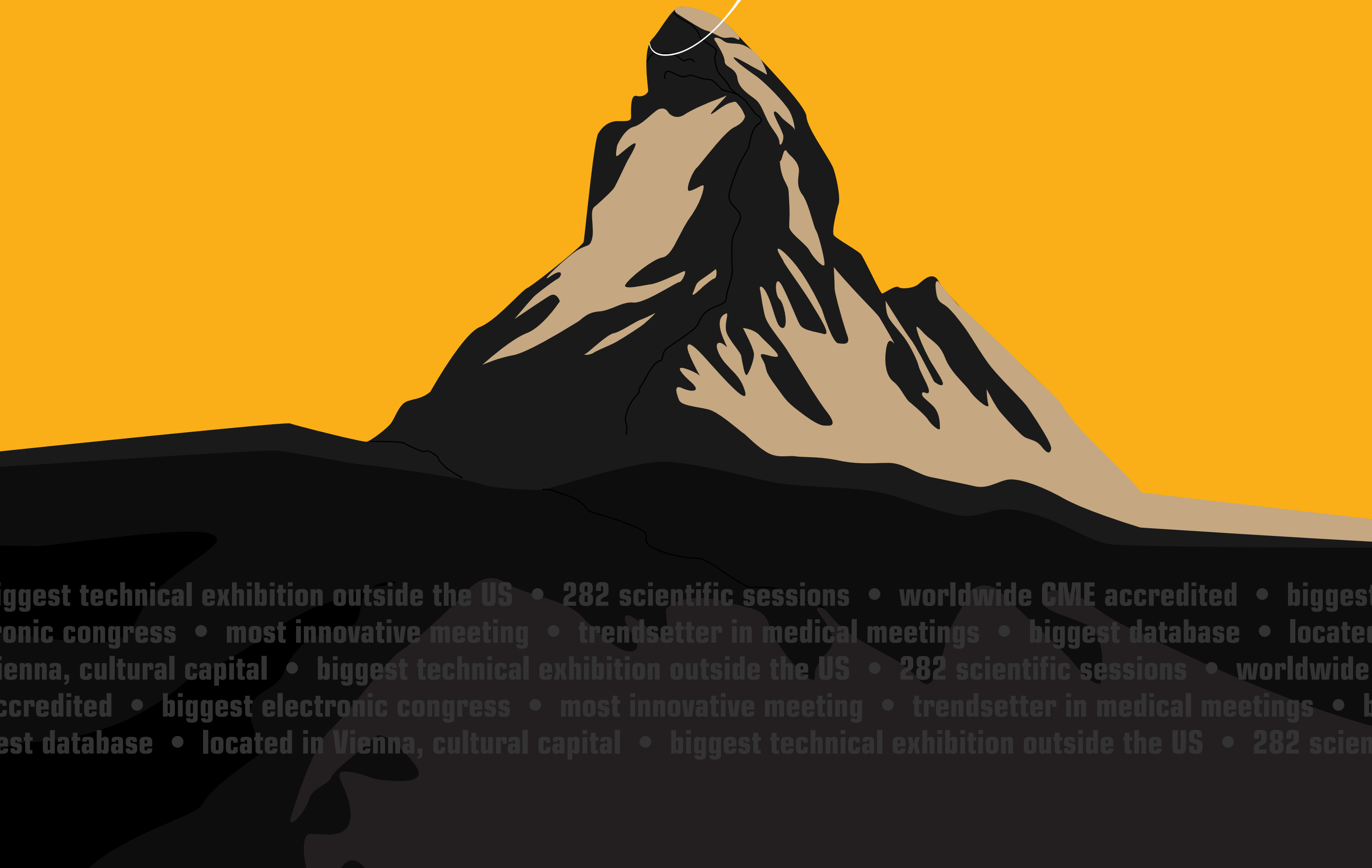

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through the microscope. Different techniques of image fusion between endoscope and microscope have been proposed over the years.[40] Intra-operative bleeding can be adequately managed in trained hands. Furthermore, saline irrigation through the sheath of the endoscope keeps the operative field clean during tumour removal, thus reducing the need for bipolar coagulation. Thanks to the smaller craniotomy and the improved ability to differentiate the tumour from the neurovascular structures and to inspect the internal auditory canal, the endoscope could shorten operating time, preserve hearing and reduce the recurrence rate.

Endoscopic Ventricular Surgery

Ventricular neuroendoscopy represents an important addition in the management of intra- and para-ventricular brain tumours. It can be used to treat associated obstructive hydrocephalus, as an optical tool during microsurgical removal or as the sole visualising tool to biopsy or resect the lesion. At present the endoscopic technique is well established for the management of intraventricular lesions causing hydrocephalus, where tumour removal, third ventriculostomy and cerebrospinal fluid (CSF) sampling can be performed in the same procedure. In patients without hydrocephalus, neuronavigation and stereotaxy can guide the endoscope towards intraventricular or deep paraventricular lesions. Depending on the tumour's characteristics (diameter, vascularisation), the endoscopic equipment and the surgeon's skill, several tumours such as craniopharyngiomas, exophytic low-grade gliomas, subependymal giant cells astrocytomas, central neurocytomas and small choroid plexus tumours can be managed in selected cases.[41–43] In the pure endoscopic procedure, the surgical corridor can be enlarged with an endoport.[44] The endoscopic ventricular technique reduces the size of the cortectomy, avoids the dissection of the corpus callosum, allows a panoramic view of the ventricular cavity and improves the distinction between tumour and ependyma.

Future Possibilities

Over many generations of neurosurgery, the evolution of the optical devices went through several steps to get to the level of technology we are familiar with today. The naked eye was surpassed by the lens glasses and later by the microscope. The limits of microsurgical visualisation were overcome by the endoscope-assisted technique, and the pure endoscopic technique has disclosed new horizons. The microscope is and will continue to be essential for many neurosurgical procedures. However, in experienced hands and well-selected patients, the endoscope is a valuable adjunct to the surgical armamentarium.

Further development of endoscopic techniques will be driven by technological advances such as high-definition intra-operative digital imaging, 3D endoscopy, chip-stick technology (i.e. a small rigid fibrescope held like a suction cannula with a chip at its distal tip), integrated operating rooms, dedicated instruments, virtual reality systems and nanotechnology. Among the sophisticated features of modern integrated operating rooms, a package of advanced capabilities in telemedicine and live telesurgery allow surgeons to instantaneously view any procedure worldwide. This technology will further speed the dissemination of the endoscopic techniques: distance education courses can be organised and more experienced neurosurgeons can be called for consulting during surgery. 3D endoscopy will provide a sense of depth similar to that of the microscope, which most neurosurgeons are familiar with, thus encouraging them to practise endoscope-assisted procedures when necessary. Virtual imaging will flank cadaver dissection in training laboratories, and one day a robot-like system may exist that operates in an up-to-date virtual space. Nanotechnologies applied to endoscopy procedures will allow further minimalisation of the imaging apparatus, irrigation and light source. Furthermore, new instruments may use nanosensors for *in vivo* realtime histopathology of lesions and may permit implantation of antineoplastic agents tailored to the tumours of patients. The advances of medical and radiation treatments will optimise the results of surgery and improve long-term benefits. Recent international congresses on endoscopy featured the concept of interactive dialogue among neurosurgeons, researchers and healthcare leaders, thus providing a basis for active co-operation and further developments.[45] Technological innovations will certainly expand our ability to improve patient care and long-term outcomes. ■

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