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Neuro-endoscope for skull base tumors

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ABSTRACT

The endoscope has traditionally been used in neurosurgery to access a lesion within a natural body cavity. The challenge has been to access and resect deep-seated intraparenchymal lesions using a minimally invasive endoscopic technique. Endoscopic endonasal trans-sphenoidal surgery has gained increasing acceptance by otolaryngologists and neurosurgeons. Surgical procedures of the skull base include exposure, resection, and base reconstruction. These approaches start at the sphenoid sinus, which provides a reference point to important vascular and neural structures. The endoscopic endonasal approach is optimal in paramedian ventral skull base tumors, allowing wide access to the ventral skull base regions and allowing early devascularization of the tumor without retraction of the brain. Limited exposure results in limited "injury" to surrounding tissue and consequently reduced post-operative pain, a shorter length of hospital stay, a reduction in the time to return to work, and decreased overall cost.

1. Introduction

Endoscopy-based endonasal trans-sphenoidal surgery is increasingly being recognized by neurosurgeons and otolaryngologists as a surgical method for the treatment of brain tumors and skull base neoplasms [1]. This method has become a routine medical technique and is currently as widely used as the conventional microsurgery technique in the world's major centers for the same surgical target. Minimally invasive endoscopy-based surgery can be used to gain direct access to brain lesions while minimizing brain retraction during craniotomy. This endoscopic approach provides access to pathological lesions through a natural opening as small as a nostril or through an incision, minimizing or entirely preventing brain retraction. Previous reports on this medical technique highlight the benefits of endoscopic surgery and its superior visualization. Minimally invasive techniques allow a more comprehensive removal of the tumor with less operative trauma and fewer complications [2–4]. Studies on the endoscopic technique indicate that its use by experienced surgical teams can reduce the incidence of surgical complications [5,6]. During the surgical removal of a tumor, a conduit trajectory that can be adjusted to access the tumor facilitates the resection of large lesions.

2. Endoscopic anatomy of the skull base

The skull base is among the most complex anatomic regions and it forms the floor of the cranial cavity. Skull base surgical approaches include open, endoscopic, and microscopic approaches to the posterior cranial fossa or the anterior middle fossa [7,8].

Gain access to the anterior middle skull base via endoscopy using an endonasal transcribiform approach from the frontal sinus to the posterior ethmoidal arteries [9]. It is recommended to remove the superior part of lamina papyracea using the endoscopic endonasal approach (EEA) to the anterior skull base to isolate both posterior and anterior ethmoidal arteries. The bone of the anterior skull base is enclosed by two orbits. Via dural openings, the olfactory bulbs can be seen at the bottom of the gyrus rectus. By retracting the brain tissues, it is possible to leave the two fronto-orbital and frontopolar arteries and their branches exposed, allowing visualization of the interhemispheric fissure.

The middle skull base can be opened via different corridors from the planum sphenoidale to the sellar floor, namely the endoscopic-based endonasal transplanum-transtuberculum approach to various lesions of the suprasellar area and the standard EEA method for various lesions of the sellar region [10]. The midline compartment of the skull base corresponds to the lateral and posterior walls of the sphenoid sinus, which can be seen via an endoscopic-based endonasal corridor. It is crucial to remove the posterior ethmoid cells and superior turbinets to widen the sphenoid sinus' anterior wall and to expose this area adequately. Injuries to the posterior ethmoidal artery must be avoided, and the removal of the anterior skull base bone should not be extended to prevent damage to the lamina cribrosa/olfactory nerve.

Expose the posterior and the middle skull base from the clivus to the

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craniovertebral junction using the endoscopy-based endonasal transclival approach [11]. The petrous bone and the occipital bone form the wall of the jugular foramen, which is divided into two parts in the intrajugular process of both bones: the anterior neural part and the posterior vascular part. The inferior petrosal sinus, Jacobson's nerve, and the IXth nerve form the anterior neural part. The internal jugular vein, several arterial meningeal branches, Arnold's nerve, and nerves X and XI form the vascular part. Before the jugular foramen, the secondary petrosal sinus continues into the petro-occipital synchondrosis; at the antero-medial side, the XIIth nerve can be found in the hypoglossal canals. Cranial nerves IX to XII are located behind the ICA under the jugular foramen, which connects freely with the hypoglossal and the carotid canal, the carotid space, the retropharyngeal space, or the poststyloid parapharyngeal space. Therefore, lesions within the jugular foramen can grow freely in these adjacent canals or spaces [7].

Gain access to the parasellar region, i.e. Meckel's cave region and the cavernous sinus via the endoscopy-based endonasal transpterygoid approach [12]. With the help of the sphenoid sinus chambers, the lateral sellar compartments, and particularly the cavernous sinuses, can be reached through the endonasal corridor [13].

3. Endoscopic skull base surgery

Because the base of the skull is one of the most challenging regions of the body to access, as it contains many structures that can be injured easily, treatment options were once limited for patients with tumors or lesions in this area [14]. It is very important for the neurosurgeon to choose the right approach for reaching the lesion without harming other structures. Because of the pioneering work of Cushing, Hirsch, Yasargil, Krause, Dandy, and other dedicated neurosurgeons, it is possible to access tumors and other lesions in the anterior, midline, and posterior cranial base. The trans-sphenoidal, frontolateral, pterional, lateral subtemporal, and lateral suboccipital approaches allow access to nearly every region of the skull base. However, recent advances and breakthroughs in treatment have provided patients with skull base tumors an array of better surgical options that can help them return to a normal and active life [15,16].

The first physician to use an endonasal trans-septal, trans-sphenoidal approach to resect a pituitary tumor was a Viennese otolaryngologist, Dr. Oskar Hirsch, in 1910 [17]. Although Bushe and Halves reported the first use of the endoscope for pituitary tumors in 1978, the endoscope was not used widely until the mid-1990s, when endoscopic sinus surgery was universally adopted by otolaryngologists. Since the 1990s, neurosurgeons have been increasingly interested in approaching various tumors of the base of the skull using a transfacial (transnasal or transmaxillary) corridor. The procedure has been refined and is widely used. The EEA is an innovative surgical technique for the removal of brain tumors and lesions—some as large as softballs—through the nose. Over the past decade, significant technologic innovations in endoscopic skull base surgery extended this surgery to the entire ventral skull base and upper cervical spine. The EEA allows surgeons to treat many hard-to-reach tumors, even those once considered "inoperable," without disturbing the face or the brain. The skull base tumors removed though EEA include pituitary adenoma, chordoma, craniopharyngioma, and meningioma [18–22]. EEA offers patients a number of benefits that may improve their quality of life, including no facial incisions or disfigurement, less trauma to the brain and critical nerves, fewer side effects, and shorter recovery times.

4. Exposure techniques

In endoscopic endonasal surgery, operative procedures are performed in three dimensions on the basis of two dimensional images, hence the importance of endoscopic anatomical landmarks to guide the operator in relation to the depth of field. It is therefore essential, whenever possible, to operate within a single cavity that is sufficiently large to allow visualization of the greatest possible number of endoscopic landmarks and to provide sufficient freedom of movement to the operator and the assistant in this frequently four-handed surgery.

Surgical access must be adapted to the planned procedure: it can range from simple unilateral luxation of the middle turbinate to complete bilateral ethmoidectomy, and may require complementary procedures such as resection of the septum and medial maxillectomy. These two procedures allow the creation of a large surgical corridor suitable for four-handed surgery, in addition to facilitating post-operative endoscopic care and surveillance [23].

5. Skull base reconstruction

Reconstruction of large dural defects is one of the greatest challenges associated with endonasal skull base surgery. The greatest advance in dural reconstruction is the use of a septal mucosal flap. This vascularized flap is large enough to reconstruct defects extending from orbit to orbit and from the frontal sinus to the sella [24,25]. Skull base defects after endoscopic endonasal resection of tumors are classified in our institute according to the dimensions of the dural defects as follows: Type I: the dura of the skull base is intact after tumor resection; Type II: the dural defect is ≤ 1 cm; Type III: the dural defect is > 1 cm. Three different reconstruction methods are used according to the classification of the skull base defects. Reconstruction of Type I defects is performed mainly using artificial materials. Reconstruction of Type II defects is performed in a multilayer fashion, mainly using an array of autologous free materials including fat, muscle, muscle fascia, and artificial materials. Reconstruction of Type III defects are performed using a vascular pedicle nasoseptal flap and autologous free material. These technologic innovations have reduced the overall CSF leak rate to less than 5% [26].

6. Three-dimensional (3D) endoscope

Since the 1990s, 2D endoscopic approaches have become increasingly popular at many skull base centers mostly because of the improved visualization afforded by this modality. However, critics suggest that the loss of stereoscopy with 2D endoscopes distorts the surgeon's visuospatial orientation, prolonging surgery and potentially increasing the risk of surgical complications. In the last 10 years, 3D endoscopes have been developed to address these shortcomings, and they represent a natural step in the evolution of ventral skull base surgery. Experts suggest that 3D endoscopes enhance visuospatial orientation, improve recognition of the relationships of anatomical structures, and potentially shorten the learning curve for trainees. Several groups showed that stereoscopy improves the understanding of object curvature and surface texture, as well the ability to distinguish objects that tend to merge into the background [27,28]. This is especially important for skull base surgeons, who depend on a detailed understanding of the subtle "hills and valleys" of the ventral skull base to identify safe entry zones when approaching complex sellar and parasellar lesions.

Three-dimensional endoscopes are powerful visualization tools used to address ventral skull base pathology. Expert opinion and cadaveric and clinical studies suggest that this modality improves surgical dexterity by affording the surgeon with depth perception when manipulating tissue and maneuvering the endoscope in the endonasal corridor. Prospective, randomized clinical studies can help assess the safety and efficacy of the 3D endoscope in comparison with the traditional microscopic or 2D endoscopic approaches to skull base lesions [29].

7. 3-Dimensional voxel-based neuronavigation system

During complex skull base procedures, it can be difficult to maintain four images on two different screens in focus. However, because in addition to possessing good surgical skills, neurosurgeons need to be