Historical vignette

History of endoscopic skull base surgery: its evolution and current reality

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The history of the endoscope exemplifies the manner in which technological advances influence medicine and surgery. Endoscopic systems have evolved and improved, and they currently provide detailed visualization of a variety of deep organ structures. Otorhinolaryngological surgeons have used the endoscope for more than 30 years. In the 1990s, a number of influential neurosurgeons and otorhinolaryngological surgeons began performing purely endoscopic pituitary surgery. Endoscopic transsphenoidal operations are now extending beyond the sella. The collaboration between otorhinolaryngologists and neurosurgeons has produced a new subspecialty of “endoscopic skull base surgery.” There is a great deal of progress still to be made in developing skills, instruments, and improving skull base repair. The extended skull base approaches allow surgical exposures from the olfactory groove to C-2 and to the infratemporal region and jugular fossa laterally. This article discusses the history of the endoscope, the pivotal technological advances, and the key figures in the burgeoning field of endoneurosurgery. (DOI: 10.3171/JNS-07/07/0206)

**KEY WORDS** • endoscope • endoscopic sinus surgery • endoscopic transsphenoidal surgery • history of neurosurgery • skull base surgery • transsphenoidal approach

Every step of the procedure must be conducted under the eye of the operator.

**Harvey Cushing**

The Pituitary Body and its Disorders, 1912

Since its inception, one of the major issues in transsphenoidal surgery has been adequate visualization of anatomical structures. As transsphenoidal surgery has evolved, technical advances have improved the surgeon’s view of the operative field. The operating microscope replaced Cushing’s headlight and Dott’s lighted speculum retractor, and fluoroscopy provided intraoperative imaging. These advances led to the modern concept of microsurgical transsphenoidal surgery in the early 1970s.

For the past 30 years the endoscope has been used for the treatment of paranasal sinus diseases, and more recently it has been used in the surgical treatment of pituitary tumors. The collaboration between neurological and otorhinolaryngological surgeons has led to the development of novel surgical procedures for the treatment of various pathological conditions of the skull base. We review the history of endoscopy and its application in endonasal neurosurgery.

**The First Endoscopes**

Until the end of the nineteenth century, the main impetus for the development of endoscopy came from inspection of the bladder, rectum, and pharynx. Philipp Bozzini (1773–1809), a German physician born to an aristocratic Italian family, is recognized for the invention of the first endoscope 200 years ago. The “Lichtleiter,” which he demonstrated in 1806 to the Academy of Medicine of Vienna, consisted of an eyepiece and a container for a candlelight, which was reflected by a mirror through a tube (Fig. 1). Visualization was quite limited, and the instrumentation was painful for the patient. Max Nitze (1849–1906) improved upon the early design (Fig. 2) and constructed an “apparatus for direct illumination and investigation of human and animal hollow organs” made by a series of lenses inside a metallic tube. This German urologist contributed two fundamental ideas: magnifying the image through lenses and illuminating the organs through internal rather than external light (Fig. 3). Thomas Edison’s invention of the incandescent light bulb in 1879 allowed further improvements to be made to this endoscope (Fig. 4), replacing the cumbersome water-cooled platinum wires that were used as the light source.

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the world pioneered the use of the endoscope in different specialties. In 1901 Hirschmann used a modified cystoscope to inspect the maxillary sinus, and he is therefore considered among the pioneers of paranasal endoscopic surgery.\cite{35,49}

A modified cystoscope was used in 1910 by Christian Jacobaeus, professor of medicine in Stockholm, to perform the first endoscopically guided thoracoscopy and laparoscopy.\cite{80}

In the same year, Victor Darwin Lespiniasse (1878–1946), a urologist from Chicago, performed the intracranial intraventricular endoscopy and coagulation of the choroid plexus for the treatment of hydrocephalus for the first time. He performed the procedure in two children; one died during the immediate postoperative period, but the second lived for 5 years after the surgery.\cite{41}

**Initial Neurosurgical Application: Ventricular Endoscopic Neurosurgery**

The endoscope’s earliest application in neurosurgery was in its use within the ventricular system. Although Lespiniasse was the first to use a cystoscope to fulgurate the choroid plexus, Walter Dandy is widely recognized as the father of neuroendoscopy. We owe to him the name of the procedure, which he first attempted in 1922 with little success.\cite{1,29} In 1932, however, he reported using endoscopic ventriculostomy to remove the choroid plexus for the treatment of hydrocephalus (Fig. 5), with similar outcomes to those he had experienced with craniotomy.\cite{28} In 1923, Mixter reported the first endoscopic third ventriculostomy.\cite{36} Intraventricular endoscopic surgery represented the most important initial influence of this technical adjunct in the field of neurosurgery.\cite{47}

**“Modern” Endoscope Evolution**

John Logie Baird, who invented television, patented the idea of transmitting images through a flexible glass cable in 1926.\cite{36} These ideas influenced Harold H. Hopkins (born in 1918 in Leicester, England), who, after graduating with degrees in mathematics and physics, invented the zoom lens in 1948. In 1960 Hopkins patented the rod lens system, which consisted of a series of glass lenses interspersed with neutral glass instead of air.\cite{26} The optical efficiency was improved ninefold over the Nitze system by lowering the refractive index and increasing the functional diameter of the lenses.\cite{55} Hopkins’ rod lenses had clear advantages over the Nitze system, providing greater light transmission, a wider

**Fig. 1.** Photograph of Bozzini’s endoscope and a drawing (inset) demonstrating the light source. The box contained a simple candle together with a partition arranged in such a way that the light was not directed towards the observer’s eye. (Photograph courtesy of the American College of Surgeons. Drawing from Jackson C: Bronchoscopy and Esophagoscopy: A Manual of Peroral Endoscopy and Laryngeal Surgery. WB Saunders, 1922.)

**Fig. 2.** Photograph of a set of endoscopic tubes for laryngoscopy, bronchoscopy, esophagoscopy, and gastroscopy at the end of the nineteenth century. (Courtesy of the Claude Moore Health Sciences Library Historical Collections.)

**Fig. 3.** Drawing of Nitze’s first cystoscope. The light source, a platinum filament lamp, was situated at the terminal end of the endoscope. A water-cooling system was included. (From Jackson C: Bronchoscopy and Esophagoscopy: A Manual of Peroral Endoscopy and Laryngeal Surgery. WB Saunders, 1922.)
view, better image quality, and a smaller diameter for the entire system. Examiners were then able to document their endoscopic findings effectively with cameras and video systems.

Coincident to this tremendous contribution, Basil Hirschowitz, an American gastroenterologist, developed an endoscope with flexible glass-coated fibers (fiberoptics) illuminated by a simple light bulb at the distal end. He called this system a fiberscope and demonstrated it at a meeting of the American Gastroscopic Society on May 16, 1957, in Colorado Springs, Colorado. Karl Storz (1911–1996) realized that in addition to transmitting visual information, the system of glass fibers could be used for the purpose of light transmission, and he licensed the idea of fiberoptic external cold light transmission coupled with the rod lens optical system in 1965.

Many other improvements were also made in the field; one of the most important of these is the charge-coupled device camera. Charge-coupled devices were introduced in 1969 by Bell Laboratories in the US. They are lightweight, low-powered, extremely sensitive image sensors—approximately 15 times more sensitive to light than standard photographic film.

**Modern Endoscopes in Neurosurgery**

Endoscopy was initially used as an adjunct to microneurosurgical techniques to provide views out of the line of sight of the microscope, views that surgeons had previously achieved with angled mirrors. Axel Perneczky, who pioneered the use of the endoscope in intracranial neurosurgery, emphasized that endoscopy “improved appreciation of micro-anatomy not apparent with the microscope” and introduced the concept of “minimally invasive neurosurgery.” The endoscope has been progressively used to assist microsurgery in practically every category of neurosurgical procedure (endoscope-assisted microsurgery), including tumor and aneurysm surgery.

In addition to being used in an adjunctive role, the endoscope has consistently been advocated for the treatment of several pathological conditions inside the ventricular system, such as obstructive hydrocephalus and intraventricular tumors or cysts.

The use of endoscopes in decompression procedures for the treatment of peripheral nerve entrapment syndromes, particularly carpal tunnel syndrome, started with the orthopedic surgeons who were relatively accustomed to its use in arthroscopic procedures. Neurosurgeons progressively added the endoscope as an important part of the armamentarium in the treatment of peripheral nerve disorders. Currently, the application of endoscopes, principally in carpal tunnel disease, has demonstrated that endoscopic surgical procedures are efficient and safe and offer the advantage of shortening the postoperative recovery.

Since the introduction of thoracoscopic and laparoscopic visualization by Jacobaeus, for the diagnosis and treatment of pulmonary tuberculosis in 1910, and subsequent technical innovations, video-assisted thoracic and abdominal surgery has been applied extensively in the treatment of thoracic and lumbar disc disease, the treatment of spinal deformities requiring anterior release, osteotomies and bone grafting, and corpectomies for the treatment of vertebral body tumors.

Burman introduced the concept of myeloscopy for direct spinal cord observation in 1931. In 1938, Pool elaborated on Burman’s work and reported myeloscopic inspection of the dorsal nerve roots of the cauda equina. In 1942, Pool expanded the concept of intrathecal endoscopy and reported the results of more than 400 myeloscopic procedures.

The endoscope was first used to perform a transthoracic sympathectomy by Matthias Kux, a German surgeon, in 1931.
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1950. Kux initially used this technique to treat angina pectoris but subsequently established its important utility in treating palmar and axillary hyperhidrosis. Currently, it is considered a standard and effective method for treating patients with palmar hyperhidrosis in neurosurgery with lower rates of morbidity, shorter operation times and hospital stays, and better cosmetic results than are achieved with the open approaches.[2,4,9,31,100]

Neuroendoscopy has grown rapidly in the last 20 years as a therapeutic modality for treating a variety of disorders.[4]

Application to Paranasal Sinus Conditions

Otorhinolaryngologists were naturally the first to use the endoscope in the nasal cavity. After Hirschmann, various otorhinolaryngologists began to develop maxillary antrostomy, approaching the maxillary sinus primarily through the inferior meatus. Because of the technical limitations of the time, however, this technique was not widely accepted.[39] The development of fiberoptic and glass wool light collectors was a decisive step that allowed image-guided biopsies and more accurate removal of small lesions.[34,42,77,99] Messerklinger revitalized endoscopy and applied it to rhinological and sinus surgery, to examining the sinuses and identifying causes of sinusitis resistant to medical therapy, to locating sites of cerebrospinal rhinorrhea, and even to performing minor operations under optical control.[6,55] The treatment of medically refractory sinusitis through an endoscope in the nasal cavity. After Hirschmann, various otorhinolaryngologists who popularized the use of modern endoscopy for the paranasal sinuses. They pioneered endoscopic sinus surgery for the maxillary, frontal, and sphenoid sinuses.[39] David Kennedy coined the term functional endoscopic sinus surgery. With advancements in suction and irrigation, the endoscope could remain in the operative field,[102,103] leading to the subsequent development of endoscopic skull base surgery.

Endoscopic Endonasal Neurosurgery

Gueriot is recognized as the first neurosurgeon to use the endoscope in the transsphenoidal approach, although he abandoned the procedure because of lack of adequate visualization.[53,73] It was not until the late 1970s that Apuzzo and coworkers[2] and Bushe and Halves reported the use of endoscopy as a technical adjunct in the microscopic resection of pituitary lesions with extrasellar extension.[47] Other authors also reported its use in transsphenoidal microsurgery as a technical adjunct.[50,71]

In the early 1990s, the pure endoscopic transsphenoidal technique (that is, using the endoscope as the only visualizing tool) was introduced thanks to the collaboration between neurological and otorhinolaryngological surgeons. In 1992, Jankowski and coworkers from the Central Hospital of the University of Nancy reported their experience with three cases using a pure endoscopic transsphenoidal approach to the sella.[54] Sethi and Pillay,[55] an otorhinolaryngologist and a neurological surgeon, respectively, from the Singapore General Hospital, reported in 1995 on the use of an endonasal transsphenoidal technique. They used a transnasal–transseptal approach with a hemitransfixion incision to create a bilateral mucoperichondrial flap, which was held apart with the use of a self-retaining retractor after removal of the nasal septum, in 40 patients. In 1996, Rodziewicz and coworkers[62] reported a similar technique, without septal bone removal, in 10 patients. Similar techniques were reported by others.[3,4,9,79,100] The use of a pure endoscopic transsphenoidal technique for the treatment of pituitary adenomas,[17,76] They reflect the history of the procedure, having started using the endoscope as an adjunct to the microscopic technique,[59] and then having moved to a pure endoscopic technique. In 1997, they were able to report on 50 patients who were treated through a pure endoscopic approach.[72] Paolo Cappabianca and Enrico de Divitiis, from Naples, were among the first to report their experience with the use of the pure endoscopic technique, introducing the term “functional endoscopic pituitary surgery” (FEP). Their contribution cannot be overestimated; they developed dedicated endoscopic instrumentation,[60] suggested technical improvements,[8,16,18] and significantly contributed to the scientific basis.[13,14,16,17,20,21,30,31] and critical assessment of the technique.[8,11,12,15,20,32] These reports have been followed by many others from around the world.[2,9,6,98]

More recently, thanks to the introduction of other technical adjuncts such as neuronavigation and the microvascular Doppler ultrasonography, endoscopic transsphenoidal surgery has been extended for the treatment of lesions outside the sella turcica, introducing the concept of “extended approaches” to the skull base.[56-58,60,74] Giorgio Frank and Ernesto Pasquini, a neurosurgeon and an otorhinolaryngologist, respectively, from Bologna, developed the ethmoid-pterygoid-sphenoid (EPS) endoscopic approach for the treatment of cavernous sinus lesions.[38] They have also applied the pure endoscopic technique for resection of suprasellar lesions,[18] performing an extended trans–planum sphenoidale approach, as initially described by Weiss in 1987[101] and used by Laws and colleagues[67] and Maira.[75] This endoscopic approach includes the initial removal of the tuberculum sellae and posterior part of the planum sphenoidale, and the opening of the diaphragma sellae, which allows access to the suprasellar subarachnoidal space, as described by Laws in 1980[66] for the treatment of suprasellar craniopharyngiomas with the microscope. More recently, neurosurgeon Amin Kassam and otorhinolaryngologists Ricardo L. Carrau and Carl Snydermann, from the University of Pittsburgh Medical Center, following the lead of Kaptain[90] and Maroon,[76] have reported on the use of the pure endonasal endoscopic technique for the treatment of various pathologies of the skull base, widening the concept of transsphenoidal surgery.

Current Extended Endoscopic Approaches

The sphenoid sinus remains a fundamental anatomical landmark for extended skull base approaches, extending from the floor of the anterior cranial fossa to the odontoid process.[51-64] An opening in the posterior wall of the sphenoid sinus will provide access to the sella turcica, allowing resection of sellar and also supra- and parasellar lesions.[55]

With an anterior extension and removal of the sphenoid roof, which is the planum sphenoidale, one can gain expo-
sure to the midline anterior fossa from the olfactory groove to the sella including exposure of the frontal lobes and anterior communicating artery complex (Fig. 6).

Posteroinferior extension, with removal of the floor of the sphenoid and clivus, allows access from the sella to the foramen magnum, exposing the basilar artery and the ventral brainstem (Fig. 7). Further inferior exposure can be obtained with dissection through the posterior wall of the nasopharynx. The level of the torus tubarius represents the juncture between the clivus and the atlas. Removal of the anterior arch of the atlas will expose the odontoid process.

The optic-carotid recess can be identified on the superolateral walls of the sphenoid sinus, harboring the optic nerves and carotid arteries (Fig. 8). Superolateral extensions of the transsphenoidal approaches can be used for optic nerve decompressions. By removing bone lateral to the carotid artery, it is possible to enter and decompress the cavernous sinus.

Inferolaterally, the sphenoid floor can be removed all the way to the clivus along with the medial pterygoid plate to expose the internal carotid artery in its transition through the petrous, foramen lacerum, and cavernous sinus segments. The infratemporal fossa can be reached endoscopically through the pterygopalatine fossa via a maxillary antrostomy, which exposes the middle fossa skull base from the foramen ovale laterally to the carotid posteromedially, as well as the region of the foramen rotundum. Through this approach, the petrous apex can be reached as well as the Meckel cave along the inferior and mesial aspect of the temporal lobes.

Thus, endoscopic extended transsphenoidal exposures are currently attainable from C-2 to the olfactory bulb and laterally to the foramen ovale.

**Summary and Future Developments**

Just as there are a number of microscopic approaches (endonasal transeptal, sublabial transeptal, and direct endonasal sphenoidealotomy), a variety of endoscopic approaches are also advocated. The pure endoscopic technique refers to a surgery in which the endoscope is the only device used for visualization; the microscope is not used for any portion of the operation. The pure endoscopic techniques may be distinguished by several features.
Three- and four-hand techniques offer the most important improvements in skull base repair by offering the acquisition of necessary skills, developing instruments and, importantly, improving the methods of skull base repair.

There are advantages and disadvantages for each of these features. Mononasal approaches and preservation of the posterior septum and middle turbinates are in keeping with a minimally invasive approach. However, these techniques offer less maneuverability of instruments. The endoscope holder allows the surgeon to have both hands free during the operation, but using an endoscope holder tends to negate the advantages of the endoscope because it hampers the dynamic and magnified viewing of regions of interest. Three- and four-hand techniques offer the most instrument maneuverability but require two skilled surgeons to be present simultaneously and require a larger sphenoidotomy to provide enough room for two instruments and the endoscope. The current endoscopic technique at the University of Virginia is a binasal, three- or four-handed approach using a wide anterior sphenoidotomy and a posterior septectomy. The endoscope holder is not used and the middle turbinates are preserved. Image guidance and lumbar drains are employed selectively.

Because the technique is relatively new, appropriate instruments are still in development. A proper bipolar instrument is still needed besides the recent development of instruments like the endobipolar and the disposable suction bipolar forceps. Slotted suckers with angled tips to work in the regions visualized by the endoscope but inaccessible with direct suction are probably the most important tools that turned the extended approaches into a reality. Because old angled suction devices are not slotted, problems could arise when placing the suction into the cavernous sinus or suprasellar region. There is also a need for smaller endoscopes with more zoom range and focus capacity. To foster a wider application of this technique, a standardized set of instruments required to begin performing these operations must be developed.

Conclusions

The history of the endoscope is an example of how technical advancements have influenced surgical techniques. Relatively recent technical improvements have led to its introduction in everyday practice by surgeons in many different areas of specialization. Its use in endonasal skull base neurosurgery appears to hold promise and requires multidisciplinary teamwork. Neurosurgeons, accustomed to the microscope and its 3D view, must learn how to operate with a 2D view, and otolaryngologists have significant experience to share. On the other hand, neurosurgeons can show otolaryngologists how to feel comfortable working close to the brain and other important intracranial structures. There is much to be done in enhancing the acquisition of necessary skills, developing instruments and, importantly, improving the methods of skull base repair.

As stated by Harvey Cushing at the very beginning of transsphenoidal surgery, interdisciplinary work is proving once again to be a major component in the development of this novel aspect of surgery. The performance becomes progressively simplified by the combined suggestion and experience of many.

Harvey Cushing

The Pituitary Body and its Disorders, 1912

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