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The history of the development of neuroendoscopy

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Abstract

The paper examines the features of the establishment and development of endoscopic neurosurgery in the first three stages of its history: rigid (1795–1932), semi-flexible (1932–1958), and in the early fibre-optic period (1958–1981). It also examines the discussion surrounding ideas and techniques of surgical approach in neurosurgery. The era of endoscopic examination in surgery began between the late 18th century and the early 19th century (Philipp Bozzini, 1795; Pierre Salomon Ségalas, 1826; John Dix Fisher, 1827). However Antonin Jean Desormeaux (1853), who created an optical device for examining the urogenital tract and called it the "endoscope", is regarded as the "father of endoscopy". The era of "proper" endoscopes begins with the work of Max Nitze, who developed a method of examining the bladder using a cystoscope that he had invented (1877–1879). The idea of visual examination of internal organs without a large incision of the skin was first advanced in 1901 (Georg Kelling; Dmitry O. Ott) Endoscopy made its way into neurosurgery in the early 20th century when, for the first time, Victor Darwin Lespinasse used an endoscope to examine the choroid plexus (1910). Walter Edward Dandy (examined brain ventricles using an endoscope; coined the term "ventriculoscopy"), Jason Mixter (inventor of endoscopic triventriculostomy; became one of the founding fathers of minimally invasive surgery) were the pioneers of neuroendoscopy. Rapid advances in physics and optics aided the improvement of endoscopes. Authors of the paper also examine surgical approach challenges in endoscopic neurosurgery: transnasal – Jules Hardy, Hae-Dong Jho, Ricardo Carrau, transcranial – Victor Horsley, transbasal, upper nasal transsphenoidal – Hermann Schloffer, transseptal – Theodor Kocher, transsphenoidal – Harvey William Cushing, who later abandoned this approach in favour of the transcranial approach, and Norman Dott, direct transethmoidal approach – Oskar Hirsch and others.

Keywords

history of endoscopy in neurosurgery, neuroendoscopy, cerebral endoscopy, history of medicine

Endoscopy dates back almost two hundred years – from the 18th century Philipp Bozzini, Pierre Salomon Ségalas) to the 19th century John Dix Fisher). Neuroendoscopy is considerably more recent: the endoscope was used to examine the choroid plexus in a clinical setting for the first time in 1910 by American urologist Victor Darwin Lespinasse (1878–1946) (Shamaev and Malysheva 2000, Grant 1996). Since then, many remarkable discoveries have been made in this field. This has facilitated a diagnostic revolution and surgical breakthrough in the treatment of numerous brain diseases, and has enabled us to reach a level of which the first endoscope inventors could never dream.

Nowadays, surgery without endoscopic treatment techniques is unimaginable. Small incisions (punctures) enable not only early detection of a tumour at its early stages (*cancer in situ*) but also the removal of considerably large spinal tumours, intestinal polyps, etc.

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History

The prototypes of endosurgical intervention trace back to the ancient Egyptians. They were associated with the traditions of mourning and embalming the dead - part and parcel of the ancient Egyptian culture and medicine. In line with this tradition, ancient Egyptian embalmers (priests who performed embalming) extracted large organs from the corpse: the heart, kidneys, liver, intestines, lungs, brain, etc., and, without a detailed examination of said organs, placed them in special vessels (canopic boxes) for storage. Postmortal removal of brain matter was carried out by accessing the anterior cranial fossa via the lamina cribrosa. This is confirmed by modern studies of the skulls of Egyptian mummies using computer-aided tomography techniques. This ancient Egyptian technique of penetrating the skull resembles modern-day transnasal endoscopic approaches to tumours of the chiasmosellar area.

The first surviving description of the brain also belongs to the ancient Egyptians. That description is given in the Edwin Smith Papyrus (dated around 1550 B.C.), in which the convolutions of the brain in the event of open head injury are compared to "molten copper". As early as the middle of the second century B.C., Egyptians had noted that brain injury causes paralysis of the limbs. Therefore, they laid the foundation of the scientific notion of the brain (Sorokina 2018, p. 75).

Another great ancient civilisation – Ancient India, whose achievements relating to the structure of the human body, surgery and the invention of surgical instruments were vastly superior to the knowledge of other contemporary civilisations (Subotyalov, Druzhinin, Sorokina 2014) in these fields – gave us exceptional treatises on medicine (*"Suśruta-samhitā", "Aṣṭānga-hṛdaya-samhitā"*). However, our attempt to find prototypes of endoscopic examination in these treatises failed.

Historical background

The era of endoscopic examination in surgery began between the late 18th century and the 19th century. The evolution of this field is closely associated with achievements in related sciences that defined five basic stages in the history of this technique: rigid (1795–1932), which began with the use of rigid endoscopes; semi-flexible (1932–1958), marked by the introduction of semi-flexible endoscopes (R. Schindler, 1932); fibre-optic (1958–1981), whose history began with the first demonstration of the fibre-optic gastroscope (Hirshowitz, 1932); digital (1981–2003) and modern-day telemedicine technology (Starkov, Solodinina, Shishin 2009). This paper examines the first three stages of the establishment and development of neuroendoscopy, as well as the discussion surrounding challenges in surgical approach during endoscopic neurosurgery.

The first device which, based on its function, can be called an endoscope was designed by German scientist Philip Bozzini (1773–1809), in the late 18th century. In 1795, the device was a rigid tube with a system of lenses and mirrors; the light source was an ordinary candle. Bozzini called his device a "Lichtleiter" (German word for "light conductor"). He used the device to examine the nasal cavity, rectum and the cervix during experiments on animals. However, he never used the device in clinical practice for fear of burns. As is known, society at that time was wary of such scientific inquiry, and Bozzini's experiments were not supported by his colleagues. Furthermore, the men of science at the University of Vienna railed against his novel ideas and condemned him "for undue curiosity" (Starkov, Solodinina, Shishin 2009), which has always been the main driving force behind progress and the accumulation of human knowledge.

Understandably, the sad results of Bozzini's experiments cooled the interest of his potential followers. However, the natural process of scientific inquiry could not be stopped, and Bozzini's idea found its continuator: in 1826 French doctor Pierre-Salomon Ségalas (1792–1875) announced that he had used an improved version of Bozzini's device. A year later (1827), American doctor John Dix Fisher (1797–1850) demonstrated his endoscope to his colleagues. The device was a bent tube fitted with mirrors for reflecting a candle flame.

However, despite that contemporary history gives precedence to Bozzini, Ségalas and Fisher, the title of the "father of endoscopy" belongs to French surgeon Antonin Jean Desormeaux (1815–1894), who in 1853 created an optical device for examining the urogenital tract and called it an "endoscope". The device consisted of a system of mirrors and lenses. Desormeaux used a spirit lamp as the light source during endoscopic examination. This enabled him to perform a more detailed and thorough examination of the urogenital tract of a female patient. However, just as in Bozzini's experiments, burns were the primary complication in such examinations (Pettorini and Tamburrini 2007, Desormeaux 1865). The same year, Desormeaux recommended his device for examining the food pipe.

In 1867, German doctor Adolf Kussmaul (1822–1902) (Killian 1901) successfully used Desormeaux's device for this purpose for the first time. A year later, in 1868, he developed a method of performing gastroscopy using a metal tube with a flexible conductor. During the procedure, the patient's upper teeth had to be on the same line as the axis of the food pipe. Kussmaul's principle would later lay the foundation for most techniques employing semi-rigid gastroscopes (Starkov, Solodinina, Shishin 2009, p. 36).

Nevertheless, the era of the first "proper" endoscopes begins with German doctor Max Nitze (1848–1906) – one of the pioneers of urology and endoscopy. In 1877–1879 he developed a technique for examining

the bladder using a cystoscope that he had constructed. This paved the way for the endoscopic examination of hollow organs and cavities of the human body. By improving previous inventions, he created an original "apparatus for direct illumination and investigation of human and animal hollow organs" with a set of lenses inside a metal tube. Therefore, Nitze was the first to put into practice two fundamental ideas: image enlargement using a lens and illumination of organs using internal light (Chuchelov 1973). He was also the first to publish a manual (1889) and atlas (1894) on cystoscopy, where he presented the results of his clinical studies.

The idea of a visual examination of internal organs without a large incision of the skin was put forward by Georg Kelling (1866–1945) in 1901. During an experiment on a dog, he examined internal organs by inserting a cystoscope through a small incision in the abdominal cavity after injecting air into the abdominal cavity.

The same year, Saint Petersburg obstetrician-gynaecologist, director of the Institute of Obstetrics and Gynaecology, Dmitry Oskarovich Ott (1855–1929), announced that he had examined the abdominal cavity using a head mirror, a candle, a mirror and a tube inserted through a culdotomy opening.

The term "laparoscopy" emerged later; it was coined by Swedish doctor Hans Christian Jacobeus (1879–1937), who in the early 1920s was the first to describe a technique of performing laparoscopy, thoracoscopy and pericardoscopy using a cystoscope (Pettorini and Tamburrini 2007, Zinovyeva, Vozisova, Barkhatova 2016).

In 1903, German doctor Alfred Hirschmann (1868–?) used a modified cystoscope to examine the maxillary sinus. He was also one of the founders of paranasal endoscopic surgery.

Endoscopy in neurosurgery

Endoscopic examination techniques made their way into neurosurgery – a new speciality in surgery – in the early 20th century. The presence of a system of cavities in the brain facilitated the development of brain endoscopy first, and the birth of intraventricular surgery later.

As mentioned before, the first intracranial intraventricular endoscopy (the examination of the choroid plexus) was performed in 1910 by Chicago-based American urologist, Victor Darwin Lespinasse (1878–1946) (Shamaev and Malysheva 2000, Grant 1996). He performed choroid plexus coagulation to treat hydrocephalus in two children (the first patient died during the post-operative period; the second lived for 5 years after the operation). This event could have gone unnoticed had he not reported it at a meeting of the local urological society (Grant 1996).

Further development of intraventricular endoscopy is associated with the work of American neurosurgeon Walter Edward Dandy (1886–1946), who is regarded as one of the founding fathers of modern-day neurosurgery and is credited with numerous discoveries and innovations in this field, including the description of the circulation of cerebrospinal fluid in the brain, surgical treatment of hydrocephalus, the practical application of ventriculography and pneumoencephalography, as well as the establishment of the first intensive care unit. In 1918 Dandy performed the puncturing of the brain ventricle and its examination using a nasal retractor. In 1922 he coined the term "ventriculoscopy", i.e., the examination of the brain ventricle using an endoscope. The same year he performed ventriculostomy by perforating the terminal plate via an intracranial approach, endoscopic resection of the choroid plexus in a patient with "communicating" hydrocephalus, as well as cannulation (dilation) of the cerebral aqueduct.

However, the inventor of endoscopic ventriculostomy (endoscopic triventriculostomy as we know it today) is another doctor – Jason Mixter (1880–1958). In 1923 he used an ureteroscope to perform puncturing on a patient with an open fontanelle and to examine the lateral ventricles. The good clinical result of his studies was approved at a conference of the Society of Neurosurgeons. To prove the effectiveness of the procedure, Mixter injected indigo carmine into the lateral ventricles, after which he performed lumbar puncturing and obtained clean, colourless fluid. He then performed triventriculostomy, after which the injected dye appeared in the lumbar fluid.

Mixter is regarded as one of the founding fathers of minimally invasive surgery. In order to minimise brain parenchymal damage, he selected the point for puncturing the frontal cortex with minimal thickness and used a pump to inject liquid into the brain ventricles in order to prevent the walls from collapsing and to maintain the necessary volume of the cavity that could enable relatively safe operation. Mixter started employing coagulation when operating inside the ventricular system. Despite technical challenges associated with the imperfection of the recently discovered photography (in the mid 19th century), it was possible to obtain pictures of target objects with long delay – up to one and a half minutes. It should be noted that this was an era without projection screens, and the surgeon was "one-eyed and one-handed" (Prevedello, Doglieto, Jane 2007).

Rapid advances in physics and optics in the 1950–1960s led to the improvement of endoscopes and aroused even more interest in endoscopy.

In 1952, English physics professor John Hopkins (1918–1994) developed a rigid endoscope with the so-called rod lens system. Thanks to this system, the device had better illumination and higher resolution. While perfecting his endoscopes, Hopkins regularly consulted doctors that were using them in their clinical practice. Similar technologies also laid the foundation of modern-day rigid endoscopes.

In 1969, three American scientists – Charles K. Kao (born 1933), Willard Boyle (1924–2011) and George Elwood Smith (born 1930) – invented a device for converting optical images into an electrical signal – charge-coupled device (CCD). This invention laid the foundation for electron-optical image converters – television screens and computer monitors.

In light of these and other discoveries, intraventricular neurosurgery in the mid 20th century, driven by achievements in related sciences, began its rapid development in a new direction: rigid endoscopes with a cold light source emerged; incandescent lamps were replaced with halogen lamps and later xenon lamps.

In 1973, Japanese neurosurgeon Takanori Fukushima (born 1942) created a ventriculofiberscope which had a diameter of 4 mm, a flexible end and a working channel. Using this instrument, Fukushima performed the first biopsy of a tumour of the lateral ventricle.

In the 1970s, British neurosurgeon Huw Bevan Griffith (1930–1993) developed the first neuroendoscopic system based on a system of optical lenses designed by Harold H. Hopkins (1918–1994). The cladding of this system had an outer diameter of 4.5 mm. Using this instrument, Griffith was able to perform biopsy of tumours, plexectomy and recanalisation of the cerebral aqueduct.

American neurosurgeon Michael Apuzzo (born 1940) was the first to use an angled endoscope (70 degrees and 120 degrees, Vision angled lenses) in various neurosurgical operations.

The problem of surgical approach in neurosurgery

Besides transnasal ventricular neurosurgery, skull base surgery, particularly the surgery of the chiasmosellar region, developed throughout the 20th century.

British neurosurgeon and physiologist, Victor Horsley (1857–1916), performed the first transcranial surgery for pituitary tumours. Italian anatomist and doctor David Giordano, (1890–1896), the chief surgeon at a hospital in Venice, was the first to anatomically justify the approach to the sellar region through the ethmoidal labyrinth. This technique became the blueprint for all subsequent transbasal and transnasal approaches to the complex anatomical area of the sella turcica (Prevedello, Doglieto, Jane 2007).

Hermann Schloffer (1868–1916) made a great contribution to pituitary surgery. Along with anatomical research, he studied the physiology of the pituitary gland, which, at that time, was poorly known. On 16 March 1907, at the University of Innsbruck, Schloffer performed the first successful resection of a pituitary tumour through an upper nasal transsphenoidal approach.

Unfortunately, the first operations in this area were extremely unsuccessful. Due to the imperfect technical capabilities of surgeons of that time and the lack of antibiotics, the operations were accompanied by severe complications, which were usually infectious and inflammatory (Gandi et al. 2009).

Distinguished Swiss neurosurgeon Theodor Kocher (1841–1917) – one of the founding fathers of modern-day surgery – proposed a transseptal approach with externalisation (i.e., turning back) of nasal passages.

Renowned American doctor Harvey William Cushing (1869–1939) also made a tremendous contribution to the development of neurosurgery. He was one of its founding fathers and is often referred to as the father of modern-day neurosurgery. Until 1921, Cushing had almost always used the transsphenoidal approach. However, after 1921, due to numerous complications, he turned to the transcranial approach, and in 1929 he stopped using the transseptal approach (Cushing 1912). His technique of operating the brain considerably reduced mortality during surgical treatment of tumours.

Transsphenoidal surgery was also developing rapidly in Europe. In 1909, Oskar Hirsch (1877–1965) – a surgeon in Vienna – conducted a direct transethmoidal approach, and on 4 June 1910, he performed the first endonasal transseptal submucosal approach. By a twist of fate, the same day on the other side of the Atlantic, in Baltimore (USA), Cushing also performed a transseptal sublabial approach. In 1911, Hirsch and Cushing met in Vienna, where Hirsch had the opportunity to demonstrate his technique to Cushing.

Notably, Hirsch used local irradiation of the tumour using a primitive radiotherapeutic device – a small spoon, similar to a teaspoon, with radium granules.

Fleeing from the Nazis, Hirsch moved to Boston in the late 1930s, where he continued his work. Meanwhile, Europe was witnessing general stagnation of transsphenoidal surgery.

Hirsch's assistant and junior colleague – American neurosurgeon Hannibal Hamlin (1904–1982) – described his work with Hirsch as an "obscure voice in the wilderness". So respected was Cushing, who described the set of symptoms of a pituitary tumour (Itsenko-Cushing syndrome) in 1932, that no one tried to operate on the pituitary gland transnasally (Gandi et al. 2009).

The revival of transsphenoidal surgery in Europe is associated with the name Norman Dott (1897–1973), a Scottish neurosurgeon from Edinburgh who served as Cushing's apprentice in the late 1920s. Almost until his death, Dott never published the results of his studies due to his respect for his mentor Harvey William Cushing, who did not recognise the transsphenoidal approach.

In North America, contemporary transnasal surgery is associated with the name Jules Hardy (born 1932). He made a sizeable contribution to the development of neurophysiology and endocrinology and claimed several awards for his work on pituitary surgery. North American doctors from Pittsburg – neurosurgeon Hae-Dong Jho and otorhinolaryngologist Ricardo Carrau

(Hardy and Wigser 1965) – made a great contribution to the development and flourishing of transnasal endoscopic pituitary surgery.

Conclusion

The endoscope fundamentally transformed surgery and opened the door for the development of neurosurgery. On the cusp of the 21st century, surgical robotic arms replaced direct contact between the surgeon's hands and the patient's tissue. The first operation using the da Vinci robotic system was performed in 1985. Robotics enabled to not only avoid direct contact between the surgeon and the patient, but also enabled to save the course of the operation in computer memory (Zinovyeva, Vozisova, Barkhatova 2016).

In our country – the Soviet Union, and later modern-day Russia – endoscopic neurosurgery advanced rapidly and continues to develop. In major neurosurgical centres such as Moscow, Saint Petersburg, Ekaterinburg, Novosibirsk and Tyumen, hundreds of brain operations are performed every year using endoscopes and other special endoscopic instruments.

In various countries, there are professional associations that bring together neurosurgeons adept at endoscopic techniques. Neurosurgeons/endoscopists actively participate in international scientific conferences. That endoscopic neurosurgery is relevant in the world is proven by the fact that in 2012 at the World Skull Base Congress held in Brighton (United Kingdom), more than 90% of all papers were devoted to endoscopic techniques in neurosurgery.

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