Why and how men first opened the skull remains a matter of speculation. It cannot be determined for certain whether they were attempting to treat medical conditions, as postulated by the English surgeon Sir Victor Horsley (1857–1916), or performing religious and cultural rituals, as suggested by the French physician Pierre Paul Broca (1824–1880). Archaeological findings from 3000 BCE and earlier show that various cultures practiced opening the skull. Early evidence of trephination comes from the famous discovery of the Incan skull by Ephraim George Squier (1821–1888) in the 1860s, which dated to 1530 CE, as well as from several other skulls showing evidence of premortem trephination found across Europe, Asia, and the Americas. Examination of these skulls suggest that most of the individuals survived the operation—suggesting that these procedures were actually attempted as medical treatments rather than religious rituals.

Archeological evidence from such skulls suggests the existence of different techniques for trephination. As explained in detail by Charles Gross, a technique used across various regions such as Peru, France, Israel, and Africa involved the use of rectangular intersecting cuts. Initially these cuts were made using hard stone tools and later using metal tools. Other techniques for trephination included abrasion with a rough tool until the dura was exposed, carving out a circular piece of bone using sharp stone tools, and the creation of multiple small holes in a circumferential manner to facilitate the cutting of a small disk of bone with sharp instruments (Fig. 1).

More detailed information about early operations on the skull can be found in documents providing insight on beliefs and techniques of early skull surgery. The Corpus Hippocraticum, a collection of more than 60 medical texts originating from between 500 BCE and 200 CE, contains the first description of trephination and provides detailed instructions in the chapter “On Head Wounds.” The Greek physician Galen of Pergamon (129–200 CE) further developed and described the technique and contributed tremendously to the understanding of neuroanatomy. In particular, he stressed the importance of maintaining the integrity of the dura mater. Evidence of the practice of trephination has also been found in many cultures outside of Greece and Rome. From ancient times through antiquity and the Middle Ages, trephination and removal of bone fragments were established as treatments for head trauma. Subsequently, cranioplasty using metal plates or even xenografts was developed and described.

After the fall of the Roman Empire, education was largely based in religious institutions, and it was not until the 11th century CE that the first universities (University of Bologna, est. 1088) and medical schools were established. However, cadaveric dissections were forbidden, inhibiting complete understanding of cranial anatomy. It was not until the Renaissance in the 16th century and the cadaveric dissections of Leonardo Da Vinci (1452–1519) and Andreas Vesalius (1514–1564) that the contents of the cranial vault including the cranial nerves became known. Several detailed illustrations of neuroanatomy were subsequently printed for the first time, and the first public dissections of the cranium were performed.

This growing knowledge of cranial anatomy was communicated through organized societies, including the Académie des Sciences in Paris, the Royal Society of London,
and others that formed around the 17th century. These societies, which originated from small scientific circles and grew in the Age of Enlightenment, were dedicated to expanding knowledge and making it publicly available.

Throughout the 17th and 18th centuries, surgeons with extensive practical experience from the battlefields helped advanced surgical technique. One well-known example is the surgeon Antoine Louis (1723–1792), who became secretary of the Académie Royale de Chirurgie in Paris. Louis introduced the use of ligatures to amputate a tumor at its base and successfully removed an extra-axial brain tumor (meningioma) in as early as 1774.

From Cranial Surgery to Brain Surgery

In the period that followed, anatomical and medical knowledge continued to grow, but the practice of cranial surgery remained largely unchanged. It was not until the 19th century that more sophisticated approaches through the skull were developed. This period was marked by scientific advancement in many fields, which allowed surgeons to perform more extensive skull openings, including openings that extended beyond the dura. The development of anesthesia, antisepsis, radiography, hemostasis, and new operating instruments enabled a deeper understanding of neuroanatomy, pathology, and physiology that laid the ground for the evolution of modern neurosurgery.

After several failures and unacknowledged initial successes, William Thomas Green Morton (1819–1868) publicly demonstrated the successful use of ether as an anesthetic on October 16, 1846. This so-called “Ether Day” marks the birth of modern anesthesia and the start of longer, more complex procedures.

Infection was the most common cause of mortality related to trephination during the 18th century. The idea of antisepsis was first described by the Hungarian physician Ignaz Philipp Semmelweis (1818–1865) in 1847 and later introduced into surgery by British surgeon Joseph Lister (1821–1888) in the 1860s. These contributions dramatically reduced rates of perioperative infection.

In 1895, the German physicist Wilhelm Conrad Röntgen (1845–1923) discovered the phenomenon of radiography, and it was introduced into surgery just 1 year later. By 1908, the German neurosurgeon Fedor Krause (1857–1937) published the first neurosurgical text containing a chapter on x-rays. The first purely neuroradiological techniques were introduced by Walter Dandy (1886–1946) in 1918 with ventriculography and in 1919 with pneumoencephalography.

These techniques were followed by the development of angiography in 1926 by António Caetano de Abreu Freire Egas Moniz (1874–1955), a professor of neurology at the University of Lisbon. After some initial testing in cadavers, Moniz injected radioopaque agents such as strontium bromide and sodium iodide into patients before x-ray examination in order to visualize cranial vessels. Moniz is also known as the father of the controversial field of psychosurgery, and in 1949 he was awarded the Nobel Prize in Physiology or Medicine for his contributions in that area.

Removal of the first brain tumor using electrocautery in 1926 marked an important step in the evolution of neurosurgery. In the late 1920s the American neurosurgeon Harvey Cushing (1869–1939) was looking for a more efficient way to ensure hemostasis than the clamp-and-tie methods, which were of limited use in neurosurgery. He found his solution in the “electro-surgical apparatus” developed by Dr. William T. Bovie (1882–1958), a biophysicist working in a nearby hospital. This device used high-frequency electricity to heat-seal or cut tissue on contact. This technique was patented in 1931 and has been used for dissection and hemostasis ever since.

The bipolar electrocautery also paved the way for microsurgery. Previously, hemostasis was achieved through a combination of packing, suture ligation, and surgical clips. From the mid-19th century onward, bone wax was used for calvarial hemostasis.

In 1898 the Italian obstetrician Leonardo Gigli (1863–1908) introduced into neurosurgery a wire saw (“Drahtsäge”), which he initially developed in 1894 during obstetrics training in Germany. The wire saw made craniotomies safer and faster and is still used by neurosurgeons today. Previously, when larger parts of bone needed to be removed, multiple bur holes were enlarged using forceps or a mallet and chisel, a technique that often resulted in concussions.

The endoscope, first developed in 1853 as a cystoscope, was used to perform the first endoscopic third ventriculostomy by Dandy in 1922. The endoscope continued to be developed for use in endonasal and other skull base approaches. Another important tool, the surgical microscope, based on the microscopes invented during the late 16th century, was introduced in 1921. However, it was not used by neurosurgeons until the late 1950s. Alongside these technical advances, surgical technique also improved, allowing for the first successful removal of a brain tumor in 1887 by William W. Keen Jr. (1837–1932).

The evolution of surgery from a risky endeavor to an
The evolution of neurosurgical approaches

evidence-based profession was acknowledged by the scientific community in 1909 when Emil Theodor Kocher (1841–1917) became the first surgeon to receive a Nobel Prize.6 In this climate of dramatic change, Harvey Cushing and others established neurosurgery as a subspecialty and began to treat tumors and other conditions with growing success. The first standardized neurosurgical approaches were developed during this period.

An important tool that enabled the development of standardized approaches was the power drill. Thierry de Martel’s (1875–1940) engineering background helped him introduce an automated drill in 1908 that was able to disengage after penetrating the skull’s inner surface. Power tools enabled surgeons to make precise craniotomies with ease and reduced operative time (Fig. 2).

The Development of Complex Approaches and the Impact of the Microscope

In this dynamic field, it is sometimes difficult to credit surgeons who invented approaches because they may not always be the ones who first described or established these approaches. In the following paragraphs, we describe the development of some of the many neurosurgical approaches (Fig. 3). Although we only mention some of their pioneers, many neurosurgeons have contributed and continue to contribute to the development of our field.

Microsurgery was first propagated by plastic surgeons and otolaryngologists and was introduced to neurosurgery by Theodore Kurze (1922–2002) in 1957. In the 1960s, fellow neurosurgeons, including Raymond M. P. Donaghy (1910–1991) and Mahmut Gazi Yaşargil (b. 1925), actively established microneurosurgery.22 The use of the microscope allowed for surgical access to regions with complex anatomy such as the skull base with its tight networks of vessels and nerves. Use of the microscope led to the development of new approaches and sophisticated modifications.26

The gradual development and subsequent modifications of surgical approaches is well illustrated by the pterional approach. Popularized by Yaşargil in 1969 for intracranial aneurysms, it soon became one of the most widely used approaches in neurosurgery because of the access it provides not only to the anterior circulation but also to lesions of the sellar region, cavernous sinus, and anterior and middle cranial fossae. This approach had its origins in the frontotemporal craniotomy described by George J. Heuer (1882–1950), Krause, and Dandy in the beginning of the 20th century. As more tools became available tools and surgical skills improved, the pterional approach was modified to include removal of the supraorbital rim (Charles Frazier, 1870–1936),12 removal of the zygomatic arch (Cushing), or combined with the orbitozygomatic approach.

Similar progression can be seen in the lateral and posterior approaches. While Krause described the subtemporal craniotomy as early as 1911, it was Charles Drake (1920–1998) who popularized the approach and described new variations and modifications. The operating microscope allowed William F. House (1923–2012) to establish the subtemporal middle fossa approach in 1961 in order to treat vestibular schwannomas.26 Numerous other modifications and extensions have been described since, including removal of the petrous apex, as described by Takeshi Kawase (b. 1944).21

Another major approach was the introduction of the retrosigmoid craniotomy, which provided access to the cerebellopontine angle. This lateral suboccipital approach was first used by Sir Charles A. Balance (1856–1936) in 1894 and was further modified by many neurosurgeons and successfully used in the treatment of vestibular schwannomas and other regional pathologies.26 Similar progression is also seen with the transphenoidal approaches. In 1907, Herman Schloffer (1868–1937) became the first to use a transspHENoidal approach52 to remove a pituitary tumor. This technique was adapted and modified by Cushing6 and others who laid the important

Fig. 2. Intraoperative photograph illustrating a translabyrinthine approach facilitated by power tools, including the hand-held drill, allowing for the fast and precise removal of compact bone.

Fig. 3. Schematic illustration showing examples of typical neurosurgical approaches. From left to right: orbitozygomatic approach, transpetrosal approach, far-lateral approach.
groundwork for further development. Austrian otorhinolaryngologist Oskar Hirsch (1877–1965) was the first to describe an endonasal approach in 1910.19 While this approach was nearly abandoned in the following decades due to high morbidity from infection, the introduction of the microscope and improved imaging techniques led to its renaissance in the late 1960s. Since then, this has been one of the most dynamic areas of neurosurgery. Today, the endonasal route is used for extended approaches to one of the most dynamic areas of neurosurgery. Today, the microscope and improved imaging techniques led to due to high morbidity from infection, the introduction of the microscope and improved imaging techniques led to its renaissance in the late 1960s. Since then, this has been one of the most dynamic areas of neurosurgery. Today, the endonasal route is used for extended approaches to reach lesions even beyond the sellar region.20 While the microscope led to the reemergence of this approach, the endoscope extended its limits.

Although the time of revolutions may appear to be over, the constantly increasing knowledge and technological progression continue to influence neurosurgical approaches to the brain and skull base. Intraoperative MRI and neuronavigation are only a few of many recent advances that have enhanced the practice of standardized neurosurgical approaches. The presence of microsurgical and skull base laboratories (Fig. 4) in neurosurgical education and research enable surgeons to push the frontiers of neurosurgery.

Conclusions

The development of cranial approaches is driven and influenced by new scientific discoveries. Although most approaches have been around for nearly a century, their widespread use and efficacy is only possible due to advances in technological advancement and scientific knowledge. Simple bur holes and extradural approaches have developed into an extensive intradural technique and into minimally invasive and microneurosurgery.

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Disclosure

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