

## History of neurosurgery as an independent medical discipline

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### Abstract

Neurosurgery is a medical specialization practiced worldwide. The term *neurosurgery* was first used in 1904, even though eighteen years before, in 1886, Sir Victor Horsley, considered to be a precursor of this discipline, performed the first craniotomy. Neurosurgery has been an independent medical discipline since the beginning of the twentieth century. It is understood here as the discipline of medicine concerned with the surgical treatment of diseases of the brain, spinal cord, nerves, brain vessels, as well as the spine. Neurosurgery also includes areas of knowledge and skills related to neurology, orthopedics, laryngology, ophthalmology or vascular surgery. Depending on the country where it is taught and practiced, there are different legal environments for training and practicing neurosurgery. In this work, we present a review of the source literature on the development of neurosurgery as an independent medical discipline from its inception until the present day, which is a period spanning nearly one hundred and forty years.

**Keywords:** history, neurosurgery, medicine

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### Introduction to the history of neurosurgery

The second half of the nineteenth century, as well as the turn of the twentieth century, are periods of rapid development of many surgical disciplines, including neurosurgery. This was associated with the discovery of anesthetics and the development of anesthesia, which made it

possible to carry out surgical procedures painlessly for the patient, along with the introduction of the antiseptic principle, which significantly reduced the number of post-surgical infections. The last 25 years of the 19th century also brought numerous

discoveries in neurophysiology, which laid the foundations for the development and rise of the new surgical discipline of neurosurgery. The most important of these was the discovery of functional differentiation of the cerebral cortex by Fritsch and Hitzig in 1870 and its connection with the presented clinical symptoms, made by the British neurologist John H. Jackson (1880). These conceptions were complemented and refined by William Gowers, one of the most luminous of English neurologists of those days. His publication allowed precise planning of surgical procedures involving the skull and the spine. Its fundamental rules are applied to this day. The beginning of the twentieth century also brought with it the discovery of diagnostic research, which provided pioneers of neurosurgery with important data for diagnosing pathologies of the nervous system. To begin with, we need to mention ventriculography here, described and introduced by Walter Dandy in 1918, along with myelography, discovered by Jean Athanase Sicard, as well as cerebral angiography, whose idea and principles were developed and presented by the Nobel laureate Egas Moniz in 1927 [1,2].

In 1929, Alexander Fleming published his initial report on a bacterial growth inhibitor which was later to be named penicillin. This discovery opened a new era in medicine and surgery, and thus also in neurosurgery [1].

The pioneers of the emerging medical discipline were Victor Horsley and William Macewen in Europe, and Harvey Cushing and Walter Dandy in North America. Their work led to the emergence of neurosurgery as an independent specialty of medicine.

### Sir Victor Horsley

Victor Alexander Horsley was an extremely talented surgeon, a devoted and inquisitive researcher, and a tireless social reformer. He demonstrated that surgery of the brain and the spinal cord can be performed with acceptable rates of mortality. Thanks to this, neurosurgery could rise as an independent surgical discipline [3].

Born on April 14, 1857 in Kensington, London, as the third of seven children, he received the name Victor in honor of Queen Victoria. He grew up in a well-to-do family; his father was a popular and well-respected painter and his grandfather was a physician. Victor spent his childhood in Cranbrook, in Kent. From his youngest years, he showed extraordinary manual dexterity – he was ambidextrous – which undoubtedly contributed to his legendary surgical skills [3, 4]. He studied medicine at London University College from 1875 to 1881; one of his teachers there was Sir William Gowers, mentioned above. He came to be known as an extremely talented and creative student. While still in college, he co-authored an article (with his teacher Charlton Bastian) later published in the prestigious magazine *Brain*. He also received a number of awards and decorations for his scientific achievements – gold medals in anatomy and surgery, and silver medals in physiology [3, 5].

In 1882, he was employed as a resident in the surgical clinic of the University College Hospital and already a year later he received the title of Surgeon granted by the Royal College of Surgeons. Despite his young age, he was already a highly valued and widely known practitioner of surgery. He believed that

surgery of the brain could not be performed without a sound knowledge of its physiology and without neurological preparation. He acquired the necessary experience and skills in this type of surgery in the course of animal experiments. By 1886, he had performed over one hundred experimental surgeries on primates, thus perfecting his neurosurgical technique and confirming in practice his previous observations in the area of neurophysiology [4, 5]. In the same year there was a vacancy at the National Hospital for the Paralyzed and Epileptic in Queen Square. The management of the facility intended "to have Horsley and nobody else." He was the only person qualified for the position [3].

At the hospital in Queen Square, Horsley developed neurosurgery as an autonomous discipline of medicine. He performed his first craniotomy on May 25, 1886. The patient was a 22-year-old man suffering from post-traumatic Jackson epilepsy (simple partial motor seizures). The seizures were the result of a scar present in the cerebral cortex in the wake of craniocerebral trauma. The operation consisted in removal of the scar with about half a centimeter margin of healthy, surrounding brain tissue. The patient endured the surgery well and presented no more epileptic seizures. By the end of 1886, Horsley had performed ten craniotomies. According to case descriptions, good results of these operations (clinical improvement or complete recoveries) were achieved in nine cases [1, 3].

In 1887, for the first time in history, he successfully performed a laminectomy to remove a tumor of the spinal cord. The patient was a 42-year-old man with symptoms of paralysis in the

lower limbs. The diagnosis and precise localization of the lesion in the spinal cord resulted from successful cooperation with the outstanding neurologist, and Horsley's former teacher, William Gowers. During the procedure, at the level of the spine indicated by Gowers, a tumor was indeed revealed, and then completely removed from the spinal cord by means of resection. Following the operation, the patient's deficit symptoms in the lower extremities receded, and he returned to good health and fitness. In 1895 at the Congress of the British Medical Association, Horsley presented a study of seven laminectomy cases, performed in the cervical section of the spine, which until then had been considered particularly dangerous surgical challenges with adverse prognosis for the patient. Three of the patients participated in this convention to serve as "living proof" of the beneficial course of this type of treatment [3, 4].

Another innovation Horsley introduced was the use of bone wax to stem bleeding from bones. In 1886, based on his experiments on animals, he developed a mixture of beeswax, salicylic acid and almond oil (antiseptic wax), which effectively inhibited bone bleeding without causing infections. Bone wax is still commonly used in neurosurgery and orthopedic surgery. Other innovations he introduced which are used in neurosurgery to this day, and include his method of cutting the scalp (arched, horseshoe-shaped) and of stopping interstitial bleeding with freshly crushed autologous muscle tissue. He also was the first surgeon to use ligation of the carotid artery in order to stop the bleeding from a ruptured cerebral aneurysm, and the first to attempt intraoperative stimulation of the brain cortex with electrodes. With Robert

Henry Clark, he designed and then built the first stereotactic frame, whose general design and operation are now widely used in functional neurosurgery and in stereotactic biopsies of brain tumors [3, 6, 7].

Victor Horsley was a very creative scientist; he published multiple reports, not only in neurology, neurosurgery and surgery. As a result, as early as 1886, at the age of only 29 years, he became a Fellow of the Royal Society. In 1891, he established *The Journal of Pathology*, which to this day remains one of the most renowned medical journals in the world [4].

In 1887 he married Eldred Bramwell. Their marriage brought forth three children. Horsley loved children and animals; his favorite place for Sunday walks was the zoo. He also became known as a social activist. A staunch supporter of women's rights, he postulated that women doctors should be allowed to work at the Queen Square Hospital, and that nursing should be recognized as a profession. This exposed him to a great deal of hostility, as did his steadfast opposition to consumption of tobacco and alcohol. He started a campaign against giving rations of rum to soldiers fighting on the frontlines of World War I. These were not actions which would have brought him popularity among soldiers. He was elected President of the British Society for Sobriety in 1896 and co-authored the book *Alcohol and the Human Body*, published in 1907. In the following years he became involved in politics. He anticipated the advantages of the law on universal insurance, introduced many years later, providing better care for patients and favorable pay conditions for doctors. His political activity was interrupted in 1915, when he was sent on a

medical mission to Egypt. A year later, in April 1916, without informing his loved ones, he left for Mesopotamia, worried about the collapse of the healthcare system there. Thanks to his efforts, he improved the functioning of the medical and sanitary system, the supply of drinking water to the province, and developed hygiene procedures in desert facilities. Satisfied with the course of his mission, he planned to set off on his way back. Just before leaving, he was summoned to the neighboring village for a medical consultation to a wounded officer. He walked several miles in full sunshine, with a very high temperature. When he returned, he complained of a severe headache and high fever. He was admitted to the military hospital, where he fell into a coma. The next day, on July 16, 1916, he died at the age of 59. Heatstroke was indicated as the cause of death. He was buried in the military cemetery in Al-Amara, in today's Iraq. [1, 3, 4, 6].

Sir Victor Horsley was one of those remarkably talented individuals who were able to combine the results of their experimental research with clinical practice, which in turn enabled the emergence and rapid development of the new medical discipline of neurosurgery.

### **Harvey William Cushing**

The pioneer of neurosurgery on the American continent was Harvey William Cushing. Born on April 8, 1869 in Cleveland, Ohio, Cushing was the youngest of ten children. His father Kirk was a physician, a descendant of the British Puritans who came to North America in the 17th century. As a child, he attended the Cleveland Manual Training School, where he developed manual dexterity, which probably influenced his

success as a surgeon in the future. He earned his medical degree from Harvard Medical School in 1895. Afterwards, he started his surgical education under the supervision of one of the most outstanding surgeons of the time, William Halsted, at the Johns Hopkins Hospital in Baltimore. At that time he learned and perfected precise surgical techniques under the watchful eye of his mentor. In 1900, he went to Europe to study surgery of the nervous system. He went to London, where he intended to complete a training placement with Victor Horsley. Unfortunately, the circumstances were not favorable for this stay. Busy with many endeavors, Horsley was unable to offer the guest sufficient commitment. As Halsted's pupil, Cushing was accustomed to the precise, meticulous performance of surgical procedures, and thus he was shocked by the momentum and pace of the operations Horsley performed. It made a great impression on Cushing. Then he went to Switzerland, to the laboratory of Theodore Kocher. As he later recalled, he spent the most fruitful year of his medical life there. He carried out tests on cerebrospinal fluid and intracranial pressure. It was then that he described the phenomenon of increased arterial blood pressure with accompanying bradycardia in response to increased intracranial pressure. This phenomenon is known today as the Cushing reflex. During his journey across Europe, he met with many prominent surgeons who performed operations on the nervous system. Apart from his short stay with Victor Horsley, he also completed an internship with William Macewen. These meetings gave Harvey Cushing an impulse to devote himself completely to neurosurgery. On his return

to Baltimore, he presented his intentions to Halsted. [2, 6, 8, 9].

By all accounts, Harvey Cushing was predisposed to devote himself to this little-known field of medicine in the United States. His outstanding abilities, imaginativeness and ingenuity, along with his legendary manual dexterity, allowed him to lay the foundations of neurosurgery on the American continent, and as it later turned out, also worldwide. Establishing his own surgical workshop on the principles of Halsted's school, he imposed on himself and his colleagues very strict standards of professional conduct, which were followed by successive generations of neurosurgeons. All this allowed neurosurgery to emancipate itself out of the mainstream of general surgery, and consolidate into a new, independent medical field. Cushing created almost from scratch a new kind of surgical technique, very different from what he saw during his stay with Victor Horsley in London. He believed that the hitherto "heavy" technique used in abdominal surgery was not suitable for use in brain surgery. He claimed that surgical technique must be particularly gentle on the operated brain, so that the damage done by the surgeon is minimal, and therefore the post-surgical impairment is as small as possible ("[the brain] should be operated on in such a way that it does not know about it").

The operations Cushing performed took many hours. Oftentimes most of this time was devoted to meticulous hemostasis. He also placed great emphasis on post-operative care and created prototypes of today's intensive care rooms. His extraordinary abilities, the technical excellence of his operations, and the strict rigor of asepticism resulted in less frequent

postoperative complications and a significant reduction in mortality during operations. His assumptions are still valid in neurosurgery today. In 1911, he was the first to use silver clips to stop bleeding, and in 1925 he used electrocoagulation for the first time. He also spread the use of medical aspirators, without which no neurosurgeon can imagine performing any operation nowadays. He also used the first blunt ventricular needle to puncture the lateral ventricle of the brain and discharge cerebrospinal fluid so as to improve the operative conditions [2,6,8]. In 1915, during the Boston Surgical Congress, he demonstrated the influence of the pituitary gland on the body's growth and development [2,8].

In 1912, Cushing took charge of the surgical department of the Peter Bent Brigham Hospital in Boston. Naturally, the majority of his patients were neurosurgical patients. In 1912 he was appointed professor of surgery at Harvard University.

In World War I, during combat in France, in 1917 he created medical stations operating in close proximity to the front lines – the so-called neurosurgical head trauma departments. They dealt with modern treatment of gunshot wounds. He put real emphasis on the thorough cleansing of the wound, removal of bone fragments and foreign bodies (bullets), as well as necrotic fragments of the brain. Thanks to this, the death rate of gunshot wound victims was reduced by almost half, from 52 to 28 percent. Afterwards, medical facilities in practically all armies fighting in the Second World War were created on the models of the neurosurgical stations, achieving a further reduction in mortality of this type of injury (up to 15%).

In 1925, together with Tracy Jackson Putnam, he announced the current theory on the formation, course and guidelines for treatment of subdural hematoma. In 1930, at the end of his professional activity, at the congress in Bern, he presented an impressive series of brain tumors he had operated on thus far – two thousand cases. In 1932, in his last monograph devoted to the pituitary gland, he gave a detailed definition and description of hyperactivity of the adrenal gland caused by adenomas of the pituitary gland, henceforth known as Cushing's disease. That was also the year when he retired. The monograph on meningiomas Published in 1938 (in cooperation with Luise Eisenhardt), is recognized as a work of monumental significance for this area [6, 9].

Achievements of the neurosurgical school created by Cushing gained worldwide fame. His clinic at Peter Bent Brigham Hospital in Boston became a world-renowned center of the new discipline of neurosurgery. The surgical technique Cushing created was adopted as standard all over the world. During his professional career, many creatively competitive neurosurgical centers were established in the United States, which brought dynamic development of the new discipline [2].

Harvey Cushing died in New Haven on October 7, 1939, at the age of 70, in the wake of complications following a heart attack. He was buried in Lake View Cemetery in Cleveland – the city of his birth [8].

### **Walter Dandy**

Another preeminent figure considered to be one of the founding fathers of neurosurgery was Walter Dandy.

Born on April 6, 1886 in the town of Sedalia, Missouri, he was the only son of John Dandy, a railroad engineer, and Rachel Kilpatrick, both of whom were immigrants from Great Britain. In 1910, he completed his medical studies at the Johns Hopkins University in Baltimore. From 1910 to 1911, he carried out research under the direction of Harvey Cushing, and then, until 1912, he worked as a surgical resident under his supervision at the Johns Hopkins Hospital, i.e. until Harvey Cushing moved to Boston. Just like his first teacher, Walter Dandy also received his general surgical training and final polish under the watchful eye of the seasoned master of surgery William Halsted, and in 1918 he earned the title of Surgeon. At the same time, he received training in neurosurgery under the tutelage of Georg Heuer, Cushing's first pupil and assistant, who went on to become his successor in Baltimore, after Cushing left for Boston. On completing his residency in surgery, Dandy joined the team of the Surgery Clinic at the Johns Hopkins Hospital. Passionate and committed, he devoted himself to surgical treatment of diseases of the brain and the spinal cord. After Georg Heuer had left for Cincinnati, Dandy took charge of the newly established Neurosurgery Ward, which he headed until his death in 1946. In 1924, he married Sadie E. Martin, with whom he had four children. The oldest of them, Walter Dandy junior, became a doctor, but as a result of an eye injury sustained in childhood, he could not fully follow in his father's footsteps and take up surgery. He became famous as an anesthesiologist, founder of the first intensive care unit in Baltimore (in the Union Memorial Hospital). He died at the age of 87 in July 2013. Walter Dandy Sr. died on 19 April

1946 in his hospital, as a result of complications following his second myocardial infarction, which took place about a fortnight after the first. He was buried at the Druid Ridge cemetery in Pikesville, Maryland [1, 6, 9, 10, 11].

Dandy gained recognition as an unsurpassed technician, performing all possible and thus far impossible innovative operations. He presented a more aggressive style of surgery in comparison to Cushing. In his research, he devoted a good deal of time to studies on the formation and circulation of cerebrospinal fluid and the formation of hydrocephalus. He described a syndrome of congenital brain defects with accompanying hydrocephalus called the Dandy-Walker syndrome. For diagnostic purposes, he developed a new, epoch-making imaging test – ventriculography, and a year later, in 1919, also pneumoencephalography (supplying of air to the fluid spaces from a lumbar puncture). This method was discovered by accident – on observing a patient in whom intracranial air was found after a skull fracture. For the first time, it became possible to pinpoint the location of a brain tumor by analyzing displacement of air in the ventricles of the brain. Some believe that the period of the emerging of neurosurgery can be divided into the era before and after pneumocephalus (after the introduction of pneumoencephalography). Since then neurosurgeons have been able to use this very helpful diagnostic method. For this discovery, Dandy was nominated for the 1933 Nobel Prize. The method remained in common usage until the introduction of computed tomography in the nineteen-seventies [1, 6].

Walter Dandy performed a number of pioneering operations, which he then described and published. The most

important of these are a complete removal of a cerebellopontine angle tumor (schwannoma), an operation with the use of an endoscope to destroy and remove the choroid plexus in order to reduce the production of cerebrospinal fluid, as a means of treating hydrocephalus, a surgical removal of a pineal gland tumor, cutting of the trigeminal nerve in the area of its departure from the brain stem in the treatment of trigeminal neuralgia, cutting of the atrial nerve in the treatment of Ménière's disease, a hemispherectomy, as well as an operation of a tumor of the third ventricle. His monograph on the anatomy of the third ventricle is illustrated with some of the best anatomical drawings in history and remains valid to this day. In 1929, Walter Dandy was also the first in the world to perform an operation to treat a herniated intervertebral disc in the lumbar section of the spine. Today this is a standard procedure, performed in every neurosurgical ward worldwide.

Walter Dandy also made enormous contributions to brain vessel surgery. On March 23, 1937, he performed the procedure of clipping a ruptured aneurysm of the artery connecting the posterior brain by means of frontotemporal craniotomy. For the first time in history, a clip was fastened on the neck of a bleeding aneurysm. Dandy described the course of this procedure and published an article one year later, in 1938. He also performed other pioneering vascular procedures, such as operations on arteriovenous malformations and on arteriovenous fistulas. Two years before his death, in 1944, he published the book *Intracranial Aneurysms*, containing a summary of his own experiences and descriptions of surgical techniques [1,6,11].

In 2011, the Walter E. Dandy Neurosurgical Society was established in St. Louis, which nowadays has its chapters in twenty-three countries of the world, including Poland. The Society provides a forum for exchanging medical information, and conducts training internships and courses for neurosurgeons and neurosurgical residents [11].

### **Egas Moniz**

An extremely interesting figure, who contributed greatly to the development of neurosurgery, was the Portuguese physician Antonio Caetano de Abreu Freire Egas Moniz, known simply as Egas Moniz. Interestingly, he was not a neurosurgeon by training, but a neurologist. He never performed any neurosurgical operation. However, his discoveries undoubtedly influenced the development of the discipline. Born on 29 November 1874 in Avancy near Aveiro, he came from a family of Portuguese aristocracy. In 1891, he began his studies in mathematics at the University of Coimbra, which he successfully completed. Then, in 1899, he completed his medical studies at the same university. Already as a student, he was particularly interested in neurology. He completed a number of training internships in France, among others with the famous neurologist of Polish origin Józef Babinski. After his studies, he worked in his alma mater until 1911, when, as a professor, he took charge of the chair of neurology at the newly established University of Lisbon, where he worked there until his retirement in 1944, and then carried on as senior professor until the end of his life in 1955. While working in Coimbra, he became active in politics. He was one of the founders of the Centro-Republican Party, founded in 1903,

and became a member of parliament on its behalf. He sat in parliament continuously until 1917. He then became an ambassador in Madrid, and in 1918 became the foreign minister.

In 1919, he led the Portuguese delegation at the Peace Conference at Versailles. After the end of the conference in 1920, he left politics and devoted himself to scientific research. As a man of broad horizons, he was also a literary critic, poet, prose writer (he wrote mainly on subjects on the borderline of history and medicine), a gambling expert, and an avid card player (he published, among others, the book *História das cartas de jogar* [History of playing-cards], reprinted in 1998). He even tried his hand as a composer and was a very good dancer. In 1939 he was shot by a schizophrenic patient, dissatisfied with the amount of medication prescribed. Since then he was partially paralyzed. In 1951 he was offered the office of Vice-President of Portugal, but refused for medical reasons. He married Elvira de Macedo Dias 1902, but the couple had no children. He died on December 13, 1955 in Lisbon [12,13].

In 1927, he developed a new diagnostic method – cerebral arteriography. Currently, after numerous improvements, it is the gold standard in diagnosing cerebral vascular diseases. Egas Moniz developed his method on animals and then used it for diagnosing human patients. Unfortunately, it turned out that the contrast medium initially used (70% strontium bromide) was toxic to patients. Of the first six studies, only one had diagnostic value; all patients experienced strong side effects, and one of them died. Only upon changing the contrast medium to sodium iodide was the safety and diagnostic value of the method

increased. Moniz improved his method in cooperation with the radiologist Pereira Caldas. They developed a method for dynamic blood flow imaging with a device that allowed recording six X-ray images per minute. He also co-created the first angiographic contrast agent – Thorotrast, which, however, turned out to be strongly carcinogenic. The technique of angiography developed by Egas Moniz gained appreciation and became widely introduced into neurosurgical practice only in the 1950s, when new, much less toxic contrast agents were developed. For his invention of arteriography, he was nominated for the Nobel Prize in 1928 [1, 12, 13, 15].

In 1935, he described the procedure of lobotomy, controversial as it later turned out, and mutilating for the patients, which was then widely used for a number of years in the treatment of psychiatric patients, especially those suffering from paranoid schizophrenia and bipolar affective disorder. It became a common treatment for schizophrenia before neuroleptics – promazine derivatives – were discovered and introduced into general use in the 1950s. In November 1935, Pedro Lima (“the father of Portuguese neurosurgery”) under the supervision of Moniz, performed the first lobotomy. Through burr holes drilled in the patient’s skull, he administered a neurolytic agent to a female patient with schizophrenia, thus destroying the nerve connections in the white matter of the frontal lobes. Following the procedure, the patient’s delusions were found to have receded; however, apathy and cognitive dysfunction were observed. For subsequent treatments, Moniz used a device he himself developed, not dissimilar from today’s devices for

ablative surgery of the brain. In 1936, he published the results of treating twenty 20 patients by means of lobotomy. He considered the results to be very promising, despite the short time of observation of the patients. In 1949, after his third nomination, he was awarded the Nobel Prize in Medicine for his “discovery of the therapeutic value of leucotomy in certain psychoses.” This method was widely disseminated in the medical world in the United States by Walter Freeman, professor of the George Washington University. He performed nearly 3400 lobotomy procedures, acting as a kind of “travelling circus.” In the record two weeks of 1952 he performed 228 such procedures. He travelled around the country in a special vehicle (later called the lobotomobile), performing lobotomies with the use of a tool he developed via the transorbital route. The procedures were often performed in hotel rooms, without proper anesthesia. It is believed that at the end of the 1940s about five thousand such procedures were performed annually in the USA. Among the patients subjected to this procedure was Rosemary Kennedy, a sister of John F. Kennedy, the future president of the United States. She was observed to have dramatic personality changes following the procedure. However, on the wave of great enthusiasm, the more and more visible side effects remained overlooked [12, 13, 14, 16].

Lobotomy was gradually prohibited in more and more countries. The first country to ban it, as early as 1950 (i.e. only one year after Moniz received the Nobel Prize), was the Soviet Union. The regulation of the USSR Ministry of Health said that “this method is contrary to the principles of humanity” and that it turns “an insane person into an idiot.” In 1956,

Brazil followed in the footsteps of the USSR, and then other countries. The method was practically stopped at the turn of the 1970s [12].

Despite the fact that lobotomy became a ‘black legend’ and a blind alley of medicine, it undoubtedly laid the foundations for the development of the branch of neurosurgery called psychosurgery in later years. In popular culture, the method is known mainly thanks to the 1975 film *One Flew Over the Cuckoo's Nest*, directed by Milos Forman. There have also been demands for Egas Moniz’s Nobel Prize to be posthumously rescinded, put forward in particular by American institutions, which focused on the victims of lobotomies. It is impossible to rescind the Nobel Prize, as stipulated in the statutes of the Nobel Foundation. In 1998 the Nobel Committee published a report by Bengt Jansson, Professor of Psychiatry. It explains that at the time of Moniz, there was no alternative to lobotomy because neuroleptics were introduced to use only in 1952 [12, 16].

The above article presents four great figures, which have influenced the emergence and development of the still not fully discovered medical discipline of neurosurgery. Their activities, so varied and at times controversial, have led to the development of many fundamental diagnostic methods and surgical techniques which are used to this day.

### Declarations

- Availability of data and materials: All relevant data are within the paper.
- Competing Interests: The authors declare that they have no conflict of interest.

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