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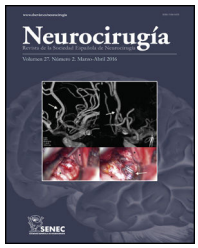

Review article

The genesis of Academic Neurosurgery. Part I: The so-called "Gestational Period" and the contributions of Harvey Cushing

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ABSTRACT

This is the first of five papers describing the origin and evolution of the so-called Academic Neurosurgery which will appear consecutively in the journal Neurocirugía. The three firsts focuse on the emergence of the specialty in Europe and the United States and its development in the last country between the origins and the present moment, paying special attention to the foundation of the neurosurgical societies (SNS, AANS, CNS) with their respective journals and the configuration of the residency programs. The fourth analyzes the same issues in Europe and, most specifically in Spain, also from the beginnigs to the XXI century. The fifth describes the development of Academic Neurosurgery in a neurosurgical unit of one of hospitals created by the National Social Security System in the early 1970s.

The present paper describes the initiatives, difficulties and achievements of the pioneers at both sides of the Atlantic during the so called Gestational Period for creating the new and independent specialty of Neurosurgey conceived as a scientific and clínico-surgical activiy with an academic profil.

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Abbreviations: SNS, Society of Neurological Surgeons; AANS, American Association of Neurological Surgeons; CNS, Congress of Neurological Surgeons; EANS, European Association of Neurosurgical Societies.

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La génesis de la Neurocirugía Académica. Parte I: El llamado "Periodo Gestacional" y las contribuciones de Harvey Cushing

Palabras clave:
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Enseñanza de postgrado
Investigación
Escuela del Johns Hopkins

RESUMEN

Este artículo es el primero de cinco enfocados sobre la génesis y evolución de la llamada Neurocirugía Académica (Ncgía-Acad) que se remitirán a la revista Neurocirugía para su publicación. Los tres primeros contemplan el nacimiento de la especialidad en Europa y los EE.UU. de América y su desarrollo posterior en este último país prestando especial atención a la creación de las sociedades neuroquirúrgicas (SNS, AANS, CNS) con sus órganos respectivos de expresión (Journals), y a la configuración del sistema de residencia de postgrado. El cuarto se ocupa de su recorrido en Europa, y más en particular de lo ocurrido en España, entre los orígenes y el momento actual; y el quinto se centra en la descripción de su desarrollo en un servicio representativo de la moderna red hospitalaria de la Seguridad Social creada en los 1970s.

Aquí se describen las iniciativas, dificultades y logros de los pioneros en la etapa inicial de la creación de la Neurocirugía (el llamado Gestational Period) para hacer de ella una especialidad independiente concebida como una actividad científica y clínico-quirúrgica de perfil académico.

"The duty of a historian is simply to understand and then convey that understanding, no more than that." Antony Beevor

Introduction

Looking at the history of medical or academic institutions, we can see them adopting approaches over time which, not being well defined at the outset, have led to the need for successive transformations in response to changes in the socio-economic or academic contexts. One example of lack of definition is what occurred at the time Neurosurgery was being created as an independent speciality, when the divergence was established between the discipline äcademic neurosurgeryänd practising neurosurgery with a purely healthcare purpose outside of teaching and research tasks. This is an alternative which, having ŕesonatedöver the last 100 years, generates new disharmony today, when the speciality is besieged by numerous challenges and difficulties.

Other approaches which have had to be reconsidered on a recurrent basis throughout the history of neurosurgery are: (1) the structuring and functioning of professional societies (such as SNS, AANS, EANS); (2) the profile and focus of the journals used as organs of expression for these societies; (3) the configuration of training and assessment programmes for residents; (4) the types and priorities of clinical or laboratory neurosurgical research; and (5) the definition and maintaining of the high standard of professionalism that has to direct neurosurgeons' relationships with patients, colleagues and, the most difficult to achieve, those responsible for healthcare administration and management.

The neurosurgeon group at Hospital Universitario 12 de Octubre [Ï2th OctoberÜniversity Hospital] has carried out a review of the origins of academic neurosurgery and how it has evolved in Europe and North America which they hope to publish in a series of articles in the journal NEUROCIRUGÍA [Neurosurgery]. In this analysis, comparatively greater importance is attached to developments in the USA. This is because the USA had taken the lead in medicine and surgery at the time when Academic Neurosurgery was forging its way as an independent speciality and, since then, it has made the most relevant contributions to its progress. The enormous economic potential of the USA, and the fact that it did not suffer the disasters caused by the two world wars on its own soil, while the participating European nations were devastated, enabled it to become a definitive reference, not only in medical practice, but also in terms of innovation and development in research and teaching at the undergraduate and postgraduate levels.

The differences between the state organisation of healthcare in European countries and the more autonomous and entrepreneurial organisation of healthcare in the USA do not mean we cannot use analyses of what has happened in the US to also try to improve European academic neurosurgery. The negative effects caused by restrictions in healthcare spending on neurosurgical practice and the functioning of the residency system have been essentially the same on both sides of the Atlantic.

This first part of the article on the origins of academic neurosurgery describes the pioneering process which, having started in Europe, spread immediately to the USA.

The emergence of academic neurosurgery in Europe and the USA and its development in the USA over the turn of the 19th-20th century (the so-called gestational period)

We should stress that academic neurosurgery has its origins not only in innovations in surgical technique, but also, and especially, in the intellectual creation of a series of concepts and principles by European and North American pioneers. These were initiators who, in addition to the concern of how to operate better, set out from the outset to find the knowledge they lacked on all four sides. We are talking here about research, which represents another of the three pillars of academic neurosurgery; but in addition to exercising the intellectual habit of enquiry, the pioneers felt the need to share and discuss what they were discovering at the congresses of a scientific society that they had to create, and also to publish it in the most reputable general journals of the time, as they did not have their own until the mid-1940s.

Therefore, rather than listing and going into detail about the major technical contributions introduced by those who enabled neurosurgery to become an independent speciality, we focus on the pathophysiological principles and conceptions established by them (more particularly those of Cushing) which were equally, if not more, decisive for its crowning as an academic speciality.[1–6]

The emergence of neurosurgery as an independent speciality was based primarily on the work of Victor Horsley in England, William MacEwen in Scotland and that of Harvey Cushing, Charles Frazier and Charles Elsberg in the USA. Cushing surpassed them all because he was the first to: (1) limit his practice to neurosurgery; (2) create with 10 other friends the first neurosurgical society (the SNS); (3) adopt the routine of carefully collecting and recording the cases he treated and then publishing the results (clinical research); and (4) create a school that attracted students and surgeons from home and abroad.[7] Hugh Cairns called him the father of modern brain surgery.

Before going any further, we need to highlight that the birth of neurosurgery in the USA was formally recorded with the publication in 1905 of Cushing's article The special field of neurological surgery, which he confessed to having written at the time of his personal decision to limit his surgical work to neurosurgery, against the advice of the vast majority of his colleagues.[8] This article represents a milestone, the contents of which Cushing returned to in 1910 and 1921 (see below). However, some believe that the principle of the independence of neurosurgery was most clearly shown with the publication of the chapter Surgery of the head, also written by Cushing in 1906 for WW Keen's *Surgery, its principles and practice*, the most important book of the time.

The first steps towards the independence of neurosurgery

Between the mid-1880s and 1900, and on the basis of isolated physiological and pathological investigations, a few operations were performed to treat tumours, abscesses, haematomas and other intracranial diseases or spinal tumours, which were only rarely successful. Victor Horsley (1857–1916), lecturer at University College, and surgeon at the Queen Square National Hospital in London, demonstrated that surgery could improve the outcome of patients with certain CNS lesions compared to what had previously been possible. However, his technique, like that of other European surgeons of the time, remained crude and closely linked to the methods of general surgery which could not be applied to delicate nerve structures. Horsley said that the surgical progress of neurosurgery was less than the improvement in the knowledge already possessed of the seat and nature of the diseases for which they applied surgery,[6] and this was even more true for the early surgeons on the European continent who operated on only a few cranial and spinal processes with worse results than Horsley.

For Horrax it was undeniable that, although at the turn of the 19th-20th century the new field of neurosurgery had already been opened up, there were still no neurosurgeons clearly recognised as such, and none had managed to develop a technique sufficiently meticulous that their operations, particularly brain operations, would provide outcomes similar to those obtained at that time with interventions on other parts of the body.[4] It was at this critical moment that Cushing, who was working as an assistant in the department of surgery at Johns Hopkins Hospital and in the Hunterian laboratory at his medical school, decided to devote himself entirely to the speciality (see below).

In any event, the exact dates and places in the period of consolidation of modern neurosurgery in the forty years that Greenblatt calls the gestational periodare uncertain.[3] Neurology had laid one of its most solid foundations with the theory of localisation of function, which began in 1861 with Broca's famous observation of a lesion at the foot of the 3rd frontal gyrus of the left hemisphere in the autopsy of an aphasic man, followed by the clinical observations of Charcot, Pitres and Jackson, and the experimental observations using faradic stimulation or ablation of the cerebral cortex by Fricht and Hitzig, or Foerster and Ferrier. However, the individuality of neurosurgery as a surgical speciality was not recognised until it established its unique principles and developed its own surgical technique.

According to Greenblatt, Cushing was, considered in isolation, the most important contributor to the development of neurosurgery during the gestational period because he introduced the technical improvements that reduced mortality rates to acceptable levels. It should be noted, however, that the impact of this pioneer on the development of what we call academic neurosurgery was due as much or more to his intellectual work than to his strictly technical contributions, and more specifically to his habit of carefully documenting and following the natural evolution of the tumours he operated on (the beginning of clinical research). But let us review the steps taken by the European pioneers, almost all of whom came from the core of Surgery.

For Wilder Penfield, Neurosurgery was born in the United Kingdom in the period 1870–1900, when William MacEwen (1848–1924), working at Glasgow Royal Infirmary, wisely combined the aforementioned principles of localisation of function in the CNS with asepsis and anaesthesia, making it

possible to perform the first modern neurosurgical operations, which were perfected in the first decades of the 20th century in the USA, following the familiar pattern of basic science in Europe and applied science in the USA.[1] Back in 1867 Joseph Lister had published in the *Lancet* his six landmark articles on the preliminary results with the use of 5% carbolic acid (phenol), which he himself used to prepare the skin and surgical instruments in the operation of a patient with a brain tumour which had been localised by David Ferrier. The opening of the dura was followed by uncontrollable protrusion of the brain, and the subsequent post-mortem examination showed that the tumour had escaped by less than an inch. This was not, however, the beginning of neurosurgery, nor would it have been if the patient had benefited from the procedure, because several of the essential principles of the speciality had not yet been established.

By conducting preoperative investigations based on anatomical and functional knowledge, and after becoming familiar with the localising techniques of Hughlings Jackson and David Ferrier, the aforementioned MacEwen, who had been a student and later colleague of Lister, was able in 1876 to puncture an abscess in a deceased man who had presented with aphasia and seizures on the right side, an experience that led him to correctly locate and remove an intracerebral haematoma, a convexity meningioma, a syphilitic gumma and a series of temporal abscesses, operations that some considered the first modern neurosurgical operations. In 1890 he reported 21 craniotomies to evacuate brain abscesses with 18 complete recoveries, but the most remarkable thing about this success is that it was based on his experience with a first case not included among the 21, because it corresponded to a child whose parents would not let him operate, whom MacEwen subjected to a post mortem transcortical puncture, which released pus from the site he had predicted. Most remarkable of MacEwen's genius was his daring to locate and remove lesions not associated with any recognisable external markings, for which he was bitterly criticised in a leading journal, even though he had demonstrated a momentous fact or principle which was still beyond the understanding of the time, namely that one could advance from basic to applied science.[1]

In 1884 Rickman Godlee (1849–1925), also related to the great Lister (he was his nephew), removed a brain tumour in Queen Square which had been diagnosed by Hughes Bennett also using the localisation theory.[9] Nonetheless, this was not the beginning of neurosurgery either, because although the localisation was particularly precise on this occasion, the surgical technique was still deficient. In fact, the patient died of infection a few weeks later, but some said that this was the prologue to Neurosurgery, and that the curtain had finally been lifted. However, this was not the case. As Penfield pointed out, those who were to play an essential role in the birth of Neurosurgery were present, watching in detail, at the operation performed by Godlee; indeed, David Ferrier and Hughlings Jackson, anxiously behind the mask, watched the tumour being removed. Even more importantly, two young surgeons mentioned above, Victor Horsley and William MacEwen, were in the audience at the meeting where, after a certain time, the case was presented and discussed.[1]

For Penfield the initial formulation of the principles of neurosurgery was in the minds of these two young men, beginners who had also been at Marshall Hall a year earlier when Ferrier presented the results of experimental interventions on the mammalian brain, stating that the time had come for neurosurgery. Penfield thought that perhaps these two men also had in mind the earlier contributions of Hughlings Jackson, then 50 years old, who had given a series of lectures on neurological science over the years and had already published his books *The diagnosis of brain tumours* and *Localised convulsions from tumour of the brain*.

In any case, and in order to do justice, it should be remembered that in this aural period of the gestation of neurosurgery, Victor Horsley had already published his first work on the motor centres in the brains of traumatised patients in 1879, and in 1886 he performed the first brain surgery in London to resect an epileptogenic focus. That same year he reported his case load of 10 craniotomies in humans (he operated without electrocoagulation, transfusions, ventriculography, ventricular puncture or antibiotics, and approached the tumours in two phases: first carving the osteoplastic flap, which he closed, and removing the tumour a few days later, achieving haemostasis with bone wax and small pieces of muscle). Two years later he reported the first successful resection of a localised spinal meningioma by neurologist William Gowers on the basis of the neurological examination of the patient, and in 1890 at the International Congress of Neurology in Berlin he presented a series of 44 cases of operated brain tumour with 19 deaths (43% mortality rate), a communication which received the most enthusiastic of accolades.

Horsley's contribution was essential in shaping the academic profile of neurosurgery, because he was among the pioneers who looked and thought and did not just operate, i.e. who used basic science to plan surgical interventions. His mentality was open early on to the experimental field, with a special interest in the CNS, and more particularly in the motor centres, gathering observations on traumatised patients which he reflected in a publication that came out only five years after finishing his degree (at the age of 25). A year later he was appointed head of the Brown Institution of the University of London, dedicated to research in physiology and pathology, where he worked on the localisation of brain function and the pathology of epilepsy. In 1884 he extended David Ferrier's findings with the localisation of function in the primate brain, to work later with Beevor and Semon on mapping with faradic stimulation of the centres of the orangutan cortex.

Horsley was fascinated by the basic sciences, and so worked in comparative anatomy and experimental pathology using, among other resources, the first stereotaxic guide designed in collaboration with Clarke to produce electrolytic lesions and deep stimulations in the laboratory animal. Despite his work and mental distractions (he cultivated numerous fronts in the sciences and humanities at the same time), Horsley was able to recruit a large group of collaborators.

Before we go on, a brief reminder that not all the leaders of early neurosurgery were surgeons beforehand. Otfrid Foerster from Breslau was a neurologist who assisted professor of surgery Kutner for a time, until in a fit of impatience he picked up the scalpel himself; Foerster's contributions were important in the field of neurophysiology, but not in surgical technique, because for him neurosurgery was above all an

opportunity to study pathological physiology and anatomy. The same happened with the Frenchman Clovis Vincent, another neurologist who turned to neurosurgery after assisting Thierry de Martel in the operating theatre.

However, if neurosurgery was born out of this mixture of surgery and basic knowledge manipulated by the pioneers, it had not yet received its baptism, and was even further from achieving adulthood, although there were already glimpses of its academic profile. In the late 1890s there was still great scepticism about brain cases; because the mortality rate was unacceptable, and the speciality could not yet be accepted as independent because the technique of those pioneers was so primitive, it embarrassed those who followed on soon after. If the nascent speciality already had some indispensable basic principles, it had to go through the next stage before it could be definitively crowned, and that took place in the USA, where a group of neurosurgeons (including Cushing, Dandy, Frazier, Sachs and Mixter) perfected the surgical technique to reduce mortality rates to an acceptable level.

In his 1948 Presidential Address to the Harvey Cushing Society entitled *Neurosurgery comes of age*, Penfield warned against undue optimism about the technical progress made by Neurosurgery in the gestational period. He declared that progress had so far been more physical than intellectual, and real progress required not only operating more safely, but also learning to think in terms of basic science, as some of the pioneers had done.[1] He said that, "To gather knowledge... is the noblest occupation of the physician. To apply that knowledge... with sympathy born of understanding, to the relief of human suffering... is his loveliest occupation", and that if it was a satisfaction to design new technical procedures and invent new instruments (technological development), even more satisfying was being able to lay down new general principles from isolated observations, "A kind of deduction which springs or emerges suddenly, perhaps in the night when we are alone writing about the analysis of those observations"; a new conception that lay, according to his admired mentor William Osler, in the öpen sesame" of constant work.

Penfield believed that, in effect, the speciality of neurosurgery consisted of a body of accepted principles and a set of technical and operating procedures adapted or conforming to them. There was still something more though, and this was, for him "the alluring promise of new discovery... that this is what makes her a formidable mistress", that which Kipling called the "everlasting whisper" "Something hidden. Go and find it. Go and look behind the Ranges... Lost and waiting for you. Go!".

Harvey Cushing's contributions to technical progress and the establishment of neurosurgery

Penfield said that Cushing had been marked (or stamped) by W. Osler and by W. Halsted (two of the founders of the Hopkins school) during his stay at this Baltimore Hospital (see below and part II of this article), but it should be noted that as early as 1895, as a graduate student at Harvard, he was competing with his fellow students in the operating theatres of Massachusetts General Hospital to administer anaesthesia and take the pulse during operations.[1–5] In his third year, he used ether to anaesthetise a patient who was to have hernia surgery who vomited and died. Drawn out of his despondency by the patient's surgeon, he introduced the ëther chartẅhich represented the first attempt at documenting vital signs such as respiration, pulse and temperature during surgery.

This venture perhaps presaged his later interest developed at Hopkins in intraoperative recording of blood pressure, respiration and pulse after he had seen the Riva-Rocci sphygmomanometer in use at Pavia during his 14-month European Ẅanderjahreïn 1900–1901; he also designed a tube connecting the stethoscope to the anaesthetist's ear to monitor cardiac function continuously, thus paving the way for the emergence of the neuroanaesthetist, who, there, was Griffith Davis. Newly arrived at Hopkins, he did the first X-ray at that hospital on a patient with Brown-Séquard syndrome secondary to a gunshot wound to the spinal cord.

It is well known that during his stay in Central Europe he had the opportunity to study the effects of increased intracranial pressure on circulation and respiration in the laboratory of the physiologist Kronecker, attached to the department of the prestigious Professor of Surgery in Bern, Theodor Kocher (Nobel Prize 1909). This research led him to describe the Cushing reflex and to begin to r̈econceptualiseẗhe adverse significance of intracranial hypertension in the evolution of patients with intracranial expansive processes.[10]

Returning home, he enrolled in the William Halsted-designed surgical residency programme at Johns Hopkins in Baltimore, where the b̈ig four(H. Welch, 23, W. Halsted, 37, W. Osler, 40, and H. Kelly, 31) were creating the first full university medical school in North America, introducing undergraduate clinical rotations and the first formal postgraduate residency system. Working there, first as a resident (1896) and then as Halsted's assistant, he made the decision to pursue neurosurgery despite Halsted's initial advice to become an orthopaedic surgeon (see below). At first he rejected Halsted's slow and painstaking but safe operative technique, which treated the tissues with exquisite care and ligated even the smallest vessels. However, he soon made it his own, recognising it as one of the main foundations of his own surgical successes.

Cushing's activity in the experimental laboratory at Johns Hopkins Hospital

In addition to clinical work, the Hopkins programme required residents to spend time in the experimental laboratory. In 1897, a year after starting his residency, Cushing began to organise the Hunterian Laboratory on Experimental Medicine (familiarly called the Dog House) of which he was the first director, and where, among others, he trained Dandy from 1910 onwards (see below). There, among other research, he developed his work on the pituitary gland, which was included in his first book *The pituitary body and its diseases*. But apart from laboratory work, he contributed to neurophysiology by practising faradic current stimulation of the central gyrus in the awake patient, thus supporting the concept that man could be exposed to experimental investigations and contribute to neurophysiological knowledge as well as, or in many cases

better than, animals (the responses in humans provided spoken information impossible to obtain in animals). In 1906 he published a report on his work in the laboratory which, according to G. Jefferson, represents one of the most fascinating accounts of surgical literature of all time; written with a mentality already fully university-based, it illustrated what should be the conception and practice of surgery with a humanitarian purpose at the highest level.

Already at that early stage, when he had the good fortune to live immersed in the academic environment of Hopkins, a school unparalleled anywhere in the world at that time in history (see part II of this article), his conceptions emerged about the equality of intellectual demand posed by surgery compared to clinical medicine, and how the neurosurgeon had to master ẗhis part of the science(̈do his own clinical work) in order to enjoy autonomy. This critical stance also served as a basis for academic neurosurgery, which raised his prestige among his colleagues, even if it caused him problems with neurologists. His philosophy was to make neurology his own and to elevate the intellectual qualities of surgeons to understand and treat disease.

Cushing's steps to declare the independence of neurosurgery

We have already mentioned that in 1904 while on the first part of his hard uncertain journey, Cushing presented the seminal paper *The special field of neurological surgery* to the Cleveland Academy of Surgery, publishing a year later in the Hopkins Bulletin,[8] in which he announced his decision to devote himself ẗull-timeẗo neurosurgery. Delivering his talk, he apologised for restricting his efforts to what then seemed an unpromising field. Neurosurgery was systematically threatened by haemorrhage, brain herniation, CSF fistula and meningitis; between 1901 and 1905 he had operated on only 29 patients with brain tumours and most of the interventions had been only palliative. However, in another similar presentation five years later (1910), also in Cleveland, he no longer apologised for devoting himself to neurosurgery, reporting that he had operated on 180 patients, with a mortality rate of 13%; this was an event that marked the future of the speciality. In 1915, when the mortality rate in Europe was still in the range of 30%–50%, he reported a rate of 10%, and the rate reported at the m̈eetingöf the American College of Surgeons in 1919 marked the definitive recognition of Neurosurgery as a distinct and independent speciality.

This radical change was underpinned by three main elements[3]:

1) The conceptualisation of the pathophysiology of intracranial hypertension (r̈econceptualisationäccording to Greenblatt), which had probably begun to take shape in his mind on the basis of his observations in the Bern laboratory mentioned above, on the influence of intracranial hypertension on the bulbar centres regulating respiration and blood pressure. In 1901 he reported the elevation of systemic arterial pressure induced by cerebral compression, a rise that was parallel to, but always slightly higher than, the intracranial pressure level, and which contradicted the then most fashionable pathophysiological hypothesis proposed by Von Bergman, that intracranial hypertension caused generalised cerebral vasoparalysis.[10]
2) The technical advances derived from this new concept (specifically the practice of subtemporal and suboccipital decompression) at a time when mannitol, steroids and intracranial pressure monitoring were not available (pressure transducers did not exist). Since the work of Horsley and Sänger it was known that opening the skull and dura mater relieved the symptoms of intracranial hypertension, so decompression was used as an adjunct to allow local protrusion of the brain tissue which was covered by scalp, thus avoiding death of the patient in the operating theatre or in the immediate postoperative period. But Cushing applied decompressive surgery as a purely palliative measure when there was no expectation of tumour removal, placing it in an area where the brain was protected not only by scalp but also by muscle, as was the case with subtemporal surgery on the right side for patients with supratentorial tumours and at the suboccipital level for those located below the tentorium.

Although, as has been said, the measure was applied to patients who were not going to have their tumours resected, it prolonged life with good quality in a very large number of cases, something which had not been possible until then. As early as 1904 he had confidentially commented that the key to his best results in tumour surgery was the control of intracranial hypertension, and in another 1905 article entitled *The establishment of cerebral hernia as a decompressive measure for inaccessible brain tumours; with the description of intermuscular methods of making the bone defect in temporal and occipital regions*, he provided the rationale and technical details of the procedure he had started to use in 1903, when he published his famous article on blood pressure control during operations (someone pointed out that if Osler introduced the routine use of the blood pressure and pulse recording chart on ward rounds, it was Cushing, and not any anaesthetist, who introduced it in the operating theatre).

We therefore have to emphasise once again that, rather than the myriad technical details such as haemostasis, gentle handling of tissues and closure of the galea,[4] Cushing's successes in the early part of his career, and in terms of survival, were essentially due to the mechanical control of intracranial hypertension, which otherwise would cause herniation of the brain (fungus cerebri) through the craniotomy window with subsequent infection.

3) The creation of a referral system for patients with intracranial expansive processes, which had tended to evolve into secondary optic atrophy before they reached the neurosurgeon. This happy initiative, which he took on personally by undertaking a pilgrimage to give talks and lectures in the different states of the East, Midwest and South of the country, as well as in Canada, with the aim of educating rather than merely informing the medical community and even the public, was also transcendental for the progress and establishment of Neurosurgery at that historic stage.[3]

After having lived the most substantial part of his career and creative process at Hopkins, Cushing returned to Boston in 1913 as a young professor of surgery at Harvard and head of the Peter Bent Brigham's Department of Surgery.

Cushing's publishing activity

None of Cushing's early publications related to neurosurgery, indicating that his initial anchoring in general surgery remained firm. His first neurosurgical profile article, appearing in 1900 and before his European trip, dealt with the resection of Gasser's ganglion, which was used to control trigeminal neuralgia, and which he had tested on cadavers without the permission of the Hopkins School professor of anatomy, Franklin Mall. At the age of 31, Cushing masterfully described the safe and reproducible resection of the ganglion and its central root, refining the Hartley-Krause technique. As a resident he published 74 articles and book chapters, and in 1909, as an associate professor at Halsted, he published 15 articles, 12 of which were of the highest quality. By the time he left Hopkins for the Brigham he had published 100 papers, 69 of which were on neurosurgery and other neurosciences. In Boston, where he reached the height of his production and prestige, he published an average of eight excellent articles per year (1922–1932) and his curriculum vitae eventually included 658 articles and 24 books.

Nevertheless, without diminishing the value of the seminal articles on intracranial hypertension and others arising from work in the laboratory, it can be said that the most substantial part of his publishing output was related to the analysis of the extensive case records of the tumours he operated on (for example, meningiomas, gliomas, neurinomas and pituitary adenomas) after systematic and meticulous observation of their presentation (for example, tendency to be located in particular sites or to recur) and how they evolved over the years. He reported these observations at congresses, such as the 1931 Bern International Congress, where he shared his case records of 2,000 tumours set out in excellent monographs written in collaboration with the pathologists Louise Eisenhardt and Percival Bailey (this was a surgeon who not only operated, but also wrote).

Cushing's research activity was one of the fundamental ingredients in the definition and establishment of academic neurosurgery (no less important than the innovations in surgical technique or the founding of the SNS and the Harvey Cushing Society). He began his research shortly after taking over Halsted's teaching position, publishing in the literature and appearing constantly as a presenter and lecturer at congresses and meetings, including those of the societies he himself helped to create.

Cushing's positioning as a mentor and teacher

Cushing's profile as a teacher is less clear and remarkable than his profile as surgeon and clinical researcher, and certainly poorer than that of his mentor Osler, who was an excellent and dedicated teacher. The exemplary teaching of Halsted was undermined for a time by a change in his personality due to a drug addiction. In any case, it should be borne in mind that at that time the participation of specialists in undergraduate teaching was almost non-existent, and the methodology of instruction and assessment of residents had not been developed beyond mere "apprenticeship" (the pupil should and could only be concerned with "sticking to the teacher").[5,7,11] If Horsley, MacEwen, von Bergmann and other European pioneers had used this method as a resource or teaching model, Cushing was already able to use a residency programme similar to the one he himself followed at Hopkins, with which he succeeded in forming a group of residents in Boston, including S. Cobb, H. Naffziger, C. Dowman, J.J. Morton, C.W. Rand, C. Bagley, B. Horrax, L. Weed, C. Walker, E. Towne, S. Harvey, H.R. Vites and W. Pen who worked hard at the Brigham for between one and three years, with almost all of them then becoming heads of some of the best centres in the country.[7] Vites developed a keen interest in the history of medicine, and Weed, a laboratory man, contributed to understanding the pathophysiology of intracranial hypertension and came to use hyperosmolar solutions to control brain swelling.

For most of his "house officers" Cushing only required a one-year rotation, which focused on pre- and post-operative management of patients and participation in the operating theatre. The demands of the job in that year were intense (almost cruel). The Oxford-based Australian, H. Cairns, said that "the Battle of the Marne was nothing compared to the stress that Cushing's assistants had to endure". Among the European visitor-attendees, and apart from Cairns, were no less than G. Jefferson, O. Foerster, C. Vincent, N. Dott and H. Olivecrona.

However, Cushing, who was at the forefront when the SNS was created "to improve the training of house officers", never made explicit, either within this society or in writing (and he wrote a lot), his teaching "philosophy". According to Catalino "he never explicitly stated his philosophy of mentoring, it can be inferred from his actions and expectations of his trainees".[7] The education he provided was eclectic, and he seems to have believed more in the efficacy of hard work, based on classic apprenticeship, than in any detailed written programme which he did not bother to design, merely transplanting to Boston an unimproved copy of the one he himself had followed at Hopkins under Halsted. As head of the surgical department at the Brigham, he commented that they had "adopted the Hopkins residency programme and structure". In a 1969 commemoration, Penfield stated that Cushing differed from Halsted and Dandy "for his teaching and writing, and his very manner with young men, . . .which were completely Oslerian". However, in view of numerous testimonies in the literature, one can only disagree in terms of his teaching, as it was far from "Oslerian".

Cushing's dedication to teaching was nothing like that of Osler, the most worthy successor of the creators of formal or systematic instruction in clinical practice (Giambattista da Monte and Herman Boerhaave), for whom clinical teaching was "the love of his life", and who chose for his epitaph the saying: "I taught my students medicine in the wards". His vast culture and humanistic training, tenacity in his work and boundless generosity were exemplary for the doctors and educators of his generation, including Cushing who, being one of the most benefited, did not succeed in passing on this torch.

In some publications that report anecdotes about Cushing's relationship with his assistants, there is no trace of affection (in fact he advised his residents to put their affections on ice during their years of training).[12] His personality, labelled by some as egocentric and obsessive-compulsive, made him a tough competitor who, as a sharp and engaging debater, always commanded and monopolised the conversation. He barely shared his ideas with his collaborators and when he asked for their opinion during surgery he never took it into account. In general, he showed little deference to any of them, and some of them he sacrificed. He opposed the directors of the Harvard School in their attempt to accept the strictfull-time teaching and research plan in operation at Hopkins, which Abraham Flexner wanted to extend to the best academic centres in the country (among them the Peter Bent Brigham) with funding provided by the Rockefeller Foundation.[11,13] For better or worse, Cushing was one of those responsible for the choice of the geographicaltype of faculty appointment at Harvard, a work regime which, unlike the strictöne, allowed private patients to be charged.

Cushing once expressed a desire for his residents to surpass him, but he used phrases that, to many, seemed more conventional than sincere. We could label as cynical his expression of satisfaction with the heights reached by his initial disciple Dandy. He did go as far as to say that Dandy had surpassed himbut, according to references, he never believed this to be true (see the history of the disagreement between the two below).[14] Perhaps he felt compelled to imitate his mentor Osler by repeating his altruistic teaching-related messages written in *Aequanimitas* and others.[15,16]

We will return to Harvey Cushing's professionalism in part II of this first article on the genesis of academic neurosurgery, discussing his relationships with his main mentor, W. Osler, and his direct boss, W. Halsted.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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