SOME OF HARVEY CUSHING'S CONTRIBUTIONS TO NEUROLOGICAL SURGERY

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To the older group of neurological surgeons in this country and abroad and to many members of the Society which is sponsoring the Journal of Neurosurgery, the name of Harvey Cushing has stood for a large proportion of the advances which have been made in this specialty since the time, some fifty years ago, when Sir Victor Horsley may be said to have established it as a separate branch of surgery. Indeed, a large number of those practicing neurosurgery today had the privilege of seeing Dr. Cushing at work, of hearing many of his addresses to medical societies, or of benefiting immediately by the contributions which he was making continuously to his chosen field. To those who followed his career and to others who have been concerned with the advances in neurological surgery, a recital of his outstanding accomplishments would be as out of place as it would be unnecessary, since they are well known alike to his pupils and to his many admirers. However, during the last decade a large, younger generation of neurosurgeons has arisen, and it is perhaps particularly to them that this communication may be of interest.

It would be impossible in the space of a short review such as this to do more than touch upon what have seemed to be Dr. Cushing's major communications as they have influenced neurosurgery directly. Many of his brilliant experimental and laboratory studies have been omitted or merely mentioned since I have undertaken to confine myself for the most part to his purely technical contributions. At times, however, the laboratory and the clinic overlap so intimately that the story of one would be quite incomplete without the other.

In order to get a background for the life and work of Harvey Cushing, we must for a moment look at the status of this newly launched specialty up to the time when he appeared upon the scene. Not until the era of anesthesia and antisepsis, and particularly not until the beginnings of cerebral localization (circa 1870) had operations upon the brain and spinal cord advanced appreciably since medieval or ancient times. Soon after this, in the middle eighties of the nineteenth century, a very few, and very occasionally successful, operations upon brain tumors, brain abscesses and spinal cord tumors were performed. Finally, during the decade from 1890 to 1900, Victor Horsley by his vigorous pioneering and tireless physiological and pathological investigations, succeeded in getting before the medical profession the fact that much more could be accomplished surgically for certain lesions of the central nervous system than had previously been supposed. However, the technic of brain operations at this time was crude, and was influenced largely by
general surgical methods which we now know cannot be applied to such delicate performances. Even as late as 1906, Horsley himself made the following statement, "In fact, the advance in technique of the surgical treatment of diseases of the brain and the spinal cord has been relatively less than the improvement in our knowledge of the seat and nature of the diseases for which surgical intervention is useful and necessary." If this was true of Horsley's own work, it was even more so of the leading surgeons in Europe, notably Bergmann, Kocher, Krause, von Eiselsberg, Chipault, Broca and others, all of whom had made signal contributions and had written extensively on the subject of cranial and spinal operations even though their results were certainly not nearly so good as those of Horsley.

In other words, at the turn of the twentieth century it was evident that a large new field of surgery was opening, indeed had been opened, but that in this new field no one had as yet appeared who fully appreciated and was able to develop a surgical technic which was sufficiently delicate and meticulous to make operations, particularly on the brain, produce results at all comparable to the results of operations elsewhere in the body. It was at this juncture that Harvey Cushing in Baltimore began to devote himself almost entirely to the study and practice of neurological surgery at The Johns Hopkins Hospital and in the Hunterian Laboratory of the medical school.

The results of this study and practice began almost immediately to appear. In 1900, Cushing published the details of a method for the total extirpation of the gasserian ganglion. In essence, it was a refinement of the so-called Hartley-Krause procedure, but because of this refinement a complete removal of the ganglion could be accomplished for the first time with certainty, whereas by the older methods, removal almost always had been either incomplete or uncertain. The operation described in this article is, to all intents and purposes, the same subtemporal approach which is used today for division of the sensory root behind the ganglion. Cushing's illustrations show that not only the ganglion but also the sensory root of the trigeminal nerve was extirpated, but it was not realized until the work of Spiller and Frazier a year later that it was necessary only to divide the root, thus making removal of the ganglion superfluous.

During the next five years there were several notable contributions. In 1901, Cushing's announcement of a regulating mechanism in the vasomotor center for the control of blood pressure during cerebral compression was an epoch making event. This study was and is so important for the understanding of clinical states, operative complications, traumatic brain conditions and the like that it must be included here, although this review is primarily from the clinical standpoint. As Cushing himself stated,

The fact that cerebral compression occasions a rise in blood pressure is universally known, but it does not seem to have been recognized that the degree of this elevation occurs pari passu with the degree of compression (measured in millimetres of mercury) to which the medullary centres are subjected.

The article contains beautiful kymographic records showing synchronized
blood pressure and intracranial pressure tracings. The author summarized his findings as follows,

As a result of these experiments a simple and definite law may be established, namely, *that an increase in intracranial tension occasions a rise of blood pressure which tends to find a level slightly above that of the pressure exerted against the medulla.*

In 1903, Cushing’s first formal paper on the routine taking of blood pressure during operations and in the clinic was read at the Boston Medical Library. He had introduced the Riva-Rocci blood pressure instrument into this country in 1901 and had made reference to its use in his Mütter Lecture in Philadelphia the same year. The importance of this measure as a routine in surgical anesthesia charts needs no emphasis since it has become a standard procedure in every first-class hospital. In this, as in other important innovations, Cushing had to reiterate his plea many times before routine blood pressure determinations during operations were adopted. In 1905 at Cleveland, he gave the following pertinent reasons for blood pressure readings, “Such a record not only furnishes instructive... general data, but often furnishes a means of properly interpreting the effects, beneficial or otherwise, of the various operative steps.”

A minor contribution in 1904 was the description of a pneumatic tourniquet for the control of scalp bleeding during operations. This was an improvement on tourniquets previously used, but he himself later discarded it for a simpler device which was used until tourniquets were entirely discarded, probably because of the advent of novocain and adrenalin anesthesia at the time of World War I.

In the following year (1905) two highly significant papers appeared. The first of these was concerned with the operative treatment of intracranial hemorrhage in the newborn. Until that time this unfortunate condition had been considered hopeless and the pitiable victims who survived the hemorrhage were destined to various states of spastic paraplegia, usually with seriously impaired mentality, blindness and other evidences of cerebral damage. Cushing was able to report four operative cases with two recoveries from serious subdural hemorrhage in infants from three to eight days old. Subsequently (1910) he reported 12 further cases with recoveries in about half the patients and without the development of spastic paraplegia. In this second article he likewise stated that one of the infants upon whom he had operated in 1905, “is now a healthy and normal child of five years of age.”

Cushing’s other important paper in 1905 related to palliative decompression for inaccessible brain tumors. It had long been known, through the work of Horsley, Sänger and others, that an opening in the skull accompanied by incision of the dura in patients harboring a brain tumor would almost always relieve headaches and other pressure symptoms and preserve eyesight by allowing choked discs to subside. Heretofore, however, these operations had been performed, as a rule, either at the supposed site of the tumor, whether or not the tumor had been found, or, as advocated by Sänger (1902), in the right postcentral region in right-handed persons. In
other words, the procedure had been used by others apparently as an adjunct to either possible or probable tumor removal, or had been done in an area which was covered only by scalp, and in the latter instances often caused unsightly protrusions or even made incipient paralyses worse because of hemorrhage or edema in the protruding herniation. Cushing’s invaluable contribution was, first, the fact that he advocated decompression often as a purely palliative measure when there was no expectation of the ability to remove an inaccessible tumor, and secondly, his advocacy of the use of an area that was protected not only by scalp but also by muscle, that is, the low right temporal region in right-handed persons for supratentorial growths and the suboccipital region for tumors below the tentorium. Referring to his 1905 paper, he himself has expressed the situation regarding “decompression” at the time when this subject was so much in vogue, and summed it up in his address at Cleveland in 1910\(^5\) in these words,

That relief of pressure in many instances had unexpectedly followed unsuccessful explorations for tumors had long been a matter of general knowledge, and Horsley, Weir and other forerunners in the work had been led to propose simple trepanation as an intentional palliative measure; but I am unaware that any author had previously suggested a purposeful decompression irrespective of possible tumor removal, and the utilization not only of a “silent” area but also of overlying muscle to prevent too great protrusion of the herniating brain, or had ever emphasized the importance of decompressing at a distance from the growth as a preliminary measure should the brain prove to be under great tension.\(^*\)

\(^*\) So far as I have been able to discover, this contention of Cushing is correct. Horsley (Brit. med. J., 1893, 2: 1963–1967), referring particularly to headache, vomiting and choked discs, made the following statement, “I wish now to advocate, as I have done before, that the opening of the skull should be undertaken for the purpose of relieving these symptoms especially. . . . I operated as much with the direct object of relieving intracranial tension as of exploration with the view of attempting the removal of the
The value of this type of palliative decompression in those early days hardly can be overemphasized. It relieved an infinite amount of suffering, preserved vision, and allowed many patients to get back to active and useful work, sometimes for years. Indeed, in not a few persons the tumors later became localizable and were removed successfully, whereas if they had not been decompressed death or blindness in all probability would have resulted. In the 1905 article concerned with decompression an illustration of the "intermusculo-temporal" operation is given, together with an illustration of the "crossbow" incision for suboccipital craniotomy. The latter operation, as well as the subtemporal procedure in simplified form, became the standard for many years (Figs. 1 and 2).

Reference was made earlier to the importance of the refined and meticulous technic which Harvey Cushing inaugurated in neurosurgery. The many and intimate features of this technic constitute one of his major contributions to the subject, in fact, it was largely because of his extreme attention growth." In 1906, after the appearance of Cushing's article, Horsley wrote the following, "To sum up, then, during the past twenty years we have learnt that . . . we can with certainty avert blindness by opening the subdural space early in cases of intracranial disease. [Preferably in the basal temporal region of the right side, that is, assuming that no attempt is made to attack the disease itself.]" From the first of these quotations, it is clear that Horsley was, of course, familiar with and practiced the principle of decompression, apparently at the site where he was exploring for a tumor. In the second quotation he does refer to subtemporal decompression as a palliative measure, but this was after Cushing's paper had appeared, and furthermore, the invaluable principle of utilizing careful closure of the temporal muscle over the decompression is not mentioned.

Fig. 3. Shoulder supports and crutch for holding head employed to safeguard respiration in operations requiring prone position.
to details that he was able to accomplish so much for patients with disorders of the nervous system. In an address before the St. Louis Surgical Society in 1908, Cushing set forth at considerable length the methods which he had found useful in performing various cranial operations. Essentially similar reiterations are to be found in his monographic contribution to Keen’s System of Surgery (1908) and in a paper (1909) delivered at the meeting of the American Medical Association in June, 1908. The description starts with the general preparation of the patient, the careful shaving of the head just before operation (not the previous night as heretofore practiced), the position on the table (Fig. 3), the anesthesia given by a trained anesthetist who kept a pulse, respiration and blood pressure chart, the preparation of the operative field with bichloride solution and alcohol, and the device of scratching out on the scalp the proposed line of incision. There follow minute directions as to the control of hemorrhage in the various tissues encountered, the performance of osteoplastic craniotomy and other operations, as well as the steps of certain intracranial procedures (Fig. 4). The reduction of increased intracranial pressure by means of lumbar puncture during the course of an operation was advocated—a new feature and extremely important at this stage of neurosurgery in order to prevent cortical rupture while opening the dura. Not the least of the principles advocated was the closure of the wound to which especial care was directed, including closure of the galea* and meticu-

* One of Dr. Cushing’s favorite themes in later years when questioned concerning his surgical contributions was, “Tell them that I closed the galea.”

Fig. 4. Dr. Cushing and his operating team at the Johns Hopkins Hospital. Note bloodless operative field and hood covering anesthetist.
lous approximation of the skin edges (Fig. 5). In his 1908 articles, Cushing refers to his method of combining an osteoplastic exploration with a sub-temporal decompression when this is necessary. A later paper (1909) was devoted to an extended description of this procedure which became a recognized standard (Fig. 6).

Perhaps the highest tribute which can be paid to Cushing's attention to detail is contained in a statement he himself made in 1908 concerning the healing of wounds. He says, "In something over 350 craniotomies I have never seen an infection, even a superficial stitch abscess, and have ceased to regard the chance of sepsis as a possible complication of these operations." Can any neurosurgeon of the present day say as much?

Although chronologically somewhat out of place, it is pertinent to mention at this juncture a device for the control of intracranial hemorrhage, with which the name of Cushing will always be connected. This is the silver clip outfit, a description and illustration of which appeared in 1911. Modifications of the original clips have since been made, but essentially the ones used today by all neurosurgeons are the same as those first described (Fig. 7). They constitute one of the major advances in the control of bleeding from dural and cortical blood vessels, and have been only partially superseded by electrocoagulation.

This 1911 article on the control of bleeding is highly important for a further reason. In it the author describes the use of muscle, bits of living tissue or well solidified blood clots as a valuable aid in arresting surface oozing or bleeding on the dura. Apparently this was the earliest reference in the literature to such a method of hemostasis, although Cushing stated in a
footnote that Dr. Lund had reported having seen Horsley demonstrate the use of muscle in the same way the year previously. However, Cushing further remarked, "Since this device for checking bleeding was first hit upon some two years ago, we have made frequent use of it, with most satisfactory results."

From 1906, when Cushing read his first paper dealing with conditions affecting the pituitary gland, he continued to make numerous and important contributions to our knowledge of the physiology and pathology of this structure, and these in turn led to great advances in the surgical attack upon tumors of the hypophysis both by him and by neurosurgeons throughout the world. It is not within the scope of this review to dwell upon his experimental contributions, in which his numerous distinguished co-workers often collaborated, and to whom he has given abundant credit. It must suffice to say that his earlier laboratory work coupled with his rapidly accumulating clinical material was put together in his first book, *The Pituitary Body and Its Disorders*, in 1912. While much had been written by others concerning the hypophysis before this time, and while a number of other surgeons had reported operations upon tumors of the gland, Cushing not only reviewed all the existing literature but also was able to report the most extensive and most successful series of operations upon the pituitary gland that had been undertaken up to that time by any one person. Undoubtedly, his results were to be attributed to two factors, first, his wide experimental laboratory experience with the gland in animals, and secondly, his consummate skill as a surgeon. The operation which he used for the most part in his earlier pituitary work, and indeed until about the year 1927, was a transsphenoidal approach which he modified and improved from the procedures used by A. E. Halstead and Hirsch. By Cushing's method a considerably larger exposure of the base of the sella could be obtained, and consequently probably a better decompression or evacuation of the sellar contents (Fig. 8).

A final report on Cushing's pituitary patients, whom he had operated upon at the Peter Bent Brigham Hospital, Boston, between 1913 and 1932, was made by one of his pupils, W. R. Henderson, in 1939. There were 338
verified tumors in the series, and all but 3 of the 319 survivors were heard from after their discharge from the hospital. Since the last patient operated upon was in 1932, the follow-up period was from five to twenty-four years, as Henderson’s data were obtained in 1936 to 1937. This report shows in convincing fashion Cushing’s unexcelled supremacy in the surgical treatment of pituitary disorders. His total operative mortality for the chromophobe adenomas (260 patients) was 4.9 per cent, reduced to 2.4 per cent during his last ten years. For acromegalis (67 patients) the operative mortality was somewhat higher, namely, 8.6 per cent. None of the 11 patients with

Fig. 8. Transsphenoidal approach to hypophysis (diagrammatic) showing beginning exposure of base of sella turcica (Cushing, H.: J. Amer. med. Ass., 1914, 62: 1515–1525).

adenocarcinoma of the gland died after operation. The increasingly good results of transsphenoidal and of transfrontal operations, and of both when followed by roentgen-ray therapy was shown. By a combination of the more complete removal of growth by an intracranial, transfrontal procedure, followed by radiation, 87.1 per cent of Cushing’s patients so treated had remained free of recurrence at the end of five years.

From the beginning of his specialization in the field of neurosurgery, Harvey Cushing was particularly interested in the problem of brain tumors, necessarily no doubt because an ever increasing number of patients so afflicted came to him for help, but also almost certainly because these serious lesions intrigued him and demanded his utmost in skill and ingenuity. It was in dealing with the problems, diagnostic and surgical, concerning brain tumors that he contributed so greatly to our knowledge of these growths in
their manifold relationships. Due to his superlative operative technic, together with his infinite patience, he was able very early in his career to surpass the efforts of all those who had preceded him in dealing successfully with intracranial neoplasms. As far back as 1909, he reported what were then brilliant results in a series of thirty-five suboccipital operations for presumed cerebellar tumors. Operations on the cerebellum in those days were thought to be the most dangerous of all intracranial procedures, and many authorities felt that cerebellar tumors were practically inoperable. Cushing, however, reported 13 successful tumor extirpations, 17 palliative suboccipital decompressions, and 2 inoperable tumors exposed. There were only 3 deaths in the series. In this and subsequent articles, he urged his belief that, contrary to the accepted ideas, cerebellar growths were even more favorable for operation than those above the tentorium. On two occasions in 1910, Cushing reported on operative experiences with brain tumors in general. In his William Mitchell Banks Memorial Lecture in Liverpool, he stated that during the past ten months he had operated upon 64 brain tumor patients. There were 8 fatalities, a mortality of 12.5 per cent. “16 cases after removal and 21 cases after decompression are, to be conservative, greatly benefited and a number of them probably cured, making a percentage of 57.8 out of the 64 patients that have regained, temporarily at least, a full measure of health.” He contrasted these figures with those given by Oppenheim in a recent communication which recorded the results of 27 tumor operations by competent surgeons during the course of three years. Of these, 2 patients were regarded as cured, 6 much improved and 1 improved; but about half of the 27 died of shock, hemorrhage or other operative complications. Again in 1910, Cushing reported upon his last 100 patients with brain tumor, saying, that in 30 instances there had been tumor extirpations or cyst evacuations with apparent cures, and 67 palliative procedures. There were only 11 deaths and none of the “oldtime postoperative complications.”

These figures may not sound very optimistic now, but it must be recalled that the most eminent neurologists of those days (Starr, Knapp and Mills in this country, and others abroad) had estimated from collected operative and postmortem material that only between 5 and 10 per cent of all brain tumors were operable, and in a large series collected from the literature Knapp found the immediate operative mortality to be 32 per cent. Furthermore, Knapp stated that a study of the cases reported as “recovered” showed that for the most part the patients merely lingered on “paralytic, epileptic or blind.” Cushing’s early accomplishments must therefore be viewed in the light of these facts and it will then be realized what strides he had already made. A further and extremely enlightening comparison of his results with those of the outstanding surgeons of other countries occurred in his discussion, published in 1915, of Professor Küttnner’s paper on brain tumors at the meeting of the American Medical Association in 1914. Küttnner gave his own operative mortality as 45 per cent and estimated the mortality in Berlin (Krause) at 50 per cent, and in Vienna (von Eiselsberg) at 38 per cent. A
study of Tooth’s statistics from London (largely Horsley) approximated 32
to 37 per cent of immediate operative deaths. Cushing presented statistics
based on the 130 patients he had operated upon in Boston only, since the data
on his older Baltimore series were not then available. This was, however, a
series comparable in point of number to those of the German and Austrian
clinics, but considerably less than the number from Queen Square. Cushing’s
total case mortality was 8.4 per cent, a figure which was epoch making and
almost unbelievable for that era. The key to his success is summed up in the
final paragraph of his paper, thus,

Specialization with some knowledge of neurology, skilled assistance—for intracranial opera-
tions are not star performances—familiarity with the safe and respectful handling of the cen-
tral nervous tissues, which is best acquired by the experiences of the experimental laboratory,
and painstaking, scrupulous technique, are the chief elements of success. An observance of
these things will not make more tumors accessible, but it will permit the removal of those
that are accessible to be more often accomplished and render those that are not, capable in
a larger percentage of cases of being safely palliated.

In this discussion of Küttner’s paper, Cushing had taken up in some de-
tail the high operative mortality which prevailed not only for brain tumors in
general, but in particular for the benign, encapsulated acoustic, or cerebello-
pontile angle growths. These tumors were made the subject of a monograph
in 1917, and this book was destined to become, as had The Pituitary Body
and Its Disorders, a veritable landmark in brain surgery. Previous attempts
at partial or complete removal of these deep seated, yet apparently favorable
growths had been highly disastrous, and the prevailing mortality even with
an occasional success was at least between 70 and 80 per cent. In his book,
Cushing gave the details of what he termed an intracapsular enucleation of
acoustic tumors, accomplished after a bilateral suboccipital exposure by
means of the “crosstbow incision” (Fig. 9). By this method, as much as pos-
sible of the contents of the capsule was evacuated by painstaking curettage
and careful hemostasis, but the capsule itself, with its vascular connections
to the pons and elsewhere, was not removed. This meant, of course, that
most of the tumors would recur after greater or lesser intervals, unless they
became quiescent, but even so, the operation was an immense step forward.
In many instances, patients remained perfectly free of symptoms for five to
ten years, in some cases longer, and likewise, some with recurrent tumors
were operated upon again with success. Cushing’s operative mortality for
these growths at the time his book was published was in the neighborhood of
20 per cent in contrast to the circa 75 per cent mortality elsewhere. Within a
relatively short time his mortality dropped to 10 per cent and even lower. In
any case, Cushing’s careful, very complete intracapsular operation for the
first time offered patients with these tumors a reasonably safe procedure
with a good chance of getting back to active normal life for a period of years,
and thus revolutionized acoustic tumor surgery.

During the last part of his surgical career Dr. Cushing became more and
more engrossed in the problems concerned with intracranial tumors, but
before resuming a review of his efforts in this respect we must turn for a moment to two other contributions which were interspersed among those relating to tumors.

In 1917, he went overseas as director of Base Hospital No. 5 of the U. S. Army. The hospital took over a British Unit in northern France, but Dr. Cushing and various younger members from time to time were soon sent up to a British Casualty Clearing Station not far behind the front. It was here that he developed what was to become the standard treatment of penetrating gunshot or shell wounds of the brain. The general principles of this treatment hold good today. A summary of his method was published in the *British Medical Journal* early in 1918.\(^\text{20}\) Cushing's chief contribution here was the careful and thorough débridement of the track of the missile in the brain by means of a catheter to which suction was applied by a hand syringe (Fig. 10). He stressed particularly the removal of all indriven bone fragments, emphasizing that these more than indriven metal were likely to be the source of future infection. He reported the results in a large series of these serious penetrating wounds in a comprehensive article in the *British Journal of Surgery* later in 1918.\(^\text{21}\) and was able to show a remarkable reduction in the

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**Fig. 9.** Successive steps in the intracapsular enucleation of acoustic neuromas. The tumor exposed by retraction of cerebellum, its contents removed by blunt spoon, and finally, only the loose capsule left in place.\(^\text{19}\)
mortality from the previously accepted rate. Thus, in 133 patients with wounds penetrating the dura, his mortality for the first 44 operated upon was 54.5 per cent (the usual accepted mortality). For the second 44 cases his mortality was 40.9 per cent, and finally, with accumulating experience, his mortality for the last block of 45 cases was 28.8 per cent.

The radical operation of sensory root division or avulsion for trigeminal neuralgia had, during the first two decades of the twentieth century, become a fairly standardized procedure with an increasingly low mortality rate in the hands of skilled neurosurgeons. Among the best, however, this rate was somewhere between 1 and 2 per cent. In 1920, Cushing published the statistics of his entire series of 322 ganglion or sensory root operations in which there had been but 2 deaths, a mortality of 0.6 per cent. These fatalities occurred in his ninth and thirty-fourth cases, leaving 298 consecutive operations without a fatality. So far as I am aware, this accomplishment surpasses that of any published record for this procedure.

We may return now to a consideration of Harvey Cushing's further outstanding contributions in the realm of brain tumor surgery. To make these contributions possible, detailed records of all his patients, including complete operative notes usually accompanied by his own sketches, pathological records of operative and postmortem material, photographs of the patients—all these and many other minutiae assembled by himself and his co-workers were brought to bear.

In the Cavendish Lecture for 1922, he coined the term "meningioma" for the group of tumors heretofore listed by a variety of names, but usually
that of dural endothelioma. Using his extensive material he was able to pick out from the whole mass of these tumors different groups which always grew in specific locations, often giving specific symptoms, so that, before operation, they could be recognized and operative plans laid accordingly. This grouping of the meningiomas was an enormous step forward in our operative attack upon them, because, to a large extent, the extreme hazards of their removal could be foreseen in many instances and certain necessary precautions taken. Thus he added directly to the technic of the operating room, in a way which he himself described in the last paragraph of his lecture,

What enables us, even in our present imperfect way, to detect, to localize, and finally, aided by all the paraphernalia of a modern operating room, to remove a brain tumour, is merely the application of most diverse fragments of knowledge contributed by countless workers in bygone ages, brought together from the ends of the earth and concentrated on a single act.

A somewhat similar, but more extensive study of the large glioma group of brain tumors was made in conjunction with Percival Bailey in 1926. This marked the beginning of our pathological grouping of these tumors in which their pathology was correlated with their life histories and clinical characteristics, and, just as in the grouping of meningiomas, has been of enormous aid in knowing how to deal with these growths surgically. Other, more specific communications grew out of this original study, as evidenced in 1931 when he analyzed his experiences with the cerebellar astrocytomas. As he pointed out in this article,

What has been chiefly contributory in recent years to the success of operations for intracranial tumors has been the tendency of those interested in the subject to concentrate upon the behaviour and traits of special tumors in special situations.

This special concentration brought out the knowledge which gradually was reached about 1925 or 1926, that to effect a permanent cure of a patient harboring an astrocytomatosus cyst, it was essential to remove completely the solid portion of tumor within the cyst, whether this was a relatively small "mural nodule" or whether it might be solid growth as large or larger than the cyst itself (Fig. 11). Likewise, because of his concentrated study, he was able as early as 1922 to predict the presence of an unseen, deep, centrally placed cerebellar tumor and to remove it after transection of what looked like normal cerebellar vermis.

In 1927, Dr. Cushing was invited to give the Macewen Memorial Lecture in Glasgow, and he chose for his subject a discussion of the so-called olfactory groove meningiomas. He called attention to the syndrome which Foster Kennedy had described in connection with the diagnosis of these and other growths in this locality, but stressed particularly the definite chronology of symptoms as of specific diagnostic importance for the meningiomas. But more important from the neurosurgical aspect was his discussion in this lecture of the first employment of electrosurgery in the removal of brain tumors. In introducing the subject, Cushing says,
When I first had the good fortune to see this loop being used bloodlessly to scoop out bits of tissue from a malignant tumour for purposes of biopsy, I foresaw that a new tool had been put into our hands to facilitate the piecemeal removal of . . . tumours. With Dr. Bovie’s co-operation, during the past few months I have gained sufficient familiarity with the instrument to realize that it holds out untold possibilities for the future of neuro-surgery.

How true was this prophecy, the present generation of neurosurgeons can attest.

FIG. 11. Removal of large solid portion of astrocytomatus cyst of cerebellum by electrosurgery.26

Among other things the Macewen Lecture produces further evidence of Harvey Cushing’s consummate patience and attention to technical details. After describing the use of the new electrosurgical apparatus in an operation for a large olfactory groove meningioma, he adds the following sentences which are sufficiently enlightening and significant to quote at length,

As matters stood, from the time when the scalp was novocainized to the final closure and dressing, seven hours were consumed . . . . To the surgeons who may be accustomed to speed
up their operations this may appear to have been an unnecessarily prolonged and formidable procedure. All said and done, it is the final result that counts, and having been brought up to believe that convalescence is shortened by attention to the technical details while the patient is on the operating-table, I have no dread of a long session . . . .

Enough has been said to indicate that we now have at our command a device which makes it possible to extirpate tumours hitherto so inaccessible that their attempted removal would have been regarded as foolhardy in the extreme . . . . Electro-surgery at least permits us to-day to remove certain brain tumours from situations and under circumstances which a year ago—indeed six months ago—I would not have thought possible.

A further article concerning the more extensive use of electrosurgical

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**Fig. 12.** Successive stages in the extirpation of a vascular meningioma of the left temporal region by means of “scalloping” and eventual removal of tumor shell.

methods in intracranial surgery was published in collaboration with Dr. Bovie in 1928. Here Cushing gave descriptions and illustrations of a variety of uses for the new apparatus for different types of brain tumors in various situations (Fig. 12). He called attention to the use of suction in keeping the field dry at the point where electrocoagulation was being applied, and
pointed out the value of suction in picking up deeply situated bleeding arteries so that they could be grasped with forceps and coagulated.

One other communication concerning a specific variety of meningioma must be mentioned. This was Cushing's paper, published in 1929 in collaboration with Louise Eisenhardt, on the tumors of this category arising from the tuberculum sellae. The importance of the contribution lies in calling attention to a diagnostic symptom-complex for a specific lesion so that a more intelligent operative attack could be planned. To use Cushing's own phraseology,

Not only is it essential that the presence of a tumor and of its precise location be reasonably assured before it is attacked, but it should be possible to make at least a presumptive guess as to its histologic nature and likelihood of recurrence, for these things will greatly influence the surgical procedure. The goal, in short, is to recognize the peculiar manifestations of a particular kind of tumor in a particular region at the earliest possible stage of the process in order that an operation may be undertaken under the most favorable auspices.

From this series of tumors, Cushing could conclude that the presence of "primary optic atrophy and bitemporal field defects combined with a normal sella turcica in a middle aged person" was practically diagnostic of a meningioma arising from the tuberculum sellae. In addition to the diagnostic criteria, Cushing's highly successful operative experience in a large proportion of his 15 patients having this type of lesion was detailed.

In 1932, Harvey Cushing ended his surgical career upon his retirement from the Moseley Professorship of the Harvard Medical School and from his position as Surgeon-in-Chief to the Peter Bent Brigham Hospital in Boston. On two occasions during the previous year he presented the mortality statistics pertaining to his large series of verified brain tumors, a grand total of 2,023 patients, 1,870 of whom were operated upon. There were 382 postoperative deaths, namely, patients who died in the hospital from any cause whatever after operation, giving a case mortality of 20.4 per cent. This series, of course, included all of Dr. Cushing's brain tumor patients, starting with his earliest experiences in Baltimore in 1902. When the extremely high mortality of the early years is considered, it is indeed amazing that his total mortality was as low as it proved to be. As a contrast to the figures for the whole series, Cushing included the statistics for the three years previous to the communication. These showed that 412 patients with verified intracranial growths had been operated upon during that time, with 55 postoperative deaths, a case mortality of 13.3 per cent. It is quite probable that these figures stand today, more than ten years after their publication, as a mark which as yet has been unattained by his successors in this branch of surgery.

Amazing and highly successful as was Cushing's experience with brain tumors in general, his achievements in respect to a single large group of tumors, the meningiomas, was, if anything, even more striking. It is not within the province of this review to attempt a summary of his last comprehensive and monumental book devoted to these tumors, which appeared
with the collaboration of Dr. Eisenhardt in 1938. The work is a vast storehouse of information, which was gathered by Dr. Cushing, his patients and his co-workers over the course of thirty-odd years, and ranks as one of his major contributions to neurological surgery. It must suffice to say that so far as the surgical statistics and end results are concerned, Cushing’s operative ability with the difficult and often extremely hazardous procedures in removing these growths was phenomenal. In all, 281 of the 295 intracranial meningiomas were operated upon, with only 55 postoperative deaths, a case mortality of 19.6 per cent. These figures, just as the ones for his whole tumor series, go back to the early days of brain tumor surgery, when mortality was extreme. A contrast, therefore, should be made with his last five year period, from 1927 to 1932 (after the advent of electrosurgery). During this period, 118 patients were operated upon, with 14 postoperative deaths, an 11.8 per cent case mortality. In addition, his records showed that no less than 172 patients at the time of writing had survived from five to twenty-seven years.*

Sufficient has been said to make it clear that Harvey Cushing’s experimental, pathological, clinical and technical contributions to neurological surgery were of such a character and of such extent as to make him the outstanding figure of his generation, surpassed in priority and in pioneering only by Sir Victor Horsley. Other very real but less tangible contributions could be enumerated, but time and space do not serve. It should at least be mentioned, however, that he continually preached the gospel, first intimated by von Bergmann, that neurosurgeons should be capable of making their own diagnoses by familiarizing themselves with the essentials of neurology, to which should be added certain features of ophthalmology. He exemplified in all his daily doings the value of patience under trying circumstances, meticulous care in everything that pertained to the welfare of those under his care and the attention to preoperative and postoperative details. His complete records of patients, together with his own exact as well as artistic operative sketches, are a model to all. All these things, as well as his wide experience aided in his almost uncanny neurosurgical judgment. Again, he organized the first society of neurological surgeons, in order that those interested in this new specialty might visit each other’s clinics and thus gain added knowledge of the subject by observation and mutual discussion. Finally, by attracting to his clinic large numbers of young men from this and many other countries, he may be said truly to have established a school of neurosurgery throughout the world.

* In connection with the follow-up records on these patients, it should be noted that shortly after Dr. Cushing’s removal to New Haven in 1933, he established the Brain Tumor Registry, with his longtime associate, Dr. Louise Eisenhardt, in charge. The Registry has been of the utmost help, not only in following groups of Cushing’s patients but in making pathological diagnoses from microscopic sections of unusual or confusing tumors submitted by neurosurgeons throughout the country.
CUSHING'S CONTRIBUTIONS TO NEUROLOGICAL SURGERY

REFERENCES


