Harvey Cushing's Approaches to Tumors in His Early Career: From the Skull Base to the Cranial Vault

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ABSTRACT

In this report, we review Dr. Cushing's early surgical cases at the Johns Hopkins Hospital, revealing details of his early operative approaches to tumors of the skull base and cranial vault. Following Institutional Review Board approval, and through the courtesy of the Alan Mason Chesney Archives, we reviewed the Johns Hopkins Hospital surgical files from 1896 to 1912. Participants included four adult patients and one child who underwent surgical resection of bony tumors of the skull base and the cranial vault. The main outcome measures were operative approach and condition recorded at the time of discharge. The indications for surgery included unspecified malignant tumor of the basal meninges and temporal bone, basal cell carcinoma, osteoma of the posterior skull base, and osteomas of the frontal and parietofrontal cranial vault. While Cushing's experience with selected skull base pathology has been previously reported, the breadth of his contributions to operative approaches to the skull base has been neglected.

KEYWORDS: Harvey Cushing, skull base, cranial vault, neuro-oncology

The turn of the 20th century saw the advent of neurological surgery as a defined specialty, with Harvey Cushing and his contemporaries pioneering operative approaches to lesions of the brain and the surrounding bony structures. Part of these pioneering advancements in neurosurgery included the advent of operative approaches to the skull base developed by Harvey Cushing and his colleagues, such as transsphenoidal transnasal approaches to the pituitary gland,¹⁻³ meningiomas of the anterior skull base,⁴ and acoustic neuromas.⁵ While Cushing's experience with these lesions has been documented, the breadth of his contributions to operative approaches to the skull base has been neglected. His operative approaches to lesions of the cranial vault itself have likewise been largely un-

known. We present operative records, illustrations, and details from Dr. Cushing's clinical series dealing with resection of varying pathology of the skull base and cranial vault during his early career at the Johns Hopkins Hospital.

MATERIALS AND METHODS

Following Institutional Review Board approval, and through the courtesy of the Alan Mason Chesney Archives, we reviewed the Johns Hopkins Hospital surgical files from 1896 to 1912. These records include the history and physical examination documented at the time of admission, as well as Cushing's operative notes and original illustrations.

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RESULTS

Five patients underwent surgical treatment of lesions involving the skull base (three patients) or cranial vault (two patients); three patients were female. The mean age was 26.2 years (range 13 to 35). The patients had the following diagnoses: unspecified malignant tumor of the basal meninges and temporal bone, basal cell carcinoma, osteoma of the posterior skull base, and osteomas of the frontal and parietofrontal cranial vault. The mean length of stay was 22.4 days (range 16 to 29 days). We present the details of the operative procedures, as documented by Harvey Cushing.

Case One: Malignant Tumor of Basal Meninges

On March 11, 1904, a 30-year-old woman presented complaining of "brain tumor." The patient had undergone a craniotomy in Montreal a few weeks before admission, which removed a portion of the temporal bone. Cushing brought her to the operating room on March 16, 1904, for "partial removal of malignant basal tumor." His illustrations (Fig. 1) and operative note document the procedure:

The old wound was reopened, the temporal lobe elevated from the scar which had formed at the base of the skull and the growth was once more freely exposed. The accompanying diagrams show its situation fairly well [Figure 1]. A large portion of the tumor was curetted and cut away [...] The growth infiltrated the temporal bone and the soft parts below the base of the

skull in all directions and it was curetted away certainly to the mid line. The operator thought that the curette very probably entered into the region of the dural body. Though if this were the case the cavernous sinus and possibly the internal carotid must have been thrombosed [...] The wound was only partially closed. It being desired to make an attempt to treat the growth by the direct application of the X-rays. This was done for several weeks after the operation was performed.

The patient was discharged on April 19, 1904, following a 29-day hospital stay. She died "some months later," as reported by Dr. Schmidt, her physician.

Case Two: Basal Cell Carcinoma

On August 31, 1908, a 35-year-old woman presented complaining of "pain and swelling of l. side of face." Cushing brought her to the operating room on September 12, his operative note describes the procedure:

An opening was made directly over the ear through the thin part of the temporal bone somewhat like a combined decompression and ganglion operation. The temporal muscle was divided across and the opening, measuring about 8 cm. in its antero-posterior and possibly 6 or 7 in its vertical diameter, was easily made. Through this opening the operator gradually elevated the dura from the roof of the temporal bone and separated the superior petrosal sinus, etc. from the pyramidal process. At a distance of about 3 cm. from

Figure 1 Cushing's original illustrations of the location of a malignant tumor of the basal meninges, in a 35-year-old woman, Case One. Cushing's labels read (left to right) "dura," "lateral view situation," "Form. Magnum," "carotid" (top), and "jugular" (bottom).

the junction of the pyramidal and squamous portions the roof on the upper surface was found absent and protruding through it a tumor mass of a dark color was disclosed [...] the operator also endeavored to chip away from it the surrounding margin of petrous bone [...] the portion of tumor removed was gritty, hard, vascular and at the time of its removal was thought to be a cysto-sarcoma.

The pathological diagnosis was "epithelioma baso-cellulare." The patient had an uneventful postoperative course, and was discharged in "unimproved" condition on September 22, 1908, after a 22-day hospital stay. The chart documents that the patient died in February 1910. No further information was available.

Case Three: Posterior Osteoma of Skull

On May 16, 1909, a 13-year-old boy presented to the Johns Hopkins Hospital complaining of a "lump on neck" (Fig. 2). A history taken on admission documented that the lesion began 7 years before admission when:

pt [patient] first noticed a small lump the size of a pea just back of left ear over the occipital bone just a little above mastoid process. It was hard and pt. [patient] cannot remember whether or not it was attached to the bone – thinks skin was freely moveable over it. The tumor grew very slowly and 2 yrs ago after 5 yrs growth it was no larger than a walnut. About eight months ago it was about half of present size but since that time it has grown rapidly and at present is about as large as a large orange.

Cushing brought the patient to the operating room on May 22, 1909, for a primary stage resection of the tumor. Cushing's preoperative photograph (Fig. 2) documents the size of the lesion. His operative note documents the procedure:

The long incision was carried up over the upper surface of the tumor from above the ear to well down in the cervical region. The soft parts were incised down to the growth, which had a definite solid capsule which bled from numerous points, requiring the placement of a number of ligatures [...] The pedicle, which proved to be about 6 cm. in diameter, was accessible at the upper side of the tumor, and here a first perforation with a burr was made. From this opening with a Montenovesi forceps an incision was cut in the bone around toward the mesial side of the tumor and outward toward the mastoid process. Here the bone became thick, and it was necessary to use a mallet and chisel, cutting through the mastoid cells down practically to the external equatorial line of growth [...] With spuds the flap was then cracked away from the dura [...] it was deemed best to postpone subsequent procedure for another sitting.

Post-operatively, the patient experienced

"considerable bleeding [...] especially from the patient's ear [...] the bleeding finally filled the ear and ruptured the drum. There was bleeding also from the Eustachian tube into the mouth.

Cushing brought the patient back to the operating room on May 25, 1909, for a second stage removal:

Figure 2 (Left) Preoperative photograph documenting the size of the posterior skull base osteoma. (Right) Postoperative photograph documenting the healing incision following extensive resection of an osteoma in Case Three, a 13-year-old boy.

With considerable hesitation the pedicle and adherent portion of the occipital bone were broken across and the muscular attachments at the lower margin were divided and the tumor liberated [...]. The dura over the cerebellum was opened with an incision of about an inch in length [...]. The dural wound was then reclosed [...]. The soft parts were then brought together by a row of silver mattress sutures [...]. a second row of fine silk sutures was placed in the galea, and the skin was closed as usual [...]. The operation was well borne. [Figure 2].

Examination of the gross pathology specimen documented:

The tissue consists of a large smooth, solid tumor about the size of an ostrich's egg. The external surface is covered by a number of vessels, showing the growth to be quite vascular [...] the pedicle of the tumor, measuring about 6 cm. in diameter, is evidently attacked [sic] to the suboccipital bone at the mastoid region [...]. A mid-section was sawn through the tumor [...] As one passed from the solid eburnated portion the structure becomes less solidly bony and the spaces are filled with what appear to be dense fibrous tissue.

The patient had an uneventful postoperative course, and was discharged on June 14, 1909, after a 29-day hospital stay.

Case Four: Diffuse Osteoma of Mid Parieto Frontal Region (Turmschadel)

On June 9, 1910, a 26-year-old man presented complaining of "loss of consciousness for the past year. (epilepsy.) Swelling of head." Cushing noted in the admission history that the patient "smokes to excess; occasional alcoholic irregularities. Tripper [gonorrhea] on several occasions. Lues denied. But admits exposure." The patient had been treated with long-term mercury injections for suspected syphilis; his symptoms continued, with frequent seizures, his last seizure before admission "occurred in Senate Chamber and doubtless precipitated the present consultation."

On physical examination, Cushing noted:

Situated in the mid-line – just over junction of coronal and sagittal sutures – there is a dome-like swelling over which the scalp is freely movable; smooth, not tender, and of bony hardness. It measures about 7 cm in both ant-posterior and transverse diameters; the summit is possibly 2 cm above the level of the surrounding scalp.

Cushing brought the patient to the operating room on June 11, for a "first stage operation for removal

Figure 3 Cushing's intraoperative illustration documenting an osteoma and tortuous temporal veins in Case Four, a 26-year-old man. Cushing's labels read (top left) "dura," (top right) [illegible], and (bottom center) "Xray shows about this condn [condition]."

of bony tumor of skull." His operative note and accompanying illustration (Fig. 3) document the procedure:

A circular flap of the scalp was made around the tumor with its base towards the left side. A tourniquet used. Not a great amount of bleeding from the vessels of the scalp excepting from the enlarged tortuous temporal which had to be clamped. The scalp was elevated from the projecting bony tumor with the periosteal elevator during the course of which procedure there was more or less bleeding from the surface of the tumor. Blood spurted from the opening in the bone. A part of this bleeding was venous, some if [sic] it arterial. It was with difficulty controlled; wax being tried and in some places tooth picks being inserted in to the bony openings. After reflecting the flaps of the scalp and scraping the periosteum from the surfaces of the tumor the operator proceeded to encircle the tumor with openings made with perforator and burr. The skull was extremely thick, the burr being completely buried before dura came into view. In some places the bone must have been certainly 2 cm in thickness. It was not especially hard or eburnated and in some places was quite soft with diploetic sinuses. On encircling the growth Hudson's largest burr was used which made a large shallow opening in the bone. The connecting bridges of bone between the burr openings were cut through with the small rongeurs so that at the end of the procedure the tumor was completely surrounded and isolated. [...] Having encircled the bony growth the operator was able to loosen and elevate it a little with the periosteal elevator. He decided to stop the procedure at this stage due to the fact that the patient had lost considerable blood from the constant slow ooze. As much of the wax was removed as possible and the field of operation was dried fairly well.

The fold was replaced again and approximated with interrupted fine silk and the skin with fine silk. A single protective drain was placed to draw off the accumulated blood.

Four days later, on June 15, Cushing brought the patient to the operating room for a second stage removal; this operation was accompanied by what Cushing believed to be a surgical milestone, namely the “first use of blood clot as hemostatic agent.”

The gutter which had been made about the central and most prominent portions of the original tumor was filled with black, four day old blood clot. This was carefully preserved and used subsequently as will be related. An attempt was made to isolate and lift the central bony tumor, but every step caused so much fresh bleeding that no more advances were made. The gutter was however continued around on the anterior part of the central area so that it became actually an island. This possibly may have been an injudicious step for it prevented further attack in the central area owing to its now movable condition. It would possibly have been best while still attached to have sewn off its upper portion and thus to have secured a central are of bone to cover the defect.

As the gutter was being gradually worked through in order to elevate the bone the longitudinal sinus was crossed at the posterior part of the island where previous bleeding had occurred. It was possible to stop this by pressure of cotton and finally the cotton was removed and a mass of blood clot placed on the bleeding surface and held there with wet cotton. It immediately checked the hemorrhage and glued itself in place. One of the meningeal arteries which was greatly dilated was also torn into at the bottom of the gutter, somewhat more anteriorly than the longitudinal sinus and this was reached by a silver clip.

Thus these devices for controlling hemorrhage proved of great value.

With the island thus freed, the scalp was replaced and sutured without a drain in the usual fashion.

The patient was discharged in “well” condition on June 27, following a 16-day stay. He returned to the Johns Hopkins Hospital twice, once without operative intervention, and once for removal of a recurrence of the bony tumor. Cushing noted in the operative chart that:

This is doubtless a case of endothelioma [meningioma] of dura with superimposed osteoma. Not recognized at time. Have since seen a number of other instances of same thing.

Cushing recalled the patient in September 1915, and the patient was operated upon at this time at the Peter Bent Brigham Hospital. Cushing briefly summarized the case in his 1938 treatise on meningiomas: “Exposure plaque ‘endothelioma’ right parasagittal angle. Fragmentary removal. Sinus occluded. Section taken for examination.”⁴

Case Five: Osteoma of Skull, Frontal Region

On October 15, 1910, a 27-year-old mail clerk presented complaining of a bony tumor along the midline frontal skull, which had been present for 5 or 6 years. His admission note documents an episode of luetic infection 3 years before the onset of symptoms. Two and a half years before admission he developed “convulsive seizures.”

Cushing brought him to the operating room on October 24:

[...]tourniquet was applied and an omega shaped flap, with its base anterior was cut down to the bone. Flap was exceedingly vascular requiring the placement of innumerable clamps, cutting large arterial branches which however in the main were controlled by tourniquet. The flap was then dissected away at first, periosteum being taken with the flap, but this seemed inadvisable as the irregular character of the surface of the bone made the operator think that possibly it might be of periosteal origin. Consequently the periosteum was laid back again on the surface and the flap removed, with the periosteum.

Having no perforator it was finally decided to remove the upper part of the tumor by means of a gili [sic] saw. The first incision was started with a Doyan saw and the Gili [sic] saw following it. Bleeding was checked by allowing the saw to run through wax. The surface of the tumor was then finally removed except at the posterior portion which was cut with great difficulty as it was eburnated. A curious mishap occurred in that the saw was led down through the dense bone so that at the anterior part of the exposed area the dura was laid bare about a certain level of the denuded field. Bleeding from this was considerable but was finally checked by the placement of a bit of periosteum taken from the under surface of the flap beyond the confines of new growth. The outline of the growth as a matter of fact was quite sharply demarcated. The remaining portion of the eburnated bone which was upon the level of the surface of the skull was then perforated in several places. The perforator was finally secured and followed by a smaller and then a larger burr until almost all of the bone was gnawed away leaving a thin layer over the surface of the dura. The dura itself exposed in several places was very rough and vascular and evidently was

participating also in the osteomatous growth. The operator began the outline of this central area with the idea that it might be wise to leave the central island as in the case of [Case Two], but there had already been considerable loss of blood and it was deemed wise after starting an inch or two of the incision to replace the flap and close the wound.

The patient had an uneventful postoperative course, and was discharged in "well" condition, following a 16-day stay. The patient returned for a re-operation by Cushing at the Peter Bent Brigham Hospital in 1915. A later note from Cushing in the Johns Hopkins chart reads: "unquestionably overlying an endothelioma a condn [condition] unrecognized in 1910 by me."

DISCUSSION

Here we report five patients in whom Cushing resected lesions of the skull base and cranial vault utilizing surgical concepts still in practice today. The cases discussed here demonstrate Cushing's understanding of several fundamentals of skull base surgery: the preferential removal of bone, and the need for large soft tissue coverage.⁶⁻⁸

The cases presented here emphasize Cushing's attention to meticulous hemostasis, employing traditional methods of bone wax and tourniquets, as well as exploring the unconventional options of toothpicks and autologous blood clots. In addition, Cushing devised multistage operations for resection of tumors that proved to have extensive vascular involvement, as in Case Four, allowing him to maximize tumor resection while minimizing patient morbidity and mortality. Concurrently, Cushing further recognized the concept of multimodality treatment, demonstrated by his use of X-ray technology for postoperative radiation in Case One.

The resection of these tumors presented the unique challenge of reconstructing the cranial vault following extensive removal of bone. In the absence of synthetic materials for reconstruction, surgeons devised osteoplastic bone flaps,⁹ using fragments of autologous bone to replace iatrogenic defects, protecting the underlying brain while offering an improved aesthetic outcome. In Case Three, Cushing resected the entire osteoma, and performed a multilayered closure of the soft tissues without attempting to bridge the defect. In Cases Four and Five, Cushing left an "island of bone" behind, which served to prevent large bony defects following resection of the large osteomas.

At the turn of the 20th century, neurological surgery remained plagued by high risks of hemorrhage, infection, and high patient mortality rates.¹⁰⁻¹² Breeching the bones encasing the brain was considered daring,

even in the eyes of Cushing, who reflected upon his early neurosurgical experience:

[...] and thus it was that the senior author (H.C.) [...] while serving as surgical house pupil (1895-1896) at the Massachusetts General Hospital under the late J.W. Elliot, one of the most brilliant and daring surgeons of his day, he ventured twice to trephine the skull for tumors involving the brain.⁴

Between this early entry to neurological surgery, and the cases reported here, Cushing became well versed in Halsted's meticulous operative technique,^{13,14} and developed his own novel approaches to intracranial lesions.^{4,5} In the span of under 20 years, Cushing created the dedicated specialty of neurological surgery,¹⁰⁻¹² and in this process contributed to the surgical resection of tumors involving the skull base and cranial vault.

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