Transfacial Approaches to the Skull Base: The Early Contributions of Harvey Cushing

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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 use of craniofacial approaches for malignant pathology of the skull base. 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, which included three patients who underwent surgical treatment of lesions involving the skull base through craniofacial approaches: two adults and one child (range 3 to 43 years). The main outcome measures were length of stay and condition recorded at the time of discharge. The indications for surgery included osteochondroma of the sphenoid sinus, sarcoma of the maxillary sinus and middle fossa, and osteoma of the frontal sinus. The mean length of stay was 24.5 days (range 7 to 45 days). Cushing employed craniofacial approaches for malignant pathology nearly 40 years before such techniques became widely used. He practiced the fundamentals of skull base surgery, including preferential removal of bone to achieving adequate exposure for resection. In addition, Cushing clearly understood the importance of proximal vascular control in approaching lesions with complex vascular involvement.

KEYWORDS: Harvey Cushing, skull base, transfacial, neuro-oncology

Skull base surgery has its documented origins in the late 19th century, when Harvey Cushing and his contemporaries popularized transsphenoidal transnasal approaches to the pituitary gland.^{1,2} Despite inadequate instrumentation and surgical illumination in the era, Dr. Cushing pioneered surgical approaches to sellar pathology (transsphenoidal, subtemporal, and subfrontal approaches). In addition, it appears that Dr. Cushing's initial experience with skull base pathology was not limited to pituitary tumors. Cushing published an extensive account of his treatment of acoustic neuromas via a bilateral posterior fossa approach.³

The surgical resection of anterior skull base pathology via transfacial approaches to cranial base pathology was employed by Walter Dandy and other neurosurgeons throughout the first half of the 20th century.^{1,4} Combined transcranial-facial approaches to lesions of the anterior skull base were described by Cushing^{5,6} and later proposed by Smith and colleagues in the 1950s⁷; however, the first series of patients undergoing a combined approach for resection of malignancies was published by Ketcham et al in the 1960s.⁸

Although Dr. Cushing's experience with various cranial base pathologies has been reported,^{3,9} his initial experience with transfacial approaches has not been

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Table 1 Demographics and Outcomes Data for Patients Undergoing Transfacial Approaches for Lesions of the Skull Base, Performed by Harvey Cushing at the Johns Hopkins Hospital

Case	Surgery Date	Age	Sex	Pathology	Length of Stay (d)	Outcome at Discharge
1	February 8, 1902	43	M	Osteochondroma of sphenoid sinus	—	—
	March 8, 1902			—	45	Well
	December 3, 1902			—	18	Improved
2	January 14, 1903	3	M	Sarcoma of superior maxilla and skull base	7	Dead
3	April 27, 1909	34	F	Osteoma of right frontal sinus	27	Well

reported. We present operative records from Dr. Cushing's early clinical series at the Johns Hopkins Hospital dealing with craniofacial resection of varying cranial base pathology.

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 exam documented at the time of admission, as well as Cushing's operative notes and illustrations. Patients undergoing transfacial approaches were selected for further review.

RESULTS

Three patients underwent surgical treatment of lesions involving the skull base through craniofacial approaches: two adults and one child (Table 1). The patients had diagnoses of osteochondroma of the sphenoid sinus, sarcoma of the maxillary sinus invading the skull base, and osteoma of the frontal sinus. One patient underwent three operations over the course of two admissions; the remaining patients underwent a single procedure each. The mean length of stay was 24.5 days (range 7 to 45 days). We present the details of the operative procedures as documented by Harvey Cushing.

Case 1: Primary Osteochondroma in Sphenoid Sinuses, Invading Sphenomaxillary Fossa and Middle Cerebral Fossa (Subtemporal Transzygomatic and Transfacial Approach)

On February 3, 1902, a 43-year-old man presented to the Johns Hopkins Hospital complaining of "pain throughout rt half of head." On physical exam, Cushing noted "posterior to soft palate can be felt on outside a round soft projection filling rt half of post. nares."

Based on these physical exam findings, Cushing brought the patient to the operating room on February 8, 1902, for "exploratory craniotomy in temporal region for suspected intracranial growth. Preliminary ligation of common carotid. Operation as for Gasserian Ganglion."

Cushing's illustration (Fig. 1) and operative note document the procedure:

Short incision made along the anterior border of the sterno mastoid and common carotid was ligated on a level with the omohyoid muscle. . . . The usual incision was then made for a gasserian ganglion operation; the zygoma divided. An opening in the squamous portion of the temporal bone about 4 cm. in diameter was made with mallet and chisel, being enlarged with Rongeur forceps. . . . The dura was lifted and at the situation of the ganglion a thick whiteish band, stretching from the foramen spinosum to the sphenoidal sinus, was disclosed. On elevating this was disclosed a soft tumor the size of a hickory nut. This was entirely extra-capsular. . . . It penetrated the bone about at the situation of the foramen ovale by an opening possibly 1 ½ cm. in diameter . . . the temporal bone was removed with Rongeurs so as to free the neck of the growth, and its body was liberated by enlarging downward the posterior angle of the horse-shoe shaped incision. The growth passed inward and forward between the articular and coronoid processes of the lower jaw.

Figure 1 Case 1: Cushing's illustration of the situation of a lesion of the skull base, as exposed through a transcranial approach during a first stage operation. Label reads: "Diagram of tumor as exposed."

Figure 2 Case 1: Cushing's illustrations of the location of a lesion of the skull base, observed during a second-stage operation, through a craniofacial approach.

The patient returned to the operating room on March 8, 1902, for "partial excision of the superior maxilla to expose deep seated tumor in situation of sphenoidal sinus." Cushing's illustrations (Fig. 2) and operative note document the procedure:

The usual incision below the orbit and at the edge of the nares, turning back a flap of the upper lip, was made as for excision of the superior maxilla. . . . In order to expose the growth it seemed advisable to remove a large part of the superior maxilla. This was done piecemeal, leaving the floor of the orbit, the malar bone, and the gums and soft parts covering the hard palate. The tumor was found apparently rising from the deep athemoid [sic] cells and from the sphenoid sinus. It could not be removed in one piece and was roughly scraped out with a spoon piecemeal. The entire sphenoidal cells, ethmoidal cells, tissues in the region of the spheno maxillary fossa, the turbinate bones, were removed, leaving a large hole about 12 cms in depth. The finger could be passed through the opening in the base of the skull to the situation of the ganglion.

Postoperatively, the patient experienced facial sensory anesthesia (Fig. 3); however, he was discharged in "well" condition on March 20, 1902.

The patient returned on December 3, 1902, with the same complaints of right-side face and head pain. He was brought to the operating room on December 8, 1902. Cushing's operative note documents the procedure:

An incision was made corresponding to the incision of his first operation. . . . The meningeal artery also had to be ligated by a double ligature . . . as soon as the temporal lobe was exposed . . . it became evident that the recurrent growth had involved this lobe to a considerable extent. . . . An attempt was made to remove the entire mass by means of an ordinary teaspoon, the shank of which, however, was too weak to enable it to be used for this purpose. The growth consequently was shealled [sic] out by pressure with the finger. . . . Subsequently a large part of the base of the tumor well down into the spheno-maxillary fossa was curetted away with a sharp spoon.

Postoperatively, the patient developed complete blindness in the right eye; he was discharged in "improved" condition on December 21.

Case 2: Sarcoma of Superior Maxilla and Skull Base (Transfacial Lateral Rhinotomy Approach)

On January 7, 1903, a 3-year-old boy presented with a 3-week history of right-sided exophthalmos (Fig. 4) and a 1-week history of bloody nasal discharge and protrusion of the hard palate. Cushing brought him to the operating room on January 14, 1903; his operative note documents the procedure:

Before beginning the operation the right carotid artery was dissected out and a ligature placed about it but was not tied. Traction was made on the ligature during the entire subsequent operation.

Figure 3 Case 1: Cushing's illustrations of the areas of facial anesthesia experienced following a craniofacial approach for a second-stage operation for removal of a lesion of the skull base. The arrow represents Cushing's depiction of the original incision.

An incision was made below the right eye down alongside of the nose and through the centre of the median part of the upper lip. The original skin incision was enlarged out over the right cheek and the skin dissected off over the anterior surface of the mass. The zygoma was cut through above. The tumor extended downward into the mouth so that the ascending ramus

of the lower jaw had to be removed. One incisor tooth was removed and the incision carried back over the hard and soft palate past the median line. . . . The tumor mass was cystic in many places . . . it was seized with forceps and the maxillae separated at about the location of the incisor which had been removed. The bone of the hard palate was cut through and the antrum and its mass were retracted outward, portions of the tumor breaking away and leaving large masses posteriorly below the base of the skull. The floor of the orbit was also involved and at this point in the operation the child's condition became serious and it was though best not to attempt any more.

The operative note states that "the child was removed from the operating table and there was some slight improvement in his condition for a time but death was the ultimate result," and the chart documents that the child "died soon after being taken from table." No cause of death was determined, and no autopsy or further correspondence from the family was available.

Figure 4 Case 2: Cushing's illustration of exophthalmos in a child presenting with a lesion of the skull base.

Case 3: Osteoma of Right Frontal Sinus (Direct Frontal Osteoplastic Flap Approach)

On April 20, 1909, a 34-year-old woman presented complaining of "pain over eye and headache." Cushing brought her to the operating room on April 27, 1909; his illustration (Fig. 5) and operative note document the procedure:

A yoke-shaped incision over both brows and dipping down toward the bridge of the nose was made so as to include the sinus . . . the incision was carried

Figure 5 Case 3: Cushing's illustration detailing his craniofacial, subfrontal approach to a lesion of the anterior skull base. Left label reads: "point of breaking down."

down to the bone and scraped away so as to bring into view the entire frontal sinus region. With perforator an opening was made into the left frontal sinus and similarly one into the region of the right sinus. . . . The perforator came down upon a large mass of ivory-like bone . . . what proved to be an actual bony tumor. The tumor apparently was about the size of a golf ball, occupying the right frontal sinus . . . by mallet and chisel, gouge and perforator the eburnated bone was perforated in one direction and another until it was finally in large part removed. The operator then in the effort to determine its depth, penetrated to a distance possibly of 3 cm. from the anterior surface of the tumor before the posterior wall of the frontal bone was brought into view. With the burr this was penetrated and a large abscess cavity was opened. This cavity proved to be in the frontal lobe and must have contained possibly two ounces of pus.

The patient had an uncomplicated postoperative course and was discharged in "well" condition on May 17, 1909.

DISCUSSION

Here we report three patients in whom Cushing resected lesions of the midline and anterolateral skull base utilizing craniofacial approaches still commonly used in practice today. Outside of pituitary tumors and acoustic neuromas, to date, the literature has not documented his experience with transfacial approaches. Combined craniofacial resection for malignancies were originally described in the literature in the late 1960s¹⁰; though the first written description of the bifrontal craniotomy was in the 1950s by Unterberger.^{11,12} The need for access to the cranial and sinonasal aspects of the skull base for the visualization and treatment of invasive and complex pathology was thought to have been derived from Walter Dandy's and other neurosurgeons work in the early 20th century. The field of craniofacial surgery was beginning to be developed by the emerging pio-

neers of plastic and reconstructive surgery in the late 18th and early 19th century, with advances in Europe by von Graefe, Delpach, Dieffenbach, Denonvilliers, and Reverdin,^{13,14} while John Mettauer, practicing at the University of Maryland, was credited as the first plastic surgeon in the United States, repairing cleft lips and palates during the first half of the 19th century.¹⁵ At the turn of the 20th century, while Cushing developed the field of neurosurgery, John Staige Davis finished medical school at Johns Hopkins in 1899, and began his work in plastic and reconstructive surgery at the Johns Hopkins Hospital, publishing papers as early as 1911.¹⁶

Although European and American plastic surgeons had begun developing the field of craniofacial surgery, there is no record of Cushing training at home or abroad with the European and American surgeons pioneering craniofacial techniques in plastic and reconstructive surgery. However, his surgical practice at the turn of the 20th century was broad, with significant forays into the realm of craniofacial plastic surgery, performing complex facial reconstruction, as well as cleft lip and palate repairs.¹⁷ A review of the literature assessing Dr. Cushing's experience with cranial base pathology primarily reveals reports of his work with pituitary tumors⁹ and acoustic neuromas.³ Yet, Dr. Cushing's initial attempts at transfacial approaches for skull base pathology has not been reported. Cushing employed such approaches for malignant pathology nearly 40 years before such techniques became widely used.^{1,8}

The operative records further highlight Dr. Cushing's understanding of several fundamentals of skull base surgery that are still underscored in modern neurosurgical training: the importance of proximal vascular control, the preferential removal of bone, and the need for large soft tissue coverage. Recognizing the potential for intraoperative vascular injury and the difficulty in intratumoral vascular dissection, in several cases, Dr. Cushing exhibited the foresight for a neck dissection to obtain control of the internal carotid artery. This is particularly remarkable

considering the poor preoperative imaging in that era, when it would be difficult to assess tumor relation to critical vascular structures; this decision would have been primarily based on crude radiography, the patient's clinical presentation, and Dr. Cushing's understanding of cranial base anatomy. Similarly, Dr. Cushing displayed an advanced understanding of surgical anatomy through his selective use of osteotomies (i.e., zygomatic arch removal, etc.) to efficiently circumnavigate the skull base while minimizing brain retraction. In an era when the relationships of external osseous/soft tissue landmarks in relation to the skull base were primarily unknown, Dr. Cushing utilized osteotomies that were clearly precursors to modern neurosurgical techniques (i.e., subtemporal transzygomatic, subcranial, etc.). Cushing employed large soft tissue flaps to obtain the exposure necessary for extensive bone removal; although the operative notes do not highlight the techniques used, the vascularity of the soft tissues of the face and scalp would require meticulous attention to maintaining hemostasis in the absence of the electrocautery or hemostatic agents. Finally, it is a testament to Cushing's meticulous surgical technique that neither of the two patients who were discharged following transfacial approaches to the skull base developed postoperative meningitis or surgical site infections, despite the lack of antibiotics. The mean length of stay for the three patients described here was 24.5 days, slightly shorter than the 27.2-day mean length of stay for all patients undergoing neurosurgical intervention by Cushing at the Johns Hopkins Hospital.

The past century has seen tremendous advances in skull base surgery; the advent of operative microscopes and the introduction of endoscopy have made transfacial approaches to the skull base an essential addition to the armamentarium of the modern skull base surgeon. In parallel, improvements in radiography, understanding of skull base anatomy, and pathology have resulted in the development of a myriad of approaches that can access the skull base from both transcranial and transfacial trajectories. The widespread use of broad-spectrum antibiotics and development of better soft tissue reconstruction techniques have further reduced the incidence of complications associated with operating in both the cranial and paranasal cavities. Although the cases described here demonstrate the fundamentals of skull base surgery, techniques have evolved to maximize exposure while minimizing brain retraction and obtaining improved cosmetic outcomes.^{1,18–20}

Operating without the accoutrements of contemporary neurosurgical practice, Cushing demonstrated surgical innovation in attempting craniofacial approaches to treat a spectrum of pathology despite not having the benefits of currently available surgical techniques, neuroanesthesia, and postoperative care. Nonetheless, he was able to achieve remarkable re-

sections; however, given the limited follow-up data, it is impossible to assess the impact of these resections on overall or progression-free survival. Although current literature credits neurosurgeons of the 1950s and 1960s with the development of craniofacial approaches to the skull base, the cases reported here demonstrate that Cushing utilized these approaches early in the development of neurosurgery and through his role in training the next generation of neurosurgeons may have influenced the development of craniofacial approaches to the skull base during the 20th century.

REFERENCES

1. Donald PJ. History of skull base surgery. *Skull Base Surg* 1991;1:1–3
2. Pendleton C, Adams H, Salvatori R, Wand G, Quiñones-Hinojosa A. On the shoulders of giants: Harvey Cushing's experience with acromegaly and gigantism at the Johns Hopkins Hospital, 1896–1912. *Pituitary* 2010;(September):7[Epub ahead of print]
3. Cushing H. Tumors of the Nervus Acusticus and the Syndrome of the Cerebellopontile Angle. Philadelphia, London: W.B. Saunders; 1917:viii
4. Dandy W. Results following the transcranial operative attack on orbital tumors. *Arch Ophthalmol* 1941;25:191–216
5. Cushing H. Meningiomas: Their Classification, Regional Behaviour, Life History, and Surgical End Results. New York: Hafner Pub.; 1962:2 v. (xiv 785 p.)
6. Patel SG, Singh B, Polluri A, et al. Craniofacial surgery for malignant skull base tumors: report of an international collaborative study. *Cancer* 2003;98:1179–1187
7. Smith RR, Klopp CT, Williams JM. Surgical treatment of cancer of the frontal sinus and adjacent areas. *Cancer* 1954;7:991–994
8. Ketcham AS, Wilkins RH, Vanburen JM, Smith RR. A combined intracranial facial approach to the paranasal sinuses. *Am J Surg* 1963;106:698–703
9. Cushing H. The Pituitary Body and Its Disorders, Clinical States Produced by Disorders of the Hypophysis Cerebri. Philadelphia, London: J.B. Lippincott; 1912:x
10. Van Buren JM, Ommaya AK, Ketcham AS. Ten years' experience with radical combined craniofacial resection of malignant tumors of the paranasal sinuses. *J Neurosurg* 1968;28:341–350
11. Feiz-Erfan I, Han PP, Spetzler RF, et al. The radical transbasal approach for resection of anterior and midline skull base lesions. *J Neurosurg* 2005;103:485–490
12. Unterberger S. Care of frontobasal wounds. *Arch Ohren Nasen Kehlkopfheilkd* 1958;172:463–484
13. Knoener W, Schultheiss D. Johann Friedrich Dieffenbach (1792–1847) pioneer in oral maxillofacial surgery. *J Hist Dent* 2002;50:117–121
14. Rogers BO. Carl Ferdinand von Graefe (1787–1840). *Plast Reconstr Surg* 1970;46:554–563
15. Horton CE, Crawford HH, Adamson JE. John Peter METTAUER—America's first plastic surgeon. *Plast Reconstr Surg Transplant Bull* 1961;27:268–278
16. Davis JS. Scalping accidents. *Bull Johns Hopkins Hosp* 1911;16:257–262

17. Dorafshar AH, Pendleton C, Quinones-Hinojosa A, Redett RJ. Cleft lip-cleft palate closure: the unknown contributions of Harvey Cushing. *Plast Reconstr Surg* 2010;126:1320–1324
18. Conway JE, Raza SM, Li K, McDermott MW, Quinones-Hinojosa A. A surgical modification for performing orbitozygomatic osteotomies: technical note. *Neurosurg Rev* 2010;33:491–500
19. Raza SM, Conway JE, Li KW, et al. A modified frontal-nasal-orbital approach to midline lesions of the anterior cranial fossa and skull base: technical note with case illustrations. *Neurosurg Rev* 2010;33:63–70
20. Raza SM, Quinones-Hinojosa A. The extended retrosigmoid approach for neoplastic lesions in the posterior fossa: technique modification. *Neurosurg Rev* 2011;34:123–129