Harvey Cushing's Treatment of Skull Base Infections: The Johns Hopkins Experience

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Abstract

Objectives In this report, we review Dr. Cushing's early surgical cases at the Johns Hopkins Hospital, revealing details of his early operative approaches to infections of the skull base.

Design Following institutional review board (IRB) approval, and through the courtesy of the Alan Mason Chesney Archives, we reviewed the Johns Hopkins Hospital surgical files from 1896 to 1912.

Setting The Johns Hopkins Hospital, 1896 to 1912.

Participants Eleven patients underwent operative treatment for suspected infections of the skull base.

Main Outcome Measures The main outcome measure was operative approach, postoperative mortality, and condition recorded at the time of discharge.

Results Eleven patients underwent operative intervention for infections of the skull base. The mean age was 30 years (range: 9 to 63). Of these patients, seven (64%) were female. The mean length of stay was 16.5 days (range: 4 to 34). Postoperatively eight patients were discharged in "well" or "good" condition, one patient remained "unimproved," and two patients died during their admission.

Conclusion Cushing's careful preoperative observation of patients, meticulous operative technique, and judicious use of postoperative drainage catheters contributed to a remarkably low mortality rate in his series of skull base infections.

Keywords

- Harvey Cushing
- skull base
- intracranial infections

Introduction

Trepanation is considered to be the oldest form of neurosurgery, arising almost 10,000 years ago.^{1–3} The prehistoric procedure of trepanation involved drilling a square piece of bone from the skull when the patient was fully awake under no anesthesia. Unfortunately, the morbidity and mortality rate was high and very few ventured to operating on the brain

for one major reason: the risk of wound infection.^{1,3} Hippocrates may have been the first to document treating purulent wounds by noting the following procedure: "cleansing with wine, apply a bandage, and then pouring wine on the bandage."³ The concept of evacuating the purulent material and dressing the wound was a concept learned very early on, though Claudius Galen, a surgeon to the gladiators, would

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make a claim that would delay the evolution of surgical treatment.³ Galen claimed that the formation of pus from the wound site was critical for wound healing; this incorrect theory would alter the course of surgical treatment until Joseph Lister's time. Galen's doctrine of suppuration laid a foundation for future surgeons to welcome the sight of pus; the resulting lack of wound care led to high morbidity and mortality.^{1,4} Louis Pasteur established the concept of antisepsis in the 1860s when he introduced the "germ theory," abolishing the idea of spontaneous generation and demonstrating that germs causing fermentation were killed by heat.^{1,3} Drawing on Pasteur's findings, Lister realized the importance of antisepsis and reported a drop of mortality rate from 45% to 15% following amputation procedures.¹ As a cranial surgeon, the results were inspiring to William Keen, who implemented a strict sanitary procedure in his operating room after listening to Lister's persuasive speech on antiseptic surgery in September 1876 at the International Medical Congress in Philadelphia.^{3,4} This adaptation of surgical infection control led Keen to be the first American surgeon to electively operate on the brain when he successfully removed a meningioma on December 15th, 1887.⁴

As intracranial operative procedures were explored at the turn of the twentieth century, Harvey Cushing's meticulous attention to sterility, careful operative techniques, keen perception to detail, and thoroughness in every step of an operation enabled him to break new ground in the treatment of intracranial pathology.⁵ Here we report Cushing's series of patients with infections of the skull base, undergoing operative intervention during his career at the Johns Hopkins Hospital. These cases demonstrate a remarkably low mortality rate, given the limitations of operative and pharmaceutical management of infections. Cushing attributed his success to the intraoperative use of meticulous surgical technique:

[Our results] depend so greatly on such details as perfection of anesthesia, scrupulous technique, ample expenditure of time, painstaking closure of wounds without drainage, and a multitude of other elements, which so many operators impatiently regard as triviality.⁶

This is the first report of Harvey Cushing's management and treatment of skull base infections during his early career at the Johns Hopkins Hospital.

Materials and Methods

Following institutional review board (IRB) 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.

Results

Eleven patients underwent operative intervention for infections of the skull base. The mean age was 30 years

(range: 9 to 63). Of these patients, seven (64%) were female. The etiology of these infections as documented verbatim in the surgical records is included in ►Table 1. The mean length of stay was 16.5 days (range: 4 to 34). Postoperatively eight patients were discharged in "well" or "good" condition, one patient remained "unimproved," and two patients died during their admission.

Case Reports

Case 5—Frontal Sinus Abscess

In November 1906, due to some financial reverses, a 55-year-old man unsuccessfully attempted suicide by striking himself in the head with a hatchet. He was initially taken to another hospital in Maryland where fragments of bone were removed and the wound was allowed to heal by secondary intention. In January 1907 he was taken to Sheppard Asylum for his severe state of depression, where he complained of supraorbital pain and developed a severe cold. Several days later the lower part of his wound broke down and began to discharge pus. On January 28, 1907 Cushing admitted the patient with a presumptive diagnosis of a ruptured frontal sinus abscess. Cushing brought him to the operating room on January 29:

The point from which pus was discharging was further dilated and it was found that the sinus led into the frontal sinuses. There was no evidence whatsoever that there was any intracranial infection [...] The sinus was irrigated out as freely as possible and then with some difficulty an opening was made into the nasal cavity by enlarging the natural channel of exit from the sinuses into them. This was done first by passing a fine probe and then gradually dilating the canal. A rubber tube was left in canal and a Pagenstecher suture in addition.

On January 30, Cushing's noted:

The rubber tube withdrawn by patient. Fortunately, the Pagenstecher suture remained in position. [...] Irrigation both ways through the tube with salt solution. Pagenstecher suture withdrawn with double heavy braided silk as follower. The emerging ends of this braided silk were then tied over the face to make a circle which cannot become dislodged.

Cushing documented on February 4 that the patient was discharged in "well" condition and was to return for a dressing change. Ten days later, on February 14 Cushing noted: "Note in morning paper to effect patient committed suicide by hanging last night" (►Fig. 1).

Case 11—Frontal Sinusitis

On December 26, 1911 a 23-year-old woman from Ohio presented to Johns Hopkins complaining of right frontal headaches and nasal discharge of approximately 6 months duration. Cushing concluded that these symptoms were caused by right frontal sinusitis and brought the patient to the operating room for "opening and dilatation of duct from

Table 1 Demographic Information, Presenting Symptoms, Operative Data, and Outcomes for Patients Undergoing Operative Intervention for the Treatment of Infections of the Skull Base, by Harvey Cushing at the Johns Hopkins Hospital, 1896 to 1912

Case	Age (Years)/Sex	Skull Base Infection (Verbatim from File)	Date of Operation	Complaint	LOS (Days)	Drainage	Outcome (Verbatim from File)
1	18/F	Necrosis of Inferior Maxillary	September 9th, 1897	N/A	20	No (cavity packed with gauze/iodoform)	Well
2	63/M	Empyema of antrum	September 15, 1898	Abscess of Cheek	7	No (cavity packed with iodoform and gauze)	Good
3	37/F	Empyema Antrum of Highmon left. Chronic	July 5, 1905	N/A	7	Yes	Well
4	22/M	Post Traumatic Necrosis	September 2nd, 1905	Dazed and complains of headaches	34	No	Unimproved
5	55/M	Abscess frontal sinus	January 29th, 1907	Supraorbital pain, epileptiform convulsion, frontal wound ruptured.	7	Yes	Well
6	35/M	Chronic frontal sinus disease	December 31st, 1907	Acute attacks (headaches) that began 2 years ago	4	No	Well
7	30/F	Infection antrum highmoni. rt	January 23rd, 1909	Pain in right side of face above and below eye	25	N/A	Well
8	9/F	Chronic mastoiditis with sinus; rt side	February 3rd, 1910	Chronic discharge from right ear and old mastoid	31	Yes	Well
9	10/F	[preoperative] Otitis Media – right pneumococcus meningitis [intraoperative] Mastoid abscess	March 30th, 1910	Earache	4	Yes	Dead
10	32/F	Cerebral abscess, meningitis secondary to staphylococcus infection of face.	May 25th, 1910	Inability to open jaw, swelling in right side of face from tooth abscess	29	N/A	Deceased
11	23/F	Frontal Sinusitis	December 29th, 1911	Headaches, nasal discharge	14	No	Well

LOS, length of stay in days.

February 7th / note in morning paper
to effect pt committed suicide
by hanging last night.

Figure 1 Cushing's handwritten note documenting the newspaper account of postdischarge suicide of the 55-year-old man in Case 5. The note reads: "note in morning paper to effect pt committed suicide by hanging last night."

frontal sinuses." His operative note documents the procedure (► Fig. 2):

Usual incision was made parallel to an in-line with the eye brows. The bone was rongeured bringing the opening into the frontal sinus. This was enlarged by rongeurs. Mucous membrane was full of watery mucous cells suggesting an old chronic sinusitis. Ducts dilated by sounds. There was considerable bleeding during these manipulations. The mucous membrane was curetted away. Closure by catgut and skin suture of silk. No drainage.

Postoperatively, the patient had an uncomplicated course; she was discharged from the hospital on January 7, 1912. No further follow-up was available.

Discussion

Harvey Cushing is regarded as a central figure in establishing the field of neurosurgery and demonstrating that operating on the brain could be both safe and effective. He entered uncharted territory by opening the "closed box" and took great risks in the operations he performed because of the lack of operative equipment and imaging technology.⁷ In this case series we report 11 patients undergoing the treatment of skull base infections suspected by Cushing based on patient history and exam findings. No information was available in the cause of death in patients that died in this series and there were no follow-up letters giving an estimated time of survival in patients that did survive.

December 30, 1912. Opening and dilatation of duct from frontal sinus.

Operation, sinus

Dr. Cushing,

With (Davis)

Usual incision was made parallel to an in-line with the eye brows. The bone was rongeured bringing the opening into the frontal sinus. This was enlarged by rongeurs. Mucous membrane was full of watery mucous cells suggesting an old chronic sinusitis. Ducts dilated by sounds. There was considerable bleeding during these manipulations. The mucous membrane was curetted away. Closure by catgut and skin suture of silk. No drainage.

(Dr. Dandy.)

Figure 2 Cushing's typed operative note describing the procedure performed on the 23-year-old woman in Case 11.

Cushing used the experiments he conducted in the laboratory as an extension to his operating room. In this case series Cushing employed a meticulous irrigation technique to clean the infected area and his experimental work on irrigation fluid in the laboratory may have aided in his high success rate of treating skull base infections. In 1901 Cushing published a paper in the *American Journal of Physiology* titled "Concerning the poisonous effect of pure sodium chloride solutions upon the nerve-muscle preparation," in which he revealed that irrigation fluid from physiological experiments involving nerve and muscle required a balanced salt solution and that saline alone was injurious.⁸ He conducted experiments on 50 frogs, irrigating the animals under various conditions. Upon gathering and interpreting the results, Cushing made the following conclusions:

The pure sodium chloride solutions are injurious to the nerve-muscle preparation, The effect is in measure related to the percentage of this salt in solution. Inasmuch as the response from indirect stimulation fails, while that from direct nerve stimulation may persist, the results primarily affects the nerve ends. The injurious effect may be promptly counteracted by the blood or serum of certain animals or by the proper "physiologically balanced salt solution." By varying the percentage of the calcium ion in the solution, with certain limitations, proportionately beneficial effects may be produced. An excess of the calcium ions in certain cases of fatigued muscle may lead to intra vitam to a permanent contraction of the muscle resembling rigor mortis.⁸

This experiment served as an instrumental discovery in developing a safe method for irrigation technique in treating skull base infections. In this case series Cushing was able to translate his laboratory findings to the operating room, where the use of irrigation was a critical technique used in every case to treat the infection. Cushing's novel irrigation method ensured minimal nerve damage and optimal infection treatment. This is reflected in the operative outcomes (► Table 1), as no patients were reported to experience postoperative nerve damage. Other notable experiments Cushing translated from the laboratory to the operating room included blood pressure studies, the application of the Riva-Rocci apparatus during neurosurgical procedures to determine the patient's hemodynamic status, and cerebrospinal fluid (CSF) studies that offered solutions to the treatment of hydrocephalus.^{5,9-11}

Cushing displayed a deep understanding of when to operate and employ certain techniques. As observed in this series he observed the patient for 1 to 2 days (excluding trauma cases) and took thorough notes before bringing them to the operating room. This stemmed from Cushing's belief that a surgeon should be able to formulate a diagnosis and decide whether operative intervention was warranted.⁵ Cushing used drainage in four patients (► Table 1), perhaps demonstrating an understanding that the placement of unnecessary drainage catheters could increase the patient's risk of infection and postoperative complications. He avoided drainage placement unless

absolutely imperative; in a talk on neurosurgical procedures Cushing said, "...wounds must be left dry before closure and closure must be without drainage..."⁶ emphasizing his scrupulous selection of patients who received postoperative drainage. Cushing's judicious use of drainage placement in this series may have contributed to the remarkably low rates of secondary postoperative infections and other postoperative complications.

In addition, Cushing was at the forefront of operative technique development for the treatment of infections of the sinuses. Although frontal sinus surgery was a developing field in the early twentieth century, the published approaches advocated the removal of some or all of the bony structures of the sinus, often with preservation of the mucous membrane lining.¹² Cushing employed complete cranialization of the frontal sinuses in two cases of chronic frontal sinusitis, a technique that did not become widely advocated until the mid-twentieth century.^{12,13}

The importance of sterility and the prevention of infection were not lost on Cushing. During his observation of Dr. Victor Horsley in England, he was appalled by the poor technique and high incidence of septic wounds experienced postoperatively.¹⁴ At the time most neurological surgeons experienced a rate of mortality between 30 and 50% postoperatively as a result of infection, and this was something Cushing wanted to avoid.¹¹ This case series demonstrates Cushing's use of multilayered, tension-free wound closure and precise treatment of bone fragments during removal and replacement, optimizing his success in the treatment of skull base infections. In Case 5, the patient presented with an unhealed wound on the head, causing an infection of the skull base. Cushing excised the infected areas and closed the wound with precise technique, treating not only the skull base infection but ensuring no secondary infection would arise as a result of poor closure. In his paper published in 1918 in *The British Medical Journal* titled "Notes on the penetrating wounds of the brain," Cushing devises an algorithm for treating wounds in the head. These main features are described as:

1. In the removal en bloc rather than piecemeal of the area of cranial penetration.
2. In the detection of the in-driven bony fragments by catheter palpation of the track rather than by the exploring finger
3. In the suction method of the disorganized brain, thereby cleansing the track of the so-called pulped or devitalized tissue, whose retention, as this case with dead tissue anywhere, favors infection.

4. In the use of dichloramine-T in oils as an antiseptic particularly suitable for infections in the central nervous tissues"¹⁵.

Cushing used knowledge he successfully collected in the laboratory and applied them to the operating room to improve patient survival. He also took meticulous notes on every case to use every experience as a learning opportunity. This careful attention to detail combined with his ability to bridge knowledge between the laboratory and operating room, and adherence to sterile operative technique, enabled him to set a foundation for the treatment of skull base infections in the early 1900s.

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