Harvey Cushing's Early Operative Treatment of Skull Base Fractures

Courtney Pendleton¹ Shaan M. Raza¹ Gary L. Gallia¹ Alfredo Quinones-Hinojosa¹

¹ Department of Neurosurgery, The Johns Hopkins University School of Medicine, Baltimore, Maryland, United States

Address for correspondence Alfredo Quinones-Hinojosa, MD, 1550 Orleans Street, Cancer Research Building II Room 247, Baltimore, MD 21231, United States (e-mail: aquinon2@jhmi.edu).

J Neurol Surg B 2014;75:27–34.

Abstract

Objectives To review Dr. Harvey Cushing's early surgical cases at the Johns Hopkins Hospital, revealing details of his operative approaches to fractures of the skull base.

Design Following institutional review board approval and through the courtesy of the Alan Mason Chesney Archives, we reviewed the Johns Hopkins Hospital surgical files.

Setting The Johns Hopkins Hospital, 1896 to 1912.

Participants A total of 24 patients underwent operative treatment for suspected fractures 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 Overall, 23 patients underwent operative treatment for suspected skull base fractures. The mechanisms of injury were known for 22 patients and included work-related injuries (41%), falls (23%), vehicle injuries (32%), and other trauma (5%). One patient had no mechanism of injury specified in the file. The outcome at the time of discharge from the hospital was "well" or "improved" in 12 patients (52%). The remaining 11 patients died during their admission.

Conclusions Although 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
- trauma
- fracture

Introduction

At the turn of the twentieth century, the fields of emergency medicine and neurologic surgery were in the early stages of development.¹ Treatment of urgent and emergent neurosurgical complaints was limited by access to hospitals and by high rates of infection and operative mortality. Fractures of the skull base were a particular challenge to neurosurgeons of the time; neuroimaging was in its infancy, forcing surgeons to rely heavily on clinical symptoms for diagnosis. Operative intervention was plagued by ineffective hemostasis, postoperative infection, and high mortality rates.^{1–4} Harvey Cushing remained at the forefront of this clinical dilemma, using the skills garnered from his extensive surgical residency with William Halsted² to increase

the safety and success of neurosurgical treatment of skull base fractures, in the urgent care setting as well as in patients with a distant history of trauma. We present operative records from Dr. Cushing's clinical series dealing with the operative treatment of skull base fractures during his early career at the Johns Hopkins Hospital.

Methods

Following institutional review board approval and through the courtesy of the Alan Mason Chesney Archives, the surgical records of the Johns Hopkins Hospital from 1896 to 1912 were reviewed. Patients operated on by Dr. Harvey Cushing were further analyzed. Patients who underwent operative

received

May 4, 2013

accepted

June 16, 2013

published online

September 13, 2013

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Stuttgart · New York

DOI <http://dx.doi.org/10.1055/s-0033-1353361>.
ISSN 2193-6331.

treatment for suspected fractures of the skull base were selected and are described here.

Results

A total of 23 patients underwent operative treatment for suspected fractures of the skull base. Patient age was available in 22 files; the mean age was 30 years (range: 2–68). Most of the patients (87%) were male. The mean length of stay was 11.9 days (range: 1–35). The mechanisms of injury were known for 22 patients and included work-related injuries (41%), falls (23%), vehicle injuries (32%), and other trauma (5%). One patient had no mechanism of injury specified in the file. The outcome at the time of discharge from the hospital was “well” or “improved” in 12 patients (52%); the remaining 11 patients died during their admission (►Table 1). Three representative cases are described here.

Case 18

On November 25, 1908, a 54-year-old laborer presented complaining of “fall down stairs. 48 hrs ago.” The history was obtained from the patient’s granddaughter, “whose knowledge of pt is very scanty.” The history documented “48 hrs before admission (Sunday) (11/22/1908) pt fell down about seven steps, striking, it appeared, his head and chest...seems to have been unconscious for perhaps a few hours after injury but has since apparently not been unconscious. Though not aware of what was going on about him, he has responded somewhat to questions and instructions...Has muttered unintelligibly much of the time but when spoke to usually replies in Polish (as stated by family) that he wishes to be left alone.”

The physical examination performed by Cushing documented:

Rigidity of right arm and leg. Passive movements resisted particularly on this side. Keeps hands locked and legs crossed and resists disengagement. Tendency to right deviation of eyes. Right cheek blown out more than left. Responds to supraorbital pressure and makes effort with right hand to remove source of discomfort. It is probable therefore that there is left weakness rather than right spasticity. No odor of alcohol.

Cushing brought the patient to the operating room on the day of admission for a “Left Subtemporal Decompression.” His operative note and illustration (►Fig. 1) documents the procedure:

In the absence of any external evidence of [sic] cranial injury other than the extensive ecchymosis and oedema in the occipital region extending chiefly on to the left side, and considering the inability to examine the patient’s eye-grounds owing to his double cataract, the propriety or need of an operation was somewhat questionable. The examination of the urine, however, was negative, and the chance was taken that the patient’s unconscious condition was due to some intracranial lesion—whether oedema or haemorrhage could not be told.

The usual left subtemporal craniectomy was performed [►Fig. 1] with the primary object of determining if possible the degree of tension of the brain and of decompression should a lesion be found. There was no observable injury of the cranium, but the dura proved to be somewhat tense. Considerable bleeding was encountered, owing to the unusual attachment of dura to overlying skull. The meningeal arteries exposed were somewhat atheromatous, were very adherent to the bone, and considerable bleeding was encountered, particularly at the lower and posterior portion of the wound. After separating the dura from bone a somewhat profuse haemorrhage was occasioned and considerable blood was lost. It was possible to ligate the bleeding point and to see that it came from the posterior branch of the meningeal, but the vessel was so inaccessible that it had to be controlled by a gauze pack. This finally was replaced by an iodoform gauze wick, which was left in situ. The dura was then opened, disclosing the unexpected presence of a considerable subdural clot, which may have been about a centimeter in thickness in this situation. Through the small opening a large part of this clot, so far as could be reached, was removed and the wound was thoroughly irrigated, without however liberating and washing out any further extravasation. The flat cortical clot was so firmly coagulated in consequence of its age (three days) that washing out was impracticable. Consequently it is probable that a large part of the extravasation was left in situ. A drain was inserted underneath the temporal lobe and the wound was partially closed as usual.

Postoperatively, the patient remained “semiconscious. Very restless, screams and attempts to get out of bed.” He developed seizures limited to the left side of his face. On postoperative day 4, the patient developed a fever to 103°F, with new onset moist rales heard in the upper lobes of his lungs bilaterally. The surgical incision “seemed tense. Protective drain going down between dura and cortex was started. There was an immediate gush of bloody cerebro spinal fluid, under considerable tension.” The patient died on November 30; a postmortem examination showed the cause of death to be “broncho pneumonia, left lung.”

Although Cushing’s original operation was designed to reduce intracranial pressure from the injury, an examination of the skull base demonstrated significant fractures of the posterior fossa, outside of Cushing’s operative field (►Fig. 2):

No fracture near operation wound. On right side was a large sub-dural clot. From the occiput radiating downward in various directions—some large and some small—were fractures of the skull. The most extensive fracture being to the left of the mid-line.

Case 20

On May 30, 1909, a 46-year-old housewife presented complaining of “fall down stairs 4 days ago.” The physical examination at the time of admission, conducted by George Heuer, documented “Pt conscious. Responds intelligently to

Table 1 Demographics, operative details, and postoperative outcomes for patients undergoing operative treatment for fractures of the skull base^a

Case no.	Age/Sex	Etiology	Etiology code	Fracture location	Surgery date	Operation title (verbatim from chart)	Complications	LOS, d	Outcome
1	30/M	Fell out of wagon onto stone pavement (V)	V	Parietal bone extending into greater wing of sphenoid	2/1/1898	Osteoplastic flap operation. Exploratory craniotomy for contra-coup hemorrhage. Removal of subdural blood clot		2	Dead
2	30/M	Fell 17 feet, "accident seems to be in some way connected with elevator," 30 min prior to admission (W)	W	Right zygoma, anterior cranial fossa	2/26/1898	Exploration of site			
3	43/M	"had drunk heavily beer and whiskey [...] staggered and fell striking his head against a revolving wheel" (W)	W	Skull Base	2/26/1898 5/20/1898	Wound reopened Scalp wound opened...bone chipped away		1 1	Dead Dead
4	31/M	"driving an ice wagon when...the horses ran away and threw him out" (W)	W	Temporal bone	6/22/1899	Craniotomy for comp. depressed fracture. Elevation of depressed fragments. Removal. Evacuation of blood under dura	Hyperthermia (to 107.9°F)	1	Dead
5	68/M	"limb fell on pts head from a height of 25 feet" 24 h prior to admission (W)	W	Skull base	10/31/1902	Refreshing edges of old incision. Trepanation, elevation of comminuted fragments of depressed fracture. Evacuation of intracranial haematoma and subdural collection of cerebrospinal fluid. Lumbar puncture. Incision and drainage		3	Dead
6	42/M	Fell from "a warehouse window about 13 ft high" 30 min prior to admission (W)	W	Os frontalis	1/30/1903	Removal of some comminuted fragments from region of sinus (frontal) opening of dura. Brain under no tension	Pneumonia	12	Dead
7	25/M	"one of two traumatic cases injured in	V	Right temporal	4/9/1904	Exploratory craniotomy. Craniectomy rt temporal		1	Dead

(Continued)

Table 1 (Continued)

Case no.	Age/Sex	Etiology	Etiology code	Fracture location	Surgery date	Operation title (verbatim from chart)	Complications	LOS, d	Outcome
8	53/M	explosion of locomotive at Union Station" (V)		Middle cranial fossa	10/9/1904	region. Evacuation of focal hemorrhage. Clot in left hemisphere about base of motor region		1	Dead
9	?/M	"Pt found unconscious at foot of stairs by Police...supposed had fallen down stairs." (F)	F	Right temporal	3/11/1905	Exploratory craniotomy both temporal regions for intracranial hemorrhage following fracture of the base of the skull		1	Dead
10	40/M	Fell off trestle 20 ft into wooden tub 3 h prior to admission (W)	W	Anterior cranial fossa	1/8/1906	Intra-muscular craniectomy		17	Well
11	17/F	"pt came home 'beaten up.' Had had 3 drinks and then doesn't remember anything until he reached Police Station House (central district) next a.m." (O)	O	Left base of skull, temporal region	10/4/1907	Decompressive craniectomy		26	Improved
12	2/M	Fell out of second-story window 1 h prior to admission (F)	F	Left temporal fossa	10/22/1907	Bursting fracture of skull; spurious meningocele; laceration of meningeal artery with extracranial bleeding; concussion; acute accumulation of bloody cerebrospinal fluid		18	Well
13	14/M	"pt fell about 40 ft from a trestle striking his head on a board floor" 6 h prior to admission (W)	W	Left temporal fossa	3/28/1908	Left subtemporal decompression		9	Improved
14	41/M	"works for the Standard Oil Co. Was engaged in building new stall at Highlandtown, when another workman fell on him" (W)	W	Coronoid process extending into skull base	4/6/1908	Bilateral subtemporal decompressive craniectomy for fracture of the base		28	Well

Table 1 (Continued)

Case no.	Age/Sex	Etiology	Etiology code	Fracture location	Surgery date	Operation title (verbatim from chart)	Complications	LOS, d	Outcome
15	3.5/F	Fell from second-story window a distance of 15 or more ft (F)	F	Occipital region, posterior fossa	6/28/1908	Left subtemporal decompression for bursting fracture of skull		13	Well
16	26/M	Fell from horse an hour prior to admission (V)	V	Skull base	6/30/1908	Decompressive craniectomy for cerebral contusion		35	Improved
17	22/M	Thrown from buggy into telegraph pole 12 h prior to admission (V)	V	Left temporal	11/25/1908	Subtemporal decompression for fracture of the base with subdural hemorrhage. Closure with drainage	Left facial palsy	18	Improved
18	54/M	Fell down about seven steps 48 h prior to admission (F)	F	Posterior cranial fossa	11/25/1908	Left subtemporal decompression. Subdural clot. Closure with drainage	Left-sided facial convulsions, aphasia, bronchopneumonia	5	Dead
19	36/M	Thrown 20 ft into pile of scrap iron (W)	W	Mid frontal, right temporal	1/15/1909	Right decompression for compound fracture of base of skull. Repair of lacerated wounds of face	CSF leak	27	Well
20	46/F	Fall down stairs 4 days prior to admission (F)	F	Vault and middle cranial fossa	5/31/1909	Left subtemporal decompression for basal fracture	Postoperative wound breakdown	25	Well
21	25/M	"patient has been drunk for the last two days... while leaning out of taxicab window he was struck by an auto going in the opposite direction" (V)	V	Foramen magnum	4/9/1910	Suboccipital decompression for the supposed fracture of the foramen magnum		3	Dead
22	7.5/M	Struck by a car (V)	V	Left frontal/orbital	6/13/1910	Left subtemporal decompression with drainage for basal fracture. Drainage of left frontal lobe and orbital abscess		21	Well
23	7/M	Struck by automobile 6 h prior to admission (V)	V	Skull base	3/7/1911	Fracture of skull. Right decompression with drainage		7	Well

Abbreviations: F, fall; LOS, length of stay; O, Other cause; V, Vehicle; W, work related; CSF, cerebrospinal fluid.

^aBy Dr. Harvey Cushing at the Johns Hopkins Hospital. Operative description and outcome at the time of discharge were taken verbatim from the surgical files.

Fig. 1 Cushing's illustration of the operative approach used in case 19. The labels read (top to bottom, left to right): "line of fracture," "fracture," "decompressive defect," "cortex," "depressed fragment," "temp[oralis]," "dura," [illegible], "ear," "mastoid."

Fig. 2 Cushing's illustration of the postmortem examination conducted in case 19, demonstrating extensive fractures of the skull base. The labels read (top to bottom, left to right): "decompressive opening," [illegible], "torcula," "attachment of tentorium," "Pole of impact." The notation at the bottom right reads "Simple depressed and comminuted fracture of left parieto-occipital region: laceration of left occip lobe; echymoses of brain; Extensive subdural hemorrhage by contra coup over right frontal lobe."

questions. Quite drowsy....Over the forehead and face the ecchym. Has turned a yellow color. Behind left ear the discoloration (purplish) is most marked. The left lid is swollen, closed, oedematous discolored" (► **Fig. 3**). A cranial

Fig. 3 Preoperative photograph of case 21, documenting soft tissue injury and cranial nerve deficits.

nerve examination demonstrated "complete ptosis left lid. Pt unable to open eye. Left pupil wide—2–3 times as large as right. Does not react either to light or accommodation. Rt pupil reacts normally. [left eye] No movement of globe upward, downward, or inward (apparently complete lesion of III cranial nerve)."

Cushing brought the patient to the operating room the day after admission, for "Left Sub temporal decompression for Basal Fracture." His operative note documents the procedure:

Before cleaning up the ulcerated wound over the left frontal region a sub temporal decompression was done. Usual obliquely placed incision was made and the fibres of the temporal muscles separated. On elevating the periosteum from the bone a fractured skull was found running obliquely from left frontal region forward toward the base of the skull. The skull was perforated with the burr and the opening enlarged with ronguers. Considerable bleeding was encountered toward the base and it was found almost impossible to check this. The operator was unable to find the bleeding point and was obliged to pack temporarily.

The dura was then opened by a radial incisions. Considerable amount of bloody fluid was encountered. The cortex of the temporal lobe appeared greatly injected. There was no subdural clot. A single protective drain was placed far down towards the base, and brought out at the lower angle of the wound. The operator then returned to the bleeding points which he had previously controlled by packing. The greatest difficulty was experienced in checking this. One of the bleeding points was found and controlled with silver clip, another could not be checked and a pack was necessary. There was evidence of considerable injury for the dura over the entire middle fossa was separated from the bone. Wound was closed in layers as usual.

The patient developed wound breakdown on postoperative day 7, which was treated with frequent dressing changes. She was discharged on June 23, following a 25-day hospital stay; her condition at the time of discharge was listed as "well."

Case 21

On April 6, 1910, a 25-year-old electrician presented with a complaint of "struck by an automobile." The history was obtained from "companions on spree":

Patient has been drunk for the last two days. Last night, April 5th 1910 at 10 PM while leaning out of a taxicab window, he was "struck by an auto" going in the opposite direction. The blow was not sufficient to knock him out of taxicab, but caused him to hang limp in the window. He soon revived, was able to move about on seat of taxicab, seemed fairly conscious as he answered questions and talked with his companions. He told them not to bring him to a hospital nor to tell his wife.

Cushing brought the patient to the operating room 3 days after his admission, for a "suboccipital decompression for supposed fracture of the Foramen Magnum." His operative note describes the procedure:

The injury was received by the boy leaning out the window of a rapidly moving taxicab and presumably the back of his head, on the left, was struck by a tree or a passing

vehicle – After 48 hrs in the hospital developed characteristic rhythmic respir., during the period of apnea – (or even before the apnea became noticeable) would be quiet and very difficult to arouse – followed by a period of extreme restlessness. No convulsions. Extrav. under skin – left.

It seemed advisable in this case to free the cerebellum and medulla from whatever pressure there might be as a result of extravasation or concussion. This was done not opening the skull bilaterally as usual, but only on the left side. There was found a fissure running upward over the occiput from the foramen but aside from edema there was nothing further found. The cysterni [sic] were opened allowing the escape of a large amount of C.S. Fluid – which continued to escape along a protective wick leading from this point to the surface of skin. Wound closed.

Cushing concluded his note saying "Pt. in very poor shape – pulse has gone from 56 to over 200 a minute. Died within a few minutes after leaving op. room." However, the autopsy report documents that "the patient stopped breathing while on table. Artificial respiration resorted to, but patient died 6 hours later," indicating a significant interlude between the conclusion of the operation and the patient's exit from the operating room.

Cushing's postmortem examination of the brain further documents the extent of the patient's injuries:

On transverse sections through the third ventricle a cavity in the right temporal lobe containing a blood clot is seen, more extensive subcortically than appears on the surface [...] the extravasation has broken into the lateral ventricle [...] This case is a good example of contracoup, and if the usual right subtemporal decompression had been done in this case instead of the suboccipital exploration the point of greatest damage would have been exposed.

No further documentation of the patient's hospital course was available in the records.

Discussion

Fractures of the skull base presented unique diagnostic and therapeutic challenges to Harvey Cushing and his contemporaries. The complexities of skull base anatomy were compounded by the lack of neuroimaging modalities and the need to rely almost entirely on neurologic examinations for the localization of intracranial injuries. The vascular anatomy traversed in these operations required meticulous hemostasis to maintain adequate visualization, to prevent intraoperative mortality, and to promote adequate postoperative wound healing.^{1,3,4}

Although the mortality rate in the cases presented here remains high (48%), it is perhaps surprisingly low when the nature of the patients' injuries, the challenges of neuro-trauma cases, and the mortality rate of >50% for neurosurgical procedures performed under the best of circumstances by Cushing's contemporaries.^{1,3-7} Although the lack of postdischarge follow-

up makes an assessment of long-term outcomes impossible, the favorable condition at the time of discharge in all 12 surviving patients indicates that Cushing's operative interventions were at least temporarily successful.

Despite the significant inpatient mortality rate among these cases, the surgical records indicate that no inpatient deaths were attributable to surgical site infections. The sole patient with an intracranial infection documented in the chart was case 23, who presented to the hospital with a distant history of head trauma and an intracranial-orbital abscess; notably, he was discharged in "well" condition. The dearth of postoperative infections is a testament to Cushing's meticulous operative techniques, and it is particularly impressive given the absence of antibiotics and contemporary sterilization methods for operative personnel and equipment.

The cases described here demonstrate Cushing's commitment to transforming the field of neurosurgery into a viable surgical subspecialty; moreover, they document Cushing's extensive work in the field of neuro-trauma, an arena rife with complicated anatomy and operative technique but without the opportunities for remuneration and academic glory presented by Cushing's beloved neurooncology and neuroendocrine pursuits.^{1,3,4,8-10}

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