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Harvey Cushing and pediatric brain tumors at Johns Hopkins: the early stages of development:

Historical vignette

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Abstract

Object—Harvey Cushing, credited with pioneering the field of neurosurgery as a distinct surgical subspecialty in the US, was at the forefront of neurooncology, publishing seminal papers on the diagnosis and treatment of pediatric brain tumors during the latter part of his career. However, his contributions to the surgical treatment of these lesions during the early stages of his tenure at the Johns Hopkins Hospital, from 1896 to 1912, remain largely unknown.

Methods—After obtaining institutional review board approval, and through the courtesy of the Alan Mason Chesney Archives, the authors reviewed the Johns Hopkins Hospital surgical files from the years 1896 to 1912. Patients younger than 18 years of age, presenting with symptoms suspicious for an intracranial tumor, and undergoing surgical intervention by Cushing were selected for further analysis.

Results—Of the 40 pediatric patients undergoing surgery for suspected intracranial neoplasms, 26 were male. The mean age among the entire sample was 10.1 years. Cushing used three main operative approaches in the surgical treatment of pediatric intracranial neoplasms: infratentorial/suboccipital, subtemporal, and hemisphere flap. Twenty-three patients had negative findings following both the primary and subsequent surgical interventions conducted by Cushing. Postoperative conditions following the primary surgical intervention were improved in 24 patients. Twelve patients (30%) died during their inpatient stay for the primary intervention. The mean time to the last follow-up was 24.9 months; the mean time to death was 10.0 months.

Conclusions—Cushing strove to maximize exposure while minimizing blood loss in an attempt to increase his ability to successfully treat pediatric brain tumors. His early contributions to the field of pediatric neurooncology demonstrate his commitment to advancing the field of neurosurgery.

Keywords

Harvey Cushing; neurooncology; pediatric neurosurgery

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Disclosure

Author contributions to the study and manuscript preparation include the following. Conception and design: Quiñones-Hinojosa, Pendleton. Acquisition of data: Pendleton. Analysis and interpretation of data: Pendleton. Drafting the article: Pendleton. Critically revising the article: all authors. Approved the final version of the paper on behalf of all authors: Quiñones-Hinojosa.

William Macewen is credited with the first publication on the successful resection of a pediatric brain tumor in 1879.^{10–12} Although literature from the time describes surgical treatment for brain tumors in general, little was written about surgical approaches in pediatric patients. Without the benefit of neuroimaging, surgeons in the late 19th and early 20th centuries relied solely on history and physical examination for the diagnosis and localization of brain tumors. Within a pediatric population, this reliance on physical examination for diagnosis presented a unique set of challenges, as such patients may present with subtle signs of increased intracranial pressure, which can easily be missed.^{7,9,13} Moreover, the neurological examination in children is limited in comparison to the detailed communication that is normally possible in examining adults.

Despite the challenges of diagnosis and localization, surgical approaches for the successful treatment of brain tumors in adult and pediatric populations as well as palliative decompressive surgeries and CSF drainage procedures were being developed by Dr. Harvey Cushing and his contemporaries.^{3,8}

Cushing, credited with pioneering the field of neurosurgery as a distinct surgical subspecialty in the US, was at the forefront of neurooncology, publishing seminal papers on the diagnosis and treatment of pediatric brain tumors during the latter part of his career.^{1,4} However, his contributions to the surgical treatment of these lesions during the early stages of his tenure at the Johns Hopkins Hospital, from 1896 to 1912, remain largely unknown. Here we review the records of 40 pediatric patients from the Johns Hopkins Hospital, in whom Cushing suspected a brain tumor and thus who underwent surgical intervention.

Methods

After obtaining institutional review board approval and through the courtesy of the Alan Mason Chesney Archives, we reviewed the Johns Hopkins Hospital surgical files from the years 1896 to 1912. Patients younger than 18 years of age, presenting with symptoms suspicious for an intracranial tumor, and undergoing surgical intervention by Cushing were selected for further analysis. In determining patient outcome, condition at the time of discharge, as documented in the surgical record, was used. Other outcome measures were the duration of hospital stay, time to the last follow-up, condition at the last follow-up, and time to death. Condition at the last follow-up was determined from written correspondence between Cushing and the patients, which was stored in the surgical files. The mean time to follow-up was calculated from the date of discharge following the primary surgical intervention. The mean time to death was calculated from the date of the primary surgical intervention.

Results

Patient Characteristics

Of the 40 pediatric patients undergoing surgery for suspected intracranial neoplasms, 26 (65%) were male. The mean age in the entire patient sample was 10.1 years (Table 1).

Surgical Interventions

Cushing used three main operative approaches in the surgical treatment of intracranial neoplasms in pediatric patients: infratentorial/suboccipital (Fig. 1), subtemporal (Fig. 2), and hemisphere flap (Fig. 3). The most commonly used approach was the infratentorial/suboccipital (65%), although he used an occipital and a parietooccipital approach in 1 patient each. Patients underwent a mean of 1.48 operations by Cushing (Table 1).

Patient Outcomes

Patients had a mean hospital stay of 33.4 days. Patients undergoing a subtemporal approach had a longer mean duration of stay (40 days) than those undergoing an infratentorial/suboccipital (33.7) or hemisphere flap approach (15.0; Table 2).

Intracranial pathology was diagnosed in 17 patients following the primary intervention. Gliomas were diagnosed in 5 patients; unspecified tumors in 4; cystic gliomas in 2; endotheliomas in 2; a neuroma, sarcoma, and tubercle in 1 patient each; and “superficial metastases, no tumor found” in 1 patient. Twenty-three patients had negative findings following both the primary and secondary surgical interventions. Postmortem examination of the brain was eventually conducted in 6 of these patients; intracranial lesions were found in 3.

Postoperative conditions following the primary surgical intervention were improved in 24 patients (60%) and unchanged in 4 (10%); 12 patients (30%) died during their inpatient stay following the primary intervention, and 2 patients died during their initial inpatient stay following subsequent operative interventions. Patients undergoing a hemisphere flap procedure had a 75% inpatient mortality rate; those undergoing an infratentorial/suboccipital approach had a 31% mortality rate (Table 2).

Twenty-six patients were successfully discharged from the hospital following their admission(s) and surgical intervention(s). Six of these patients were lost to follow-up. Among the remaining 22 patients at the last follow-up, 5 were improved, 1 had an unchanged condition, and 14 were dead (Table 3). The mean time to the last follow-up was 24.9 months. The mean time to death was 10.0 months (Table 2).

Illustrative Cases

Case 32: Hemisphere Flap Approach

On November 2, 1911, a 13-year-old boy presented with a 4-year history of “twitching” in the right foot, no loss of consciousness, a positive Wassermann reaction (a diagnostic test for syphilis), and decreased visual acuity. Cushing brought him to the operating room on November 8, 1911, for “attempted enucleation/exploration of large endothelioma with fatal results.”

Under tourniquet a bone flap was turned down over the left hemisphere. The bone was somewhat thick in places but showed a single area of thinning particularly in the median line. ... The dura was reflected and an incision was made through the postcentral gyrus near its upper end. This disclosed a yellowish cortex which for

the moment was thought to be tumor and a fragment of it was removed. However, on removing this fragment the upper end of a nodular, enucleable reddish growth was disclosed. Its surface was covered with a multitude of tortuous blood vessels. The cortex was then further incised and most of the upper surface of the tumor was disclosed by slow dissection, the brain being pushed away from the tumor by pledgets of cotton. A growth, about the size of a tennis ball, was then brought into view and the fingers were introduced around it in the wound and it was picked out. Profuse hemorrhage followed for the moment. ... It seemed for about a half an hour that he was going to revive and at this juncture a transfusion from his father was given. During the transfusion the boy died, apparently with a primary cardiac failure.

A postmortem examination of the brain was performed, and Fig. 4 documents the location of the tumor.

Case 2: Infratentorial/Suboccipital Approach

On December 7, 1903, a 2-year-old girl presented with a 7-month history of trouble walking as well as pain in her head and neck. Cushing brought her to the operating room on December 17; the operative note and accompanying drawing (Fig. 5) document the procedure.

An incision was made through the muscles of the neck about 1 or 2 cm. below the insertion of the cervical muscles at the occipital ridge. Subsequent developments showed that it would have been wise to have made a longer longitudinal incision, which might have been carried from the occiput down to the lower cervical vertebrae if necessary. Such a longitudinal incision would have allowed the soft parts to be retracted extensively to the side, and would also have obviated the circulatory difficulties which arose from the semilunar incision made in this case. On dividing the muscles, the incision was carried to the occipital bone below the ridge. The periosteum was entirely cleared away and the bone removed, as shown in the diagram [Fig. 5], from this entire area across the median line and down in to the foramen magnum. There was no great bulging of the dura. The operator thought that probably there was no underlying tumor whatever. The dura was opened and we were brought face to face with what was taken for cerebellum, although it had a peculiar appearance inasmuch as there were no indications of gyri. The incision was then carried across the median line, the median sinus of the occipital falx being divided after another incision had been carried carefully up to this lateral margin, and then two lobes of cerebellum retracted so that it was possible to get clamps on each side of the sinus, between which it was divided and then ligated at its end.

The cerebellum as exposed on the right side as well as that first exposed on the left, presented the somewhat peculiar appearance above described. The operator stupidly did not recognize that this was a new growth until an incision was made into it for the purpose of removal of what was supposed to be cerebellum. For the purpose of examination inasmuch as it did not look quite moveable. The section showed a translucent, grayish white structure which was beyond peradventure a malignant growth, and a sarcoma. ...

It was then found that almost the entire posterior fossa of the skull, underneath the tentorium, was filled with this growth. It represented practically the whole of the cerebellar cavity, the cerebellum itself being squeezed into the upper anterior and lateral portion of the space below the tentorium in a hollow, cupshaped configuration in which the tumor lay. The cerebellum in no place could have touched the occipital bone. The tumor itself began slowly and gradually to protrude into the wound before an attempt had been made to enucleate it. ... [T]he entire tumor was freed from the overhanging shelf of cerebellum, to which it was attached only by very fine filaments. There was no definite capsule, and yet a perfectly complete and distinct delineation between the under surface of normal, though compressed cerebellum, and the upper surface of the tumor. The entire body of the tumor was then thoroughly delivered. It consisted of two main masses and a lateral expansion on each side, which must have passed around on each side of the medulla.

The dissection must have passed very close to the side of the medulla in liberating the two lateral lobes of the tumor because at one time when on the left side the lateral lobe was lifted up from its bed, the blunt instrument used for this purpose twitched the spinal accessory nerve and caused a sharp elevation of the shoulder.

Had there been a larger exposure, or had the space between the foramen magnum and the first vertebra been opened so as to expose the lower part of the fourth ventricle, it seems quite probably that it would have been possible to have removed the growth from its attachment.

In the immediate postoperative period, the child fared poorly: "Pt returned to ward from operating room very much shocked, being almost pulseless." However, she was discharged on February 28, 1911, in an "improved" condition. No further follow-up was available.

Discussion

The cases described above illustrate Cushing's surgical approaches to brain tumors in pediatric patients. In the absence of neuroimaging, intraoperative visualization was the key to localization and subsequent resection of these lesions. In his operative interventions, Cushing strove to maximize exposure while minimizing blood loss in an attempt to increase his ability to successfully treat pediatric brain tumors. His operative notes reflect his frustration with suboptimal exposure.

Despite his determination to optimize the surgical treatment of pediatric brain tumors, the mortality rate in the series presented here is 30%. This rate reflects the challenges of surgical intervention in the pediatric population, as Cushing published mortality rates of 12.5% for all patients surgically treated for brain tumors at the Johns Hopkins Hospital.^{5,6}

The field of neurosurgery was still in its infancy, with surgical instrumentation being supplemented with the operator's hands, as documented in the operative notes for Case 32. As Cushing pioneered the field, he expected nothing less than thoughtful, meticulous work from himself as well as his colleagues. His operative notes from Case 2 illustrate the harsh judgment he passed on himself. Although these tendencies earned Cushing a reputation for

being a difficult surgeon to work with,² they also undoubtedly allowed him to transform neurosurgery and neurooncology from fools' errands into viable surgical subspecialties.

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Fig. 1.
Case 18. Cushing's illustration of the exposure gained by the suboccipital approach using a "cross-bow" incision. Reproduced courtesy of the Alan Mason Chesney Archives.

December 1911.

Right subtemporal decompression and drainage

Operation,

for possible tumor.

Dr. Cushing,

Ether.

Under very light anaesthesia a right temporal defect was made without difficulty and a large bone opening made. The dura was found to be very tense. On making a small primary opening cerebrospinal fluid escaped. This was clear. The dura was then opened widely and there was some tendency for the brain to herniate through. After a time, however, enough fluid escaped from the arachnoidal spaces to allow the brain to settle back. The fluid continued to come in excessive amounts, however, through the remainder of the operation. There was no evidence of surface lesion whatever. A protective drain was inserted below the temporal lobe

Fig. 2.

Case 33. Cushing's operative notes describing the subtemporal approach. Reproduced courtesy of the Alan Mason Chesney Archives.

September 7, 1911.

Operation,

Exploration of Pineal Region for presumed tumor.

Dr. Cushing,

Ether.

Under tourniquet a large bone flap was turned down exposing the posterior half of the right hemisphere. Very little bleeding. The bone appears normal, perhaps an excessive diploe. Dura tense. On opening the membrane a wet brain was disclosed and considerable fluid was evacuated.

Ventricular puncture. About 150 cc were withdrawn demonstrating internal hydrocephalus. The brain collapsed, one large point of anchorage (cf. sketch) connecting the longitudinal sinus and cortex. The vein was clipped and incised, clips, however did not hold. The upper edge was caught with a heavy clamp and a mosquito forceps put on the lower half of the vein which was ligated without difficulty. The brain was then gradually ^{pressed} ~~directed~~ away until the falx, sinus ^{rectus} and upper part of tentorium were seen. There was a second small point of anchorage at the lower part of the occipital lobe. This was not ligated and it is possible that the upper one need not have required ligation. The splenium of the corpus callosum was easily brought into view. The large veins making up the bundle of velum interpositum were seen and the mesh work of lipto-meninges about it punctured in several places. It would have been a very easy matter to have ligated these veins.

Fig. 3.

Case 30. Cushing's operative notes describing the hemisphere flap approach. Reproduced courtesy of the Alan Mason Chesney Archives.

Fig. 4.
Case 32. Postmortem photograph showing the location of an endothelioma (*arrow*).
Reproduced courtesy of the Alan Mason Chesney Archives.

Fig. 5.

Case 2. Cushing's illustration of the cerebellar tumor. Label on the middle right reads: "Weight 11.2 grams." Label on the lower left reads: "Diagram tumor showing compressed cerebellum and medial line [illegible].- HC" Reproduced courtesy of the Alan Mason Chesney Archives.

TABLE 1

Summary of baseline characteristics of 40 patients with suspected brain tumors who underwent primary surgical intervention by Cushing

Parameter	No. (%)
sex	
M	26 (65)
F	14 (35)
age in yrs	
mean	10.1 ± 4.56
range	1.9–18
no. of ops	
mean	1.48 ± 0.75
range	1–4
primary approach	
hemisphere flap	4 (10)
occipital	1 (2.5)
subtemporal	8 (20)
infratentorial/suboccipital	26 (65)
parietooccipital	1 (2.5)

TABLE 2

Outcomes following 40 primary surgical interventions for suspected brain tumors

Parameter	No. (%)
hospital stay in days	
mean	33.4 ± 23.6
range	1–83
outcome at discharge	
improved	24 (60)
unchanged	4 (10)
dead	12 (30)
time to last FU in mos	
mean	24.9 ± 47.0
range	0.47–119
time to death in mos	
mean	10.0 ± 22.3
range	0.03–08.5
hemisphere flap approach	4
mean hospital stay in days	15.0 ± 14.45
outcome	
improved	0 (0)
unchanged	1 (25)
dead	3 (75)
subtemporal approach	8
mean hospital stay in days	40.0 ± 21.4
outcome	
improved	6 (75)
unchanged	2 (25)
dead	0 (0)
infratentorial/suboccipital approach	26
mean hospital stay in days	33.7 ± 22.1
outcome	
improved	17 (65)
unchanged	1 (3.9)
dead	8 (31)

Summary of characteristics in 40 patients undergoing surgical intervention for suspected brain tumors at the Johns Hopkins Hospital between 1896 and 1912*

TABLE 3

Case No.	Date of Op	Age (yrs), Sex	Procedure Description	Anesthesia	Estimated Blood Loss	Complication	Diagnosis	Outcome at Discharge	Last Known Outcome	Cause of Death
1	10/9/1902	4, M	"removal of occipital bone below level of protuberance. Exploration of cerebellum, evacuation of tubercle in left cerebellar lobe."	ether		CSF leak; "acute serous leptomeningitis"	"numerous conglomerative tubercles in lung"	dead		cerebellar herniation
2	12/17/1903	2, F	"Exploratory craniotomy. Partial excision"	ether	"With a haemoglobin of 25% to begin with, and the loss of blood, which although not great, was enough to cause considerable upsetting up the pulse rate."	postop bradycardia, fever to 103°	"a translucent, greyish white structure, which was beyond peradventure a malignant growth, and a sarcoma."	improved	lost to FU	
3	11/9/1904	5, M	"exploratory craniotomy. Fatal attempt to remove a very large cerebral tumor"	chloroform	"inefficient tourniquets... much more blood was lost than would otherwise have been the case and this the patient could ill spare."	death	"the growth weighed... 341 grams." "Sarcoma: round-cell fibromyxosarcoma, or glioma" and "When I compare these sections with Borst, plate ix, fig. 51, I am inclined to think we are dealing with a glioma."	dead		"at the last moment, however, of freeing the growth the child's respiration became very bad and the pulse could no longer be palpated. The great hole was filled with cotton and warm salt solution and the wound temporarily held together while efforts were made to resuscitate the child. These efforts were absolutely unavailing."
4	12/12/1905	9, M	"Decompressive suboccipital craniectomy"	ether	"early hemorrhage" & "somewhat bloody"	none	"tumor or abscess of right occipitoparietal lobe"	improved	death	large suboccipital hernia
5	3/14/1907	8, M	"Suboccipital Decompression. Cross-bow incision. Cerebellar Tumor. Closure s Drainage."†	ether	"this mid occipital crest was as usual the source of considerable bleeding. The operator, however, was unusually fortunate in	none	negative findings	improved		

Case No.	Date of Op	Age (yrs), Sex	Procedure Description	Anesthesia	Estimated Blood Loss	Complication	Diagnosis	Outcome at Discharge	Last Known Outcome	Cause of Death
5	6/12/1908	10	"Evacuation of enormous cerebellar cyst."	ether	this particular case in being able to control all of the bleeding from the emissary vessels by means of wax."	required 3 bedside drain-ages of cyst	cystic glioma	improved	improved	
6	5/3/1907	10, F	"Exploratory Craniotomy. Wagner bone flap. Brain Tumor. Partial Enucleation. Closure without Drainage."	ether	"the brain substance it-self peeled away from tumor without bleed-ing...the slight oozing which occurred from time to time was per-fectly controlled by the use of hot saline wisps of cotton."	postop fever to 104° & tachycardia	glioma			
6	5/10/1907	10	"Second Stage Opera-tion"	none		operation abandoned due to pus in wound; postop unable to maintain PO intake. "Pt fed [4 parts] milk + [2 parts] brandy through stomach tube."	glioma			
6	5/14/1907	10	"Attempted removal of enormous cerebral tu-mor."	none	"there was but compara-tively little loss of blood"	intraop massive CSF leak; child developed "pulse-less condition;" 0.5-hr resuscitation efforts; death	glioma	dead		"Following [intraventricular tumor removal] there came a great gush of cerebro-spinal fluid and the child quickly passed into an almost pulseless condition...she died about one-half hour later."

Case No.	Date of Op	Age (yrs), Sex	Procedure Description	Anesthesia	Estimated Blood Loss	Complication	Diagnosis	Outcome at Discharge	Last Known Outcome	Cause of Death
7	11/21/1907	13, M	"Suboccipital Exploration for Tumor. Decompression."	chloroform	"serious bleeding was encountered on one or two occasions, owing to large diploetic sinuses in the median line which had to be controlled by plugging with sections of match and with wax."	none	negative findings	improved	dead	none given
8	2/29/1908	1.9, F	"Combined Lumbar and Ventricular Puncture"	chloroform		none	negative findings			
8	3/11/1908	1.9	"Second Ventricular Puncture"	chloroform	"punctured bloodlessly"	none	negative findings	improved		
8	4/29/1909	3	"Suboccipital Exploration. Evacuation and partial enucleation of cerebellar cyst"	ether	"the exposure was fairly satisfactory and was conducted drily" & "at this stage a sudden gush of venous blood filled the wound, apparently from the laceration of one of the connecting vessels of cerebellum to tentorium." Patient was prepared for a transfusion. "The father prepared for transfusion, which, however, did not seem necessary, as the bleed- ing stopped."	death	cystic glioma	dead		"About 4 P.M. there was a sudden collapse, and the infant died in the course of the following half hour, just as preparations were being made to transfuse it from the father's radial artery."
9	3/10/1908	14, M	"Suboccipital Exploration. Tapping of left cerebellar cyst"	ether	"the median incision... carried down to the spines a little to the right of the median line, occasioning a greater loss of blood than usual" & "considerable bleeding from the left side owing to the diploetic emissary vessels"	none	cystic glioma	improved		
9	3/15/1911	17	"Evacuation of large left Cerebellar cyst. Drain-	ether		none	cystic glioma	improved	lost to FU	

Case No.	Date of Op	Age (yrs), Sex	Procedure Description	Anesthesia	Estimated Blood Loss	Complication	Diagnosis	Outcome		Cause of Death
								at Discharge	Last Known Outcome	
10	9/23/1908	16, M	age.” [left] exploratory craniotomy, combined with decompression, lumbar puncture”	ether	“bleeding from the scalp was profuse” & “a slight amount of bleeding occurred from one of the cortical vessels which was secured with a silver clip.”	none	negative findings	improved		
10	12/8/1908	16	“combined bone flap and decompressive operation on right side preparatory to exploration of left uncal region”	ether	“superficial smearing with wax was necessary in order to dry the field.”	none	negative findings	improved		
10	2/13/1909	16	“exploration of left temporal lobe through former decompressive opening”	ether		none	“Temporal Lobe (left) glioma”	unimproved	dead	“cerebellum and medulla evidencing a considerable foramen hernia”
11	1/21/1909	8, M	“Final shaving after administration of anaesthesia. Simple left subtemporal decompression. No complications”	ether	“two silver clips used on bleeding margin of dura”	none	negative findings	improved	improved	
12	1/30/1909	9, F	subtemporal exploration & decompression; ventricular puncture	ethyl chloride & ether		return of symptoms of increased ICP: headache, vomiting, protrusion of skin overlying craniectomy	negative findings			
12	2/20/1909	9	It exploratory craniotomy; drainage of ventricle permanent	chloroform, ether	“the gaping wounds were filled for a short time with cotton pledgets, which effectually checked the oozing from the vascular cortex.”	postop fever 3/7/1909	negative findings	improved	improved	
13	6/24/1909	10, M	“Combined Exploration and Decompression. Respiratory Failure.”	ether	“the rapidly forming hernia led to a rupture of one of the large veins	death	unspecified tumor	dead		“as the skin sutures were being placed respirations suddenly ceased.... The suboccipital region was opened...in the hope that

Case No.	Date of Op	Age (yrs), Sex	Procedure Description	Anesthesia	Estimated Blood Loss	Complication	Diagnosis	Outcome at Discharge	Last Known Outcome	Cause of Death
14	7/3/1909	4.5, M	"Suboccipital Exploration and Decompression"	ether	traversing the wound, possibly a vein communicating between cortex and dura, and for a moment there was considerably [sic] bleeding."	postop Day 2: convulsions w/ loss of consciousness; fever to 108°; did not regain consciousness; took to OR for ventricle tap & insertion of permanent drain; death	negative findings	dead		a jammed medulla might be present. There was no evidence of this howeverJust what was the cause of the respiratory failure is uncertain—possibly again a Thymus-Tod...or profound anesthesia."
15	7/11/1909	9, F	"Suboccipital Exploration for Tumor. Partial Enucleation"	ether	"considerable bleeding but no special loss of blood was occasioned"	death	neuroma	dead		"protrusion [of the brain] was so great that closure was accomplished with great difficulty and only after the removal of considerable [parts] of both cerebellar hemispheres...child did not recover consciousness after operation. Gradually weakened and died about 3 hrs after operation."
16	10/5/1909	6, M	"Primary Stage Operation for Removal of Cerebellar tumor"	ether	"there was considerable bleeding from the diploae and many dilated and tortuous vessels, which necessitated the use of wax in the bone"	none	endothelioma			

Case No.	Date of Op	Age (yrs), Sex	Procedure Description	Anesthesia	Estimated Blood Loss	Complication	Diagnosis	Outcome at Discharge	Last Known Outcome	Cause of Death
16	10/13/1909	6	"Second-stage Operation for Cerebellar Tumor. First Use of Suction Apparatus."	ether	"without much loss of blood" but later "there was considerable bleeding. The wound was packed with cotton."	intraop death	endothelioma	dead		"Respiration soon began to fail, and artificial respiration, kept up for sometime, resulted merely in a few occasional gasps."
17	1/6/1910	15, F	"Sub-occipital exploration for presumed cerebral tumor. Negative Findings. Closure."	ether	"the emissary was torn on the left but easily controlled by the use of wax"	fever to 105.7°; bradycardia; respiratory failure; death	cystic glioma of midbrain	dead		"sudden death this p.m. from respiratory failure"
18	2/19/1910	9, F	"Cerebellar Exploration for Tumor. Decompression."	ether	"there was marked bleeding from the bone in the mid-line nec- cessitating [sic] the frequent use of wax."	none	negative findings	improved		
18	10/4/1910	10	"Second Stage Exploration for Suboccipital Tumor. Puncture Left Lateral Ventricle."	ether		none	negative finding	improved	dead	none given
19	3/21/1910	7, M	"Exploration for cerebral tumor. Superficial metastases. One removed. Puncture left lateral ventricle during closure. Decompression."	ether	"considerable bleeding being occasioned [sic]. This bleeding was checked by silver clips."	none	superficial metastases, no primary tumor found	improved		
19	7/19/1910	7	"Second exploration for cerebellar tumor. Partial enucleation of a definitely encapsulated glioma."	ether	"there was no particular bleeding" and "some little bleeding occurred but it was not difficult to check this with pledgets of cotton."	Cheyne-Stokes respirations; tachycardia; death	glioma	dead		"at the close of the operation, child was somewhat blue and respirations not particularly good."
20	4/16/1910	5, F	"Removal of bone flap from left hemisphere. Right ventricular puncture. First stage operation."	ether	"the operator feared that the considerable loss of blood was as much as the child could stand."	Cheyne-Stokes respirations; no response to painful stimuli	glioma			
20	4/20/1910	5	"second stage operation"	none	"without any loss of blood"	Cheyne-Stokes res-	glioma	improved	dead	none given

Case No.	Date of Op	Age (yrs), Sex	Procedure Description	Anesthesia	Estimated Blood Loss	Complication	Diagnosis	Outcome at Discharge	Last Known Outcome	Cause of Death
						pirations; required pirations; required bedside ventricular puncture; postop blindness				
21	8/4/1910	4.5, F	"Suboccipital Decompression."	ether	"no bleeding from bone"	none	negative findings	improved	dead	none given
22	9/30/1910	5, M	"Cerebellar Exploration. Negative Principles. Puncture Lateral Ventricles. Closure Without Drainage. Decompression. Dry Exploration."	ether	"the enlarged emissary vessels... were controlled without difficulty"	required 6 bedside lumbar punctures & 1 bedside ven-tricle puncture	negative findings	improved	dead	none given
23	10/10/1910	9, M	"Suboccipital Exploration"	ether	"considerable bleeding from the median emissary vessels emerging from bone. It was necessary to use considerable wax."	postop elevated temperature; positive Kernigsign, LP w/ "withdrawal of 60cc turbid, yellowish fluid." "make meningitis almost certain."	negative findings	dead		"terminal temp 106.5 F"
24	11/5/1910	10, M	"Suboccipital Exploration for Presumed Cerebellar Tumor"	ether	"a dural sinus was opened leading to considerable bleeding, necessitating the placement of clamps"	required bedside ventricular puncture	negative findings	improved		
24	1/20/1912	12	"Suboccipital operation with evacuation of cyst and partial extirpation of its gliomatous wall."	ether	"it may be said that bleeding had been sufficiently troublesome at the first part of the operation"	required drainage through bedside puncture through operative wound	glioma	improved	dead	"Entered the Brigham Hospital [no. omitted] Jan 15, 1914. Large glioma which had extended the length of the spinal cord. (Death)."
25	4/4/1911	5, F	"Suboccipital Exploration for Presumed Cerebral Tumor. Negative Findings. Aspiration of Left	ether	"there was extreme difficulty owing to bleeding from large emissary vessels...	postop Day 2: vomiting, aspiration, fever to	negative findings	dead		"it was found that there was considerable foramenal herniation of the cerebel-

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			Ventricle"		this required all devices that were possible to prevent excessive loss of blood."	105°, HR170-180, required 2.5 hrs artificial respiration (0.5-hr chest compressions, 2-hr tracheostomy w/ bellows), emergent bilateral ven-tricular puncture, death.				lar lobes. These tended to project into the vertebral canal at the first vertebra. The medulla itself could not be seen, (perhaps the cause of the sudden respiratory failure.)"
26	4/14/1911	18, M	"Puncture of right Ventricle. Internal Hydrocephalus. Right subtemporal Decompression."	ether		none	negative findings			
26	5/2/1911	18	"Suboccipital Exploration for possible Subtentorial Lesion. Ventricular Puncture. Kocher's Point."	ether		none	negative findings	unimproved	dead	none given
27	4/26/1911	18, F	"Ventricular Aspiration. Right Subtemporal Decompression"	ether	"there was no bleeding from the dura. No clips were placed."	none	negative findings	improved	dead	"she was taken worse"
28	5/16/1911	18, M	"Suboccipital Exploration for supposed Subtentorial Lesion."	ether	"there was considerably [sic] bleeding"	none	negative findings	improved	dead	none given
29	7/25/1911	15, M	"Suboccipital exploration for presumable right cerebraal tumor. Puncture left ventricle during operation"			none	glioma	improved		
29	5/22/1912	16	"Second stage cerebellar after lapse of a year"			none	cystic glioma	unimproved	lost to FU	
30	9/7/1911	8, M	"Exploration of pineal region for presumed tumor"	ether	"very little bleeding" & "an incision was made across the edge of the tentorium. Some little bleeding was encountered but this was	none	negative findings	unimproved	lost to FU	

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					finally stopped by the placement of a clamp and a silver clip."					
31	10/13/1911	18, F	"Cerebellar Exploration and Decompression for supposed cerebellar tumor."	ether	"a few small emissary veins. Bleeding from these was controlled without difficulty."	none	negative findings	improved	improved	
32	11/8/1911	13, M	"Attempted Enucleation of large endothelioma with fatal results."	ether	"a growth, about the size of a tennis ball...fingers were introduced around it in the wound and it was picked out. Profuse hemorrhage followed for the moment. This was controlled by packing with cotton." Patient received transfusion from father	extensive blood loss intraoperatively requiring a transfusion from father; death.	endothelioma	dead		"during the transfusion the boy died, apparently with a primary cardiac failure"
33	12/1/1911	16, M	"Right subtemporal decompression and drainage for possible tumor."	ether		none	negative findings	improved	lost to FU	
34	12/9/1911	12, M	"Suboccipital exploration. Decompression." "This dictated note is given a month after the operation. Though I am somewhat hazy about it the following gives the data as well as I remember them."	ether	"many emissaries causing considerable bleeding"	none	negative findings	improved	no change	
35	1/2/1912	13, F	"Right subtemporal decompression"	ether	"a generous opening was made without meeting with bleeding from the bone"	ulceration of skin from "fluid pressure"	negative findings			
35	1/23/1912	13	"Left subtemporal decompression"	ether	"there was some little bleeding"	required multiple lumbar & ventricle punctures	negative findings			
35	2/3/1912	13	"Puncture of right lateral ventricle"	ether		none	"the operator's im-			

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35	2/13/1912	13	"Extrirpation of large gelatinous glioma from temporal region"	ether	"[a vessel] was found and later examination proved it to be a large artery, very possibly a branch of the middle cerebral. It is there-fore possible that an increase of damage to cerebral centers might have been brought about and the patient will probably be hemiparetic."	none	glioma	unimproved	dead	none given
36	1/23/1912	8, M	"Cerebellar Decompression. Left Ventricular Puncture."	ether	"considerable bleeding was encountered"	postop temperature elevated to 104°; delirium; death	negative findings	dead		postop fever, nausea, vomiting; increasing fluid collection under scalp
37	4/20/1912	10, M	"Brain Tumor. Suboccipital exploration. Puncture left lateral ventricle."	ether	"the communicating vessels from the dura to scalp being exceedingly large, tortuous and bloody"	none	unspecified tumor	unimproved	improved	
38	4/29/1912	12, M	"Cerebellar exploration. Attempted puncture lateral ventricle. Removal of head of Atlas. Decompression"	ether	"considerable bleeding"	none	cystic tumor	improved	dead	"Increase in all symptoms"

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39	5/25/1912	13, F	"Suboccipital exploration with removal of posterior half of atlas and exposure of glioma, with decompression. Ventricular puncture"			none	glioma	improved	dead	none given
40	6/1/1912	17, M	"Right Subtemporal Decompression"	ether		none	negative findings	improved	lost to FU	

*FU = follow-up; HR = heart rate; LP = lumbar puncture; PO = per os (by mouth); Pt = patient

[†]That is, closure without drainage.