Published in final edited form as:

J Neurosurg Spine. 2011 March ; 14(3): 412–420. doi:10.3171/2010.10.SPINE10147.

“No performance in surgery more interesting and satisfactory”: Harvey Cushing and his experience with spinal cord tumors at the Johns Hopkins Hospital

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Abstract

Although Harvey Cushing was a neurosurgical pioneer, his work on the spine remains largely unknown. In fact, other than his own publications, Cushing's patients with pathological lesions of the spine who were treated while he was at the Johns Hopkins Hospital, including those with spinal cord tumors, have never been previously described. The authors report on 7 patients with spinal cord tumors that Cushing treated surgically between 1898 and 1911: 2 extradural, 3 intradural extramedullary, and 2 intramedullary tumors. The authors also describe 10 patients in whom Cushing performed an “exploratory laminectomy” expecting to find a tumor, but in whom no oncological pathological entity was found. Cushing's spine surgeries were limited by challenges in making the correct diagnosis, lack of surgical precedent, and difficulty in achieving adequate intraoperative hemostasis. Other than briefly mentioning 2 of the 4 adult patients in his landmark monograph on meningiomas, these cases—both those involving tumors and those in which he performed exploratory laminectomies—have never been published before. Moreover, these cases illustrate the evolution that Harvey Cushing underwent as a spine surgeon.

Keywords

Harvey Cushing; history of neurosurgery; sacrococcygeal teratoma; spinal meningioma; spinal cord tumor

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Disclosure: The authors report no potential conflicts of interest, be they financial, personal, or professional in nature, concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Bydon, Gokaslan, Quinones-Hinojosa. Acquisition of data: Dasenbrock, Pendleton, Quinones-Hinojosa. Analysis and interpretation of data: Bydon, Dasenbrock. Drafting the article: Dasenbrock, Bydon. Critically revising the article: Bydon, Pendleton, Wolinsky, Gokaslan, Quinones-Hinojosa, Cohen-Gadol. Reviewed final version and approved it for submission: all authors. Study supervision: Bydon.

Harvey Cushing played a central role in the founding of neurological surgery in the US.^{3,35,37,39,54} Although Cushing made important contributions to cerebrovascular surgery,^{7,8} radiology,⁴⁸ anesthesia,⁴⁰ and endocrinology,³⁴ he is best known for his work on intracranial pressure and brain tumors. Cushing was a forefather of the transsphenoidal approach to pituitary tumors.^{6,25,38} He also developed many of the surgical techniques for the resection of posterior fossa tumors, and was the first to characterize meningiomas.^{9,33,49,52} Few know, however, that Cushing was also a spine surgeon.^{10–13,47} In fact, Cushing made important contributions to the understanding of spinal cord tumors, and his description of meningiomas was partially due to his experience with spinal cord tumors. However, other than in his own publications, Cushing's cases of spine disorders treated while he was at Johns Hopkins from 1896 to 1912, including patients with spinal cord tumors, have never been previously described.

Cushing's first experience with a spinal cord tumor was in 1903: a patient presented with progressive paraplegia, and Sir William Osler urged Cushing to perform an exploratory laminectomy. An intradural extramedullary “dural endothelioma” (the term for a meningioma at the time) was found, and the patient had a remarkable post-operative recovery.¹⁶ Cushing published this case in 1904 and was so encouraged by this patient's improvement that he later wrote

there is no performance in surgery more interesting and satisfactory than the diagnosis and localization, followed by the removal from the spinal canal of one of these benign meningeal endotheliomata. The subsequent relief from excessive pain and the resurrection from crippledom of one of these unfortunates is chief among findings which make for optimism in neurological surgery.²⁰

We present 7 cases of spinal cord tumors, both pediatric and adult, that Cushing treated while he was at Johns Hopkins. Although Cushing briefly mentioned 2 of the 4 adult patients in his monograph on meningiomas published in 1936, the other cases have never been published before. We also report 10 previously unreported “exploratory laminectomies” that Cushing performed expecting to find a compressive lesion, but in which no pathological entity was found intraoperatively. These cases are important in understanding the development of Cushing's theories on and techniques for the resection of spinal cord tumors.

Methods

The records at the Chesney Medical Archives of the Johns Hopkins Hospital for the period from 1896 to 1912 were reviewed, and the files of patients with Cushing listed on their operative notes were collected. The original patient files have been destroyed, and all of the records obtained, including the sketches in this paper, were from microfilm copies.

Results

Cushing treated both adult (Table 1) and pediatric (Table 2) patients with spinal cord tumors. Their pathological findings included 2 extradural tumors, 3 intradural extramedullary tumors, and 2 intramedullary tumors. Cushing also performed exploratory

laminectomies in 10 patients in whom no pathological entity was found intraoperatively (Tables 3 and 4).

Cushing was an artist in his own right. He drew his own sketches of many of his patients' sensory examinations, including a 17-year-old boy with sensory deficits involving L-5 and the sacral dermatomes on the left leg (Fig. 1); a 40-year-old man with anesthesia extending from his left C-7 to upper thoracic dermatomes (Fig. 2); and a 68-year-old man with "saddle anesthesia" (Fig. 3). Cushing is also known for his postoperative sketches.^{41,55} He drew an intraoperative view of the lesion in a 31-year-old woman who had a large intradural extramedullary tumor (Fig. 4) and the spinal cord of a 20-year-old man in whom he found no oncological pathological entity (Fig. 5). The following illustrative cases further characterize Cushing's early experience with spinal cord tumors.

Illustrative Cases

Case 3: Intradural, Extramedullary Tumor

Presentation and Examination—This 43-year-old Canadian woman was admitted on April 11, 1909, with a 1-year history of back pain and paraplegia. Physical examination was remarkable for paralysis of her LEs, a sensory level 6 cm below her nipples, and hyperreflexia with clonus.

Operation—Four days later, Cushing performed an exploratory laminectomy:

A mid-longitudinal incision of 20 cm long ... there was considerable loss of blood in exposing the spinal meninges—possibly more bleeding than usual.... Some cotton, and in one or two places wax, was necessary in order to control the oozing. The meninges ... showed no abnormality. The exposure corresponded... [with] L1 to T6.

An incision was made in the dura throughout the entire line of its exposure.... No abnormality in the cord was seen ... it was determined to pass a delicate catheter up under the canal under the arachnoid, in order to see whether an obstruction could be met with; and just as this was to be done the lower margin of the growth was found to be apparent underneath the upper edges of the laminectomy opening. This necessitated ... the removal of two more [spinous processes] and laminae.

The incision in the meninges was carried upward ... the tumor was found to have compressed the cord to a mere ribbon and over the growth passed two or three nerve roots that were adherent. It was necessary, in order to dislocate the tumor completely, to cut away a portion of the dura to which it was adherent, and also to remove one or two of the nerves....

The dura was resutured.... The entire length of the incision was 32.5 cm.

Postoperative Course—By postoperative Day 2, spontaneous movement in the patient's left toes was noted; by postoperative Day 5, the patient was able to achieve a slight dorsiflexion and plantar flexion of her left foot. On discharge, she could flex and extend both legs and had normal LE sensation.

Follow-Up—One year later, her physician wrote to Cushing saying she “is now quite well. She gets about nicely and has been walking the street with no assistance other than a cane ... the case is a complete success.” Twenty-eight years later, she was well and active.²¹

Case 6: Intramedullary Tumor

Presentation and Examination—This 14-year-old girl from Idaho presented on September 22, 1908, with kyphoscoliosis and a 6-month history of difficulty ambulating and incontinence. Cushing noted a Brown-Séquard pattern—weakness in her left LE and sensory deficits in her right LE. Cushing wrote that the

probable seat of the lesion [is] on the left side somewhere between the 5th cervical and 1st thoracic segments—very probably a lesion of wide vertical extent. There seem to be no neurological signs of segmental distortion, hence above the first or second thoracic.

Operation—The next day, Cushing performed an exploratory laminectomy.

A median incision was made through the soft parts exposing the [spinous processes] possibly from the 4th or 5th cervical to the 2nd thoracic.... On removing the [spinous processes] the dura bulged.

In opening the membrane at the lowest part of this possibly 5-inch exposure, the operator incised the cord, which was not only tightly pressed against the dura, but was also in this situation adherent to it ... the cord which was soft in feeling and very much larger than usual was tightly distending the dural sac ... at one place in particular on the patient's right side the cord bulged outward between two of the spinal roots in a very unusual fashion. Here palpation of the cord showed a distinct soft fluctuation and the points of a fine pair of dural scissors were gradually insinuated into what proved to be a cyst and at least 3 or 4 cm of clear fluid was seemingly evacuated. This, however, did not greatly diminish the tension of the cord, which would have been expected to have collapsed. It seeming unwise to make any further investigations of this nature, the operator returned to the seat of hemorrhage and, although a number of ways of controlling the bleeding point were attempted, none succeeded. It seemed unwise to endeavor to pass a needle under the vessel for it could with difficulty be seen owing to the rapid bleeding and it was feared that the cord would be seriously damaged. It was found that smaller and smaller wisps of cotton would control the bleeding ... the dura was not closed....

Postoperative Course—The first postoperative note mentioned that “movement of lower extremities [was] not so good immediately after [the] operation.” The patient also had worsening of her urinary and fecal incontinence; on discharge, she had also developed new paresthesias in her right hand. There is no further follow-up on her.

Case 7: Extramedullary Tumor

Presentation and Examination—This 2.5-year-old girl from Georgia presented with her parents on July 15, 1909. At birth, the child's parents noticed a large lump at the inferior portion of her spine, which was soft and fluid-filled. The mass measured $9 \times 9 \times 4$ cm, and

was arising from a base measured to be 6.5×6 cm. Cushing had the child photographed, and he made sketches of the mass (Fig. 6).

Operation—Eight days later, Cushing excised the sacrococcygeal tumor.

A spindle shaped incision, with its long diameter transversely [sic], was made around the base of the tumor so as to allow a transverse flap of skin, which would enable closure of the wound to be made at as great a distance as possible from the anal margin.

Dissection was carried down to a tense, lobulated, fibrous mass, which was gradually dissected out.... The points of attachment of the cyst seemed to be on the anterior surface of the coccyx.... The mass, which by this time had become free was cut off at this point. A small amount of clear fluid suspiciously like cerebrospinal fluid escaped as the final division of the stalk was met.... All the bleeding vessels—and there were many—being picked up by these buried sutures. There was considerable loss of blood during the operation.

Cushing opened the surgical specimen, finding its center to be “occupied by a cyst possibly holding an ounce of yellowish, odorless fluid, which looked like pus and contained numerous fine hairs, evidently an atheromatous or dermoid cyst....”; another part of the tumor resembled muscle.

Postoperative Course—By postoperative Day 9, the patient's wound had healed, and she was discharged with no postoperative complications. There is no follow-up on her.

Case 10: Exploratory Laminectomy With no Oncological Diagnosis

Presentation and Examination—This 20-year-old student at Harvard presented on October 20, 1909. Two years earlier he had noticed he was dragging his left foot during football games; he also had other episodic LE sensory and motor deficits and paroxysmal incontinence. Examination was remarkable for anisocoria and bilateral “hazy” optic discs; “lead pipe” rigidity and spasticity in the left LE, where hyperreflexia with clonus was noted; and a positive Romberg sign with ataxic gait.

Operation and Postoperative Course—Three days later, Cushing performed a T1–5 exploratory laminectomy and durotomy. Although there was “considerable bleeding owing to large intra-spinal veins,” arachnoid adhesions were the only abnormality seen, which he sketched (Fig. 5). Cushing's diagnosis in this patient was “chronic adhesive arachnoiditis.” The patient had no initial postoperative improvement during his admission.

Follow-Up—Five months later, Cushing received a letter from the patient saying “college has done wonders for me [and] I feel well in every aspect.” At his 1-year follow-up visit, his symptoms had returned, for which Cushing recommended exercise.

Discussion

Harvey Cushing was rarely deterred by the unknown. In Case 7, the patient presented with an odd mass that Cushing was unsure what to make of. He thought it was a dermoid cyst, but the morphological features of the mass as well as the presence of hair and muscle in the tumor suggest that it may have been a sacrococcygeal teratoma. It is now known that sacrococcygeal teratomas are the most common neonatal tumors,^{2,50,51,59} and today excision is often performed soon after birth.^{22,24,44} The first reported resection of a sacrococcygeal teratoma was in 1906.^{32,36}

Spinal cord tumors were only slightly better understood than sacrococcygeal teratomas at that time. In 1888, Sir Victor Horsley, working with William Gowers,²⁶ was the first to remove an intradural extramedullary spine tumor. Subsequently, several reports of the removal of these tumors were published.^{1,5,23,27,28,31,46,53,58} Most of these patients probably had a meningioma, which at the time was known as a dural endothelioma; it was not until 1922 that the term meningioma was coined—in fact, by Harvey Cushing—in part due to his experience with spine tumors.¹⁷

Cushing was struck by the remarkable recovery of the patient whose case he published in 1904. He also believed that spinal cord tumors were much more common than had previously been thought: “probably these meningeal...tumors are by no means rare, and that so few successful extirpation have been recorded in this country is possibly due to the fact that mistaken diagnoses have been frequent [and] explorations have been lamentably rare.”^{18,19} Cushing's early attempts at spinal cord tumor resection were limited by 3 factors: difficulty in making a correct diagnosis, lack of surgical precedent, and difficulty achieving adequate hemostasis.

The presenting symptoms and epidemiology of spinal cord tumors were only coming to be understood; therefore, making an accurate diagnosis was challenging. In his contribution to Osler's *The Principles and Practice of Medicine*, Cushing was quite simplistic: “when constant and severe root pains are associated with a progressive paralysis, the diagnosis [of a spinal cord tumor] may be easily made.”⁴³ Due to his enthusiasm for the potential improvement after the resection of a spinal cord tumor and his early belief that they were common, Cushing performed exploratory laminectomies on at least 10 patients, hoping to find a compressive lesion, but no oncological pathological entity was found. Some of the patients who underwent exploratory laminectomies may have had multiple sclerosis, which was also poorly understood at that time.⁴² For example, the patient in Case 8 had fluctuating motor and sensory deficits with episodes of improvement. Other patients may have had degenerative spine conditions, which had not yet been described.⁵⁷

The localization of spinal cord tumors was challenging. In Case 3, Cushing initially performed a T6–L1 exploratory laminectomy, basing his exposure on tenderness to deep palpation along the spinous processes. On incising the dura mater, Cushing did not see a mass, and so he passed a catheter under the arachnoid looking for an obstruction, only to find it 2 levels higher. Ultimately, a 10-level laminectomy was performed, and the final incision was 32.5 cm.

A lack of surgical precedent was another limitation. Encountering an enlarged dura as he did in Case 6, Cushing incised the dura mater at the level of the swelling, rather than starting at an unaffected level and working toward the lesion, as would be preferred today. In doing so, Cushing accidentally incised the spinal cord, and the girl's condition was significantly worsened by the operation. Rather than being discouraged by such accidents, Cushing learned from them.⁴⁵ He meticulously noted his errors. In Case 3, he reported an incidental durotomy that caused a CSF leak; similarly, in Case 14, there was "an ugly accident at the upper part of the incision due to the slippage of the perforator through the canal ... however ... it had gone to the side of the cord." Cushing critically assessed his findings, shortcomings, and complications to refine his techniques.

Additionally, when Cushing first removed spinal meningiomas, he did not resect any dura that was adherent to the tumor. The patient whose case Cushing published in 1904, despite his initial response, had a recurrence only 2 years postoperatively. Eventually, Cushing realized the importance of removing adherent dura.²¹

Intraoperative blood loss was yet another significant limitation.⁵⁶ Suturing and clamping were not possible on bone or in the CNS. Blood loss was dangerous, and transfusions were not readily available. Occasionally, as was seen in Case 5, operations were aborted due to difficulty with hemostasis. Throughout Cushing's spine surgery cases, his most common method for hemostasis was cotton, which was used in Case 6: "the operator returned to the seat of hemorrhage and, although a number of ways of controlling the bleeding point were attempted, none succeeded.... It was found that smaller and smaller wisps of cotton would control the bleeding." In Case 3, in addition to cotton, he used Horsley's antiseptic wax.³⁰

In the landmark monograph on meningiomas that he cowrote with Louise Eisenhardt and published in 1938, Cushing wrote that "To the adage that 'one learns most from his [or her] mistakes' might be added 'particularly if their evil consequences show up sufficiently soon for him [or her] to profit from them.'"²¹ Despite these initial limitations, Cushing built on these experiences to provide the foundation of the knowledge and techniques for the resection of spinal cord tumors. With time, Cushing learned to appreciate the diagnostic challenges and the rarity of spinal cord tumors. Cushing eventually advocated the removal of dural attachment of meningiomas.^{11,15} Difficulty achieving adequate hemostasis led Cushing to develop the silver clip in 1911.¹⁴ After Cushing left Johns Hopkins, he used electrocautery.^{4,29,37} Many of Cushing's experiences with spinal cord tumors were later published in his monograph on meningiomas, which is the foundation on which today's knowledge about and techniques for the resection of meningiomas has been built.²¹ Cushing's willingness to encounter new situations, critical assessment of his shortcomings, and creativity in finding solutions to challenging problems were important characteristics that led him to make his contributions to neurosurgery.

Conclusions

Although best known for his contributions to cranial surgery, Harvey Cushing was a spine surgeon. We report on 7 patients with spinal cord tumors that he treated while at Johns Hopkins. Cushing was one of the first to report the successful resection of an intradural

extramedullary tumor, which he viewed as the most gratifying operation in all of surgery; his enthusiasm led him to perform exploratory laminectomies in 10 patients in whom no pathological entity was found intraoperatively. Although limited by difficulty in making the correct diagnosis, lack of surgical precedent, and intraoperative blood loss, Cushing learned from his shortcomings, eventually making important contributions to our understanding of spinal cord tumors.

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Abbreviation used in this paper

LE lower extremity

Fig. 1.

Case 5. This 17-year-old boy presented with difficulty walking, urinary retention, and a 25-lb weight loss. His sensory examination is shown in these drawings by Cushing, with shaded areas representing decreased sensation from a lateral (A), posterior (B), anterior (C), and medial (D) view; his deficits are most consistent with a lesion in the spinal cord at L-5. Cushing noted landmarks in these drawings, including the fibula (A), the interior malleolus (C), and that the view was posterior (B).

Fig. 2.

Case 2. This 40-year-old physician from Richmond, Virginia, presented with right arm radiculopathy and bilateral LE weakness. Cushing made a sketch of the patient's sensory examination, which was most consistent with a lesion extending from C-7 through the upper thoracic levels, and has written "Total (?) anesthesia to Pain ... on back same—but incl[ude]s most of forearm. Only a very narrow radial strip Escapes."

Fig. 3.

Left: Case 11. This 68-year-old man presented with low-back pain, right LE radicular pain, and urinary incontinence; his examination was remarkable for right LE weakness and hyporeflexia, loss of rectal tone, and saddle anesthesia, depicted in this sketch by Cushing.

Right: Case 14. This 40-year-old woman with a history of episodic LE motor and sensory deficits presented with numbness in the region drawn by Cushing. He noted her sensory deficits began “10 cm above the navel” and extended to her midthigh.

Fig. 4.

Case 1. This 31-year-old woman presented with progressive paraplegia. Cushing performed an exploratory laminectomy and durotomy, where he found a “large lobulated tumor of the spinal meninges ... [it] is impossible to enucleate the growth.” Cushing thought that the growth was a sarcoma, and sketched his intraoperative view, labeling the spinous process of “1st thoracic, completely free” as well as the spinous processes of T-6 and T-7.

Fig. 5.

Case 10. This 20-year-old man presented with episodic LE motor and sensory deficits, as well as bowel and bladder dysfunction. Intraoperatively, the only pathological entity that Cushing found was arachnoid adhesions, and he sketched the intraoperative view of the spinal cord.

Fig. 6.

Case 7. This 2.5-year-old girl presented with a congenital sacrococcygeal mass which measured $9 \times 9 \times 4.5$ cm. Cushing's meticulous drawings depict this unusual mass from the posterior (**A**) and lateral (**B**) views; he also had the child and her mass photographed, with posterior (**C**) and supine (**D**) views.

Table 1
Harvey Cushing's cases of adult spinal cord tumors at the Johns Hopkins Hospital*

Pt Data	Case No.			
	1	2	3	4
age (yrs), sex	31, F	40, M	43, F	62, M
hometown	Baltimore, MD	Richmond, VA	Kingston, ON	Richmond, VA
admit date	05/20/1904	09/12/1905	04/11/1909	11/10/1911
presenting Sx	17.5 yrs of progressive paraplegia, bowel & bladder incont	shooting pain in rt arm & numbness of 4th & 5th fingers	back pain & progressive paraplegia	bilat LE paralysis & paresthesias, bandlike pain around thorax
physical exam	bilat LE spastic paraplegia, numbness starting 7 cm above nipples	bilat weakness in dorsiflexion, anesthesia in lt UE & chest, urinary retention	bilat LE paralysis, anesthesia below sensory level 6 cm below nipples	bilat LE paralysis of dorsiflexion/ plantar flexion, anesthesia below lower thorax
op	T2–5 exp lami & durotomy	C5–T1 exp lami & durotomy	T4–L1 exp lami & durotomy	T3–9 exp lami & durotomy
intraop notes	“Large lobulated tumor of the spinal meninges ... impossible to enucleate....”	what was supposed to be the cord was a large pinkish-gray structure	considerable blood loss, had to extend the incision	intradural extramedullary growth on anterior portion of cord, did not resect
diagnosis	Cushing thought it was a sarcoma, probably a meningioma	intramedullary tumor	“Dural Endothelioma,” probably a meningioma	“Dural Endothelioma,” probably a meningioma
outcome	letter from pt: “As far as any beneficial results arising from the operation ... [there] appear to be none.”	initially gained weight & better strength in LE (died on April 7, 1907; 16 mos after discharge)	“On the whole the case is a complete success”; able to ambulate w/ assistance 1 yr later, well 28.5 yrs later [†]	improved sensation in legs, better bowel & bladder control (died in 1925 after prostatectomy) [†]

* exam = examination; exp = exploratory; incont = incontinence; lami = laminectomy; Pt = patient; UE = upper extremity.

[†] From Cushing and Eisenhardt, 1938.

Table 2
Harvey Cushing's cases of pediatric spinal cord tumors at the Johns Hopkins Hospital*

Pt Data	Case No.		
	5	6	7
age (yrs), sex	17, M	14, F	2.5, F
hometown	Roseville, PA	Ashton, ID	Fitzgerald, GA
admit date	09/02/1898	09/22/1908	07/15/1909
presenting Sx	back & leg pain, difficulty walking, urinary retention, 25-lb weight loss	kyphoscoliosis, gait difficulty, progressive urinary & fecal incont	congenital mass, smaller at presentation than at birth, no motor Sx
physical exam	lt LE weakness in plantar/dorsiflexion, pain in lt L-5 & sacral distribution	Brown-Séquard pattern: lt LE weakness, rt LE sensory loss	sacroccygeal mass, 9 × 9 × 4.5 cm
op	lumbosacral lami w/ partial removal of tumor	C4–T2 exp lami & durotomy, puncture of intramedullary cyst	excision of sacroccygeal tumor
intraop notes	substantial bleeding, tumor invading spinal canal, dissected off of nerve roots, but pt's condition was bad	significant bleeding, accidental incision into spinal cord when opening the dura	intraop CSF leak, tumor had hair & muscle
diagnosis	sacral myxoid chondroosteosarcoma	intramedullary tumor	dermoid cyst, likely congenital sacroccygeal teratoma
outcome	initially improved, could void w/o cath (died 5 mos after discharge)	increased weakness, worse bowel & bladder control, no follow-up	no follow-up

* cath = catheterization.

Table 3
Cushing's exploratory laminectomies in patients with no oncological diagnosis (1906–1910)

Pt Data	Case No.					
	8	9	10	11	12	
age (yrs), sex	20, M	47, M	20, M	68, M	39, M	
admit date	10/11/1906	03/26/1908	10/20/1909	03/28/1910	04/25/1910	
presenting Sx	paresesthesias in rt LE, bilat LE paralysis	bilat LE paralysis, bowel & bladder dysfunction	lt foot drop, episodes of sensory loss, bowel & bladder dysfunction	low-back pain & rt LE radicular pain down leg into calf, urinary incontinence	low-back pain, possible paresthesias, sexual dysfunction	
physical exam	paralysis & severe spasticity of bilat LE, T-10 sensory level	bilat LE spastic paralysis, T-12 sensory level, bilat Babinski sign	anisocoria, hazy optic discs, lt LE spasticity & hyperreflexia, Romberg sign/ataxia	rt LE weakness & hyporeflexia, saddle anesthesia, loss of rectal tone	rt LE hyperreflexia, otherwise normal	
op & intraop notes	T5–10 exp lami & durotomy, thickened lepto-meninges	T3–8 exp lami & durotomy, thickened arachnoid, cord was shrunken	T1–5 exp lami & durotomy, considerable blood loss, arachnoid adhesions	L4–sacral exp lami & durotomy, “no lesion of any kind discovered”	T10–S1 exp lami & durotomy, “no gross abnormality”	
diagnosis	arachnoiditis serosa spinalis	meningitis	chronic adhesive arachnoiditis	carcinoma of sacrum	spondylitis deformans	

Table 4
Cushing's exploratory laminectomies in 5 patients with no oncological diagnosis (1910–1912)

	Case No.				
	13	14	15	16	17
Pt Data					
age (yrs), sex	18, M	40, F	46, F	35, F	36, F
admit date	05/13/1910	10/10/1910	10/31/1910	10/23/1911	02/05/1912
presenting Sx	lt LE weakness, numbness in lt hip & thigh	episodic LE numbness & motor deficits that improved	pain radiating in rt LE into calf, pain in rt face, gait difficulty	bilat LE weakness & radicular pain in soles of feet, urinary incont	rt LE weakness & spasticity (episodic), bowel & urinary incont
physical exam	lt LE weakness, anesthesia from xiphoid process to thigh on lt side	rt foot drop, rt LE spasticity, rt hyperesthesia from abdomen to thigh	numbness on rt side from shoulder to leg, rt LE spasticity & weakness	bilat LE weakness, numbness in sacral dermatomes, poor rectal tone	nystagmus, spasticity & hyperreflexia w/ clonus in LE, Romberg sign
op & intraop notes	T4–9 exp lami & durotomy, dorsal rhizotomy of 3 nerve roots	5-level exp lami & durotomy, cord was small, no evidence of any lesion growth	T2–5 exp lami & durotomy, "normal in all respects"	T10–L2 exp lami & durotomy, cord adherent to dura at L-3 level	5-level lower thoracic exp lami & durotomy, normal cord
diagnosis	chronic leptomenigitis spinalis	none documented	chronic arachnoiditis	cauda equina syndrome	spinal arachnoiditis