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Long-term outcome after resection of brainstem hemangioblastomas in von Hippel-Lindau disease

Joshua J. Wind, M.D.^{1,2}, Kamran D. Bakhtian, M.S.¹, Jennifer A. Sweet, M.D.^{1,2}, Gautam U. Mehta, M.D.¹, Jayesh P. Thawani, M.D.¹, Ashok R. Asthagiri, M.D.¹, Edward H. Oldfield, M.D.^{1,3}, and Russell R. Lonser, M.D.¹

¹Surgical Neurology Branch, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, Maryland ²Department of Neurological Surgery, George Washington University Medical Center, Washington, DC ³Department of Neurological Surgery, University of Virginia Health System, Charlottesville, Virginia

Abstract

Object—Brainstem hemangioblastomas are frequently encountered in patients with von Hippel-Lindau (VHL) disease. These tumors can cause significant morbidity, and their optimal management has not been defined. To better define the outcome and management of these tumors, the authors analyzed the long-term results in patients who underwent resection of brainstem hemangioblastomas.

Methods—Consecutive patients with VHL disease who underwent resection of brainstem hemangioblastomas with a follow-up of 12 months or more were included in this study. Serial functional assessments, radiographic examinations, and operative records were analyzed.

Results—Forty-four patients (17 male and 27 female) underwent 51 operations for resection of 71 brainstem hemangioblastomas. The most common presenting symptoms were headache, swallowing difficulties, singultus, gait difficulties, and sensory abnormalities. The mean follow-up was 5.9 ± 5.0 years (range 1.0–20.8 years). Immediately after 34 operations (66.7%), the patients remained at their preoperative functional status; they improved after 8 operations (15.7%) and worsened after 9 operations (17.6%) as measured by the McCormick scale. Eight (88.9%) of the 9 patients who were worse immediately after resection returned to their preoperative status within 6 months. Two patients experienced functional decline during long-term follow-up (beginning at 2.5 and 5 years postoperatively) caused by extensive VHL disease–associated CNS disease.

Address correspondence to: Russell R. Lonser, M.D., Surgical Neurology Branch, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Building 10, Room 3D20, Bethesda, Maryland 20892-1414. lonser@ninds.nih.gov.

Disclosure

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Conclusions—Generally, resection of symptomatic brainstem hemangioblastomas is a safe and effective management strategy in patients with VHL disease. Most patients maintain their preoperative functional status, although long-term decline in functional status may occur due to VHL disease–associated progression.

Keywords

brainstem; hemangioblastoma; outcome; surgical treatment; von Hippel-Lindau disease

Brainstem hemangioblastomas account for approximately 10%–15% of CNS hemangioblastomas in VHL disease.^{4,19} They are highly vascular, benign tumors that are derived from embryologically arrested hemangioblasts.²⁰ Brainstem hemangioblastomas are frequently located in the medullary region,²⁹ but rarely they can be present in other brainstem locations. Patients with brainstem hemangioblastomas most often present with coughing, singultus, swallowing difficulties, headache, nausea, vomiting, sensory abnormalities, and ataxia.²⁹ Despite the potential morbidity associated with brainstem hemangioblastomas in VHL disease, information describing the long-term follow-up of patients with VHL disease with surgically treated brainstem hemangioblastomas is limited. Subsequently, the treatment and outcome of patients with these tumors has not been defined. We describe and analyze the surgical results of patients with VHL disease and brainstem hemangioblastomas treated at the NIH.

Methods

Patient Population

Patients with VHL disease who underwent surgical treatment of brainstem hemangioblastomas at the NIH between 1988 and 2009 with 12 or more months of follow-up were included in this study. All patients met the clinical criteria for diagnosis of VHL disease.^{10,13} To provide long-term follow-up data, this analysis also included updated clinical data from patients with brainstem hemangioblastomas that have been previously reported.²⁹

Patient Evaluation

Clinical Evaluation—Clinical information was obtained using hospital charts, clinic notes, and operative reports. Clinical assessments were performed preoperatively, immediately postoperatively, and at 6- to 12-month intervals after surgery. Neurological function was assessed, and a functional grade was assigned based on the classification scheme described by McCormick and colleagues¹⁶ (Table 1), and KPS scores were determined for each patient based on clinical evaluations.⁹

Imaging Evaluation—Magnetic resonance imaging was performed in each patient preoperatively and postoperatively at 6- to 12-month intervals associated with clinic visits. Tumor volumes were calculated for each imaging study using contrast-enhanced T1-weighted MR imaging by determining the product of the largest tumor diameters in the anteroposterior, mediolateral, and dorsoventral planes and then dividing by two.¹⁵ Syringobulbia (if present) volumes were calculated on T2-weighted MR images using the

same equation. Tumors were classified by MR imaging as completely intramedullary, primarily extramedullary (50% of the tumor mass was extramedullary), or combined intra- and extramedullary (< 50% of the tumor mass was extramedullary).

Surgical Technique

The technique used for brainstem hemangioblastoma resection has been previously described.²⁹ Because most brainstem hemangioblastomas are located in the obex, we use a posterior midline approach to remove most brainstem hemangioblastomas. Briefly, the patient is placed in cranial fixation and positioned prone with neck flexion. A midline suboccipital incision is made, and a midline suboccipital craniectomy is performed with or without the addition of a C-1 laminectomy depending on tumor size. The dura is opened in a Y-shaped fashion. Under the operative microscope, the cerebellar tonsils are separated and retracted laterally. If the tumor has a pial presentation, it is circumferentially dissected along the tumor margins using bipolar cauterization and microscissors, individually interrupting the feeding and draining vessels, and dissecting precisely at the interface of the surface of the tumor and the normal tissue until the tumor is removed en bloc. A midline myelotomy is performed with a diamond knife to provide access to portions of tumors without a surface presentation.

Statistical Analysis

Ordinal logistic regression models were used to assess the relationship between patient, operative, and tumor variables, and changes in McCormick grade and KPS score. The proportion of patients who remained at or below their preoperative McCormick scale grade was determined by Kaplan-Meier analysis of long-term outcomes. Time-to-event data were calculated as the time between the first operation at NIH for brainstem hemangioblastoma and later functional decline. Statistical analyses were performed using the software R (R version 2.8.2, The R Foundation for Statistical Computing). Statistical significance was determined using a 2-sided p value < 0.05. Mean values are reported as mean $\pm$ SDs throughout.

Results

Patient Characteristics

Forty-four patients who underwent surgical treatment of brainstem hemangioblastomas at NIH with 12 or more months of follow-up were identified. The 44 patients underwent 51 operations for resection of 71 brainstem hemangioblastomas. The mean patient age at time of surgery was 35.7 ± 10.8 years (range 12.7–58.0 years). There were 19 operations in male patients (37.3%) and 32 in female patients (62.7%). The mean follow-up was 5.9 ± 5.0 years (range 1.0–20.8 years). Ten operations (19.6%) had follow-up for 12–24 months, 15 operations (29.4%) for 25–48 months, and 24 operations (47.1%) for longer than 48 months. Patients underwent 1.2 ± 0.5 operations (range 1–3 operations) for brainstem hemangioblastomas. The most frequent presenting signs and symptoms were headache, swallowing difficulties, and singultus (Table 2). The median preoperative McCormick grade was I (range I–IV). The median preoperative KPS score was 80 (range 40–100).

Tumor Characteristics

The mean resected tumor volume was $0.9 \pm 1.3 \text{ cm}^3$ (range 0.01–7.2 cm^3). Twelve operations (23.5%) included multiple brainstem hemangioblastomas that were resected contemporaneously (range 2–4). The mean combined tumor volume in these patients was $1.2 \pm 1.6 \text{ cm}^3$ (range 0.01–8.8 cm^3). Two operations (3.9%) were for tumors with associated intratumoral cysts, whereas 31 operations (60.8%) were for tumors with associated syringobulbia (peritumoral cyst). The mean total syringobulbia volume in these cases was $2.3 \pm 2.2 \text{ cm}^3$ (range 0.01–10.5 cm^3). The combined mean tumor and syringobulbia volume was $3.0 \pm 2.4 \text{ cm}^3$ (range 0.3–10.6 cm^3). Eleven tumors (33.3%) with associated syringobulbia also demonstrated peritumoral edema, but 22 tumors (66.7%) with associated syringobulbia did not have associated peritumoral edema. All tumors without associated syringobulbia demonstrated peritumoral edema.

Thirty-eight (74.5%) of the 51 operations were for tumors in the obex (Fig. 1), 12 (23.5%) were for tumors at the cervicomedullary junction, and 1 (2.0%) was for a tumor in the anterolateral pontomedullary junction.

Surgical Characteristics

The mean number of tumors resected at each operation was 1.4 ± 0.9 (range 1–4). A myelotomy was required to gain access to the tumor in 21 operations (41.2%). While a tumor-associated cyst was entered during the course of tumor resection in 18 (54.5%) of the 33 tumors with associated syringobulbia, it was not entered in the remaining 15 tumors (45.5%) associated with syringobulbia.

Radiographic Outcomes

All tumors (100%) demonstrated gross-total resection on postoperative contrast-enhanced MR imaging. There was no evidence of tumor recurrence in any case at the last follow-up. Edema surrounding tumors (56.9% of tumors) resolved in all cases (100%). All (100%) of the 33 tumors with associated syringobulbia demonstrated collapse of syringobulbia at the last radiographic examination (Fig. 2). The radiographic collapse of syringobulbia occurred regardless of whether the cyst or syrinx was entered during tumor resection.

Clinical Outcomes

Immediate Postoperative Outcome—The median immediate postoperative McCormick grade remained at I (range I–IV). Thirty-four operations (66.7%) produced no change in immediate postoperative McCormick grades (compared with preoperative grade). After the operations, patients in 8 cases (15.7%) had improvement in their immediate postoperative McCormick grades. Patients in 9 cases (17.6%) had worsening of their immediate postoperative McCormick grades. Seven (77.8%) of these were a deterioration of 1 grade, and 2 (22.2%) were a deterioration of 2 grades. The median immediate postoperative KPS score remained at 80 (range 30–100). After 6 operations (11.8%), the patients required placement of a tracheostomy or gastrostomy for exacerbation of lower cranial nerve dysfunction. Patients in 5 (83.3%) of these cases immediately worsened as a result of surgery (by 1 McCormick grade in 3 patients and by 2 McCormick grades in 2

patients) and 1 patient (16.7%) had significant preoperative functional deficits that remained at the same grade postoperatively (McCormick Grade II). All but 1 deterioration in McCormick grade was transient and resolved by 6 months (mean time to recovery 3.2 ± 1.5 months, range 2.2–6.2 months).

Short-Term Outcome (6 Months)—The median 6-month postoperative McCormick grade was I (range I–IV). The median 6-month postoperative KPS score was 90 (range 50–100). Patients in 39 cases (76.5%) had stable 6-month postoperative functional status compared with preoperative status, as measured by McCormick grade. Patients in 11 cases (21.6%) had improved, and 1 (2.0%) had worsened compared with preoperative status. Eight (88.9%) of the 9 cases in which the patient experienced immediate postoperative worsening of their functional status returned to their preoperative grade within 6 months (mean time to recovery of the 9 patients was 3.2 ± 1.5 months; range 2.2–6.2 months). Four (66.7%) of the 6 patients who had placement of tracheostomy or gastrostomy after surgery had them removed during short-term follow-up; 2 (50%) of these 4 patients underwent removal by 3 months (mean time to removal 2.0 months, range 0.9–4.1 months). Two patients (3.9%) required tracheostomy and gastrostomy (1 patient) or gastrostomy (1 patient) through long-term follow-up.

Long-Term Outcome (Longer Than 12 Months)—The median McCormick grade at final follow-up was I (range I–IV). The median KPS score at final follow-up was 90 (range 30–100). Patients in 38 cases (74.5%) had stable long-term postoperative functional status compared with preoperative status. Patients in 10 cases (19.6%) had improved, and those in 3 cases (5.9%) had worsened compared with the preoperative status. Kaplan-Meier analysis was performed to demonstrate the number of patients who remained at or below their preoperative McCormick grade throughout long-term follow-up, including the last known McCormick grades before death (Fig. 3). After stable immediate postoperative McCormick grades, 2 patients experienced 1 grade worsening of their McCormick grade over the course of long-term follow-up due to progression of extensive CNS disease. Six patients died during long-term follow-up (mean age at death 45.5 ± 5.5 years, range 36.9–51.9 years) of CNS progression of VHL disease or complications related to renal cell carcinoma.

Analysis of Preoperative Variables and Outcomes—Univariate ordinal logistic regression analysis was performed to determine if preoperative patient characteristics were associated with functional decline in McCormick grade or KPS score immediately after surgery, at 6 months after resection, or at long-term follow-up. Variables analyzed included patient sex, age, number of tumors, need for myelotomy, intramedullary tumor location with or without a surface presentation, tumor size, presence of syringobulbia, and combined volume of tumor and syringobulbia (Table 3). Only the presence of syringobulbia had a trend toward being associated with better immediate postoperative McCormick grades ($p = 0.07$).

Postoperative Complications

Postoperative complications included pneumonia (in 5 patients), gastrointestinal ulceration (in 3 patients), development of new hydrocephalus requiring placement of a

ventriculoperitoneal shunt (in 1 patient), deep vein thrombosis (in 1 patient), and CSF leak (in 1 patient). Pneumonias occurred in patients with exacerbated lower cranial nerve dysfunction and aspiration. These patients were treated with intravenous antibiotic administration and tube feeding until resolution of lower cranial nerve dysfunction. Gastrointestinal ulceration was treated with proton pump inhibitor therapy in 2 cases but required surgical repair in the third case. Deep vein thrombosis was treated with anticoagulation for 6 weeks. The CSF leak was successfully treated with lumbar drainage for 4 days.

Histological Results

All resected tumors were histopathologically diagnostic for hemangioblastomas. The tumors were composed of polygonal, lipid-laden cells with a rich vascular network and they exhibited positive reaction to neuron-specific enolase on immunohistochemical analysis. No tumor had evidence of metastatic deposit.

Discussion

Von Hippel-Lindau Disease

Von Hippel-Lindau disease is a multisystem tumor syndrome that occurs in roughly 1 in every 39,000 live births.¹³ It is inherited in an autosomal dominant pattern, with a penetrance of greater than 90% by 60 years of age.¹ Von Hippel-Lindau disease has been linked to mutations in the *VHL* gene, a tumor suppressor gene located on the short arm of chromosome 3.^{11,13} Patients with VHL disease are prone to develop tumors in visceral organs and the nervous system. Visceral tumors and cysts can occur in the kidneys, adrenal glands, pancreas, epididymis, and broad ligament. Tumors also develop within the CNS. Sixty percent to 80% of patients with VHL disease develop CNS tumors, including hemangioblastomas of the cerebellum, brainstem, spine, and retina, as well as endolymphatic sac tumors.¹³ The most frequent locations of CNS hemangioblastomas in patients with VHL disease are the cerebellum and spinal cord, followed by the brainstem.^{18,26}

Previous Studies

The literature regarding long-term management of brainstem hemangioblastomas in VHL disease is limited. Most studies examining brainstem hemangioblastoma treatment often analyze a combination of VHL disease and sporadic tumors.^{21,23,27,29,30} The management of hemangioblastomas in patients with VHL disease presents complexity not present in patients with sporadic hemangioblastomas, as those with VHL disease often harbor multiple hemangioblastomas in multiple locations throughout the craniospinal axis, and patients with VHL disease experience growth of existing hemangioblastomas as well as development of new hemangioblastomas over their lifetimes. Furthermore, visceral VHL disease-associated lesions add complexity to the treatment of these patients.

Clinical Implications

Surgery for VHL Disease–Associated Hemangioblastomas—Similar to other neurosurgical disorders, the indications for resection of brainstem hemangioblastomas in

VHL disease are based on their natural history. Several important aspects of the behavior of VHL disease–associated hemangioblastomas must be taken into consideration when deciding to resect these tumors. Patients with VHL disease will frequently develop multiple new tumors during their lifetime. Previously, in long-term analysis, it was found that 45% of symptomatic hemangioblastomas requiring resection were not apparent on initial radiographic studies.¹ Alternatively, not all VHL disease–associated CNS hemangioblastomas evident on MR imaging will become symptomatic and require resection. Furthermore, CNS hemangioblastomas have a saltatory growth pattern, with periods of growth and quiescence (often lasting years). Subsequently, radiographic progression does not necessarily correlate with symptom development, and defined radiographic features to predict symptom formation are yet to be established. Surgical intervention is reserved for patients with early symptoms to maintain long-term function but prevent additional unnecessary operations. Therefore, we have avoided operating on patients with asymptomatic VHL disease who harbor brainstem hemangioblastomas.

Clinical Presentation—Presenting signs and symptoms are listed in Table 2. Many symptoms (swallowing difficulties, singultus, nausea, vomiting, coughing, and speech difficulties) were attributable to local pathology affecting lower cranial nerve nuclei or tracts. Tumors at the obex may manifest with clinical symptoms due to their proximity to the area postrema, hypoglossal nucleus, dorsal motor nucleus, nucleus ambiguus of the vagus nerve, and nucleus tractus solitarius. The nuclei gracilis and cuneatus are located just lateral to the obex and may also account for symptomatic presentation that includes paresthesias, hypesthesias, or proprioceptive difficulties. Disruption of brainstem satiety pathways by tumors such as hemangioblastomas could lead to interference with normal physiological satiety.²⁴ Larger tumors can obstruct CSF outflow from the fourth ventricle, resulting in obstructive hydrocephalus and more generalized symptoms of headache, nausea and vomiting.

Patient Outcome—Overall, most patients remained at their preoperative baseline after surgery. We analyzed McCormick grade and KPS scores preoperatively, immediately postoperatively, at the 6-month follow-up, and at the last follow-up. Patients in 9 cases (17.6%) experienced worsening of their immediate postoperative McCormick grade. All but 1 McCormick grade deterioration was transient, resolving by 6 months (mean time to recovery 3.2 ± 1.5 months, range 2.2–6.2 months). Due to CNS progression of VHL disease, patients in 2 cases (3.9%) experienced late clinical worsening over the course of long-term follow-up after stable immediate postoperative neurological function. Thus, most patients maintain their preoperative functional status, and surgery offers a lasting treatment that prevents progressive functional decline attributable to the treated brainstem hemangioblastoma. Patients with VHL disease will experience new CNS and non-CNS lesions that may ultimately contribute to functional decline.^{1,26}

Tumor Control—Previous studies have described rates of subtotal resection of brainstem hemangioblastomas as high as 15%.^{21,27,30} Incomplete resection of hemangioblastomas frequently leads to the need for resection of recurrent tumors at a later time. In this series, imaging confirmed complete resection in all tumors, and there was no evidence of tumor

recurrence over long-term follow-up. These findings underscore the importance of careful circumferential dissection at the margin of the tumor, allowing complete resection in all brainstem hemangioblastomas in this series. Complete resection can translate to lasting patient benefit and cure.

Effect on Syringobulbia—Syringobulbia was present in most cases (66.7%) preoperatively. All patients demonstrated resolution of their syringobulbia postoperatively as a consequence of tumor resection, whether or not the syrinx or cyst was entered at the time of resection. Previous analysis demonstrated that tumor vascular permeability leads to increased interstitial pressure and peritumoral edema.^{6,14} Once the volume of fluid extravasated through the highly permeable tumor vasculature exceeds the capacity of the surrounding tissue to reabsorb edema, a cyst may develop. Because the tumor is the sole source of syringobulbia, no attempt was made to surgically address the peritumoral cyst in terms of resection, fenestration, or cyst fluid shunting, as resolution of syringobulbia occurs following tumor resection.

Complications—Mortality associated with the resection of brainstem hemangioblastomas varies widely within the literature, with contemporary series documenting rates as high as 24%.^{5,21,27,29,30} Published data on surgical morbidity includes rates of gastrointestinal hemorrhage in patients with solid brainstem hemangioblastomas as high as 30% and cranial neuropathies as high as 21.2%.³⁰ As in those studies, complications in this series were related to the unique anatomy of the region where these tumors were located. For example, dysfunction of the descending hypothalamic autonomic fibers to the dorsal motor nucleus of the vagus nerve may alter parasympathetic innervation to the gastrointestinal tract and account for gastroduodenal ulceration (5.9%) immediately after surgery in our patients.^{3,12} Use of perioperative gastrointestinal prophylaxis with H2-blockers or proton pump inhibitors may reduce the incidence of this complication.

Factors Affecting Outcome—While previous reports have suggested that larger brainstem tumors are associated with increasing surgical morbidity and mortality,^{27,30} detailed analysis in our series of patients did not confirm this hypothesis. To determine preoperative patient factors that may predict outcomes in patients undergoing surgery for brainstem hemangioblastomas, we performed regression analysis of these factors with respect to immediate postoperative, 6-month, and last McCormick grade. There was a trend toward the presence of syringobulbia being associated with improved immediate postoperative McCormick grade. This may be explained by the fact that syringobulbia may facilitate resection of the hemangioblastoma by minimizing the need for surgical tissue manipulation. Alternatively, this association may be due to the fact that syringobulbia is associated with preoperative symptoms that improve with surgical treatment and subsequent syringobulbia resolution. This trend disappeared by the 6-month follow-up examinations and is likely due to the fact that the majority of patients were at their baseline preoperative McCormick grade by 6-month follow-up.

Radiation Therapy

Stereotactic radiosurgery has been proposed as an alternative treatment strategy for CNS hemangioblastomas. These reports have presented excellent control rates within short-term follow-up, with some reports of control rates exceeding 90% at 2 and 5 years.^{7,8,17,22,25,28} Recent long-term prospective evaluation of radiosurgery for the treatment of cerebellar and brainstem hemangioblastomas in VHL disease revealed favorable control rates at 2 and 5 years but declining efficacy in tumor control over time, reaching 61% and 51% at 10 and 15 years, respectively.² Furthermore, exacerbation of neurological deficits as a result of increased peritumoral edema after radiosurgery may limit the use of this modality in symptomatic patients. Investigation of the natural history of hemangioblastomas in VHL disease has demonstrated a saltatory growth pattern of these tumors, and periods of tumor quiescence coinciding with treatment may inaccurately suggest tumor control after radiosurgical treatment.¹ Subsequently, whether stereotactic radiosurgery results in significant control of these tumors over the long term compared with the natural history of the tumor remains to be determined.

Conclusions

Patient outcomes over long-term follow-up demonstrate that most patients with VHL disease and brainstem hemangioblastomas experience stable or improved neurological function after resection. Despite the successful treatment of brainstem hemangioblastomas in patients with VHL disease, some patients develop late deterioration of their functional status due to progression of their disease elsewhere in the craniospinal axis or systemically.

Abbreviations used in this paper

KPS	Karnofsky Performance Scale
NIH	National Institutes of Health
VHL	von Hippel-Lindau

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Fig. 1. Axial (**A**) and sagittal (**C**) postcontrast T1-weighted and axial (**B**) and sagittal (**D**) T2-weighted MR images obtained in a patient with VHL disease and a brainstem hemangioblastoma in the region of the obex.

Fig. 2. Preoperative sagittal postcontrast T1-weighted (**A**) and T2-weighted (**C**) and postoperative sagittal postcontrast T1-weighted (**B**) and T2-weighted (**D**) MR images demonstrating the resolution of tumor-related syringobulbia following resection of a brainstem hemangioblastoma.

Fig. 3.

Kaplan-Meier analysis of last recorded McCormick grades demonstrating that most patients with VHL disease and brainstem hemangioblastomas remain stable over the long term. The proportion of patients who remained functionally stable according to their McCormick grade at 2, 5, 10, and 15 years follow-up was 98%, 94%, 94%, and 94%. The *dashed lines* indicate 95% CIs. *Tick marks* represent censored data at the point of last follow-up.

TABLE 1McCormick clinical grading scale for neurological function¹⁶

Grade	Definition
I	neurologically normal; mild focal deficit not significantly affecting function of involved limb; mild spasticity or reflex abnormality; normal gait
II	presence of sensorimotor deficit affecting function of involved limb; mild to moderate gait difficulty; severe pain or dysesthetic syndrome impairing patient's quality of life; still functions & ambulates independently
III	more severe neurological deficit; requires cane/brace for ambulation or significant bilateral upper-extremity impairment; may or may not function independently
IV	severe deficit; requires wheelchair or cane/brace w/ bilat upper-extremity impairment; usually not independent

* Reprinted from McCormick et al: **J Neurosurg** 72:523–532, 1990.

TABLE 2

Preoperative clinical characteristics

Symptomatic Presentation	No. of Cases (%)
headache	30 (58.8)
swallowing difficulties	17 (33.3)
singultus	16 (31.4)
gait difficulties	16 (31.4)
ataxia	15 (29.4)
visual disturbances	13 (25.5)
limb paresthesias	13 (25.5)
decreased sensation in upper extremities	13 (25.5)
decreased sensation in lower extremities	12 (23.5)
nausea or vomiting	12 (23.5)
speech difficulties	10 (19.6)
lower-extremity weakness	9 (17.6)
vertigo	8 (15.7)
upper-extremity weakness	7 (13.7)
fatigue or changes in sleep/wake cycle	6 (11.8)
coughing	8 (15.7)
anorexia	2 (3.9)

TABLE 3

Analysis of factors influencing immediate postoperative, 6-month, and final follow-up McCormick grade*

Factor	p Value		
	Immediate Postop	6-Mo Follow-Up	Final Follow-Up
sex	0.999	0.744	0.331
age	0.782	0.648	0.936
no. of tumors	0.769	0.975	0.935
need for myelotomy	0.282	0.744	0.689
intramedullary tumor location w/o surface presentation	0.578	0.845	0.464
largest tumor vol	0.350	0.402	0.860
presence of syringobulbia	0.068	0.336	0.199
cyst/syrinx entered at time of op	0.710	0.749	0.690
tumor & syringobulbia vol	0.427	0.465	0.384

* The analysis was performed using ordinal regression.