

Spinal Hemangioblastomas: Analysis of Surgical Outcome and Prognostic Factors

Alberto Feletti (✉ alberto.feletti@gmail.com)

NOCSAE Modena Hospital <https://orcid.org/0000-0001-6285-3648>

Alessandro Boaro

NOCSAE Modena Hospital

Davide Giampiccolo

NOCSAE Modena Hospital

Giorgio Casoli

University of Modena and Reggio Emilia

Fabio Moscolo

NOCSAE Modena Hospital

Massimiliano Ferrara

Veneto Institute of Oncology, IOV-IRCCS

Francesco Sala

NOCSAE Modena Hospital

Giacomo Pavesi

University of Modena and Reggio Emilia

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Abstract

Background. The prognostic factors for surgically removed spinal hemangioblastomas, the impact of VHL disease on outcome, and the role of intraoperative neuromonitoring are still not completely clear. The aim of this study was to review our experience with spinal hemangioblastomas in order to assess potential predictors of neurological outcome after surgery.

Methods. All cases of spinal hemangioblastomas removed at two Italian academic institutions from 1985 to 2020 were reviewed. Data about clinical presentation and symptoms duration, diagnosis of VHL, surgical approach, use of IONM, duration of hospital stay, follow up, McCormick grade before and after surgery were extracted.

Results. Sixty-one patients (31 F, 30 M) underwent 69 surgeries to remove 74 spinal hemangioblastomas (37 cervical, 32 thoracic, 5 lumbar). Improvement was found in 32.3% of cases, neurological condition remained stable in 51.6% of cases, and deteriorated in 16.1% of patients.

A worsening trend in VHL patients and an improvement trend in non-VHL patients were detected, despite the lack of statistical significance. Laminotomy and use of IONM were found to be associated with better outcome, although no association was found between surgery without IOM and worse outcome.

Conclusion. In most cases, patients affected by spinal hemangioblastomas can expect a good long-term outcome. In our experience, laminotomy seems to be associated with better outcome compared to laminectomy. While its absence is not associated with worse outcome, IONM seems to be associated with a better neurological outcome. Our study suggests that the more impaired the preoperative neurological condition, the worse the outcome.

Introduction

Hemangioblastomas (HBs) of the central nervous system are histologically benign entities that can present with symptoms due to mass effect and compression of neural structures, especially in the presence of associated edema, cyst or syrinx. They are relatively uncommon, accounting for 2-6% of all spinal cord tumors and 2-15% of intramedullary tumors [1, 6, 13, 16, 18, 28]. They are sporadic in 70-80% of cases, while 20-30% of them are associated to von Hippel-Lindau (VHL) disease [9]. More than 50% have accompanying syringomyelia [3]. To date, only case reports and small series are available in the literature, with just a few large series having been published so far. Moreover, despite biologically identical, sporadic and syndromic HBs pose specific issues in terms of decision of proper surgical timing and follow up. Therefore, the optimal management strategy especially related to surgery timing, prognostic factors, and surgical outcome is still controversial. Similarly, surgery with the aid of intraoperative neurophysiological monitoring (IONM) may be favored but its impact is debated.

In this report we review our experience with 74 spinal HBs removed during 69 procedures in 61 patients (24 of them affected by VHL disease) and provide a thorough review of the pertinent literature. We focused especially on the assessment of potential predictors of neurological outcome after surgery.

Methods

We reviewed all cases of spinal hemangioblastomas surgically removed at two Italian academic institutions from January 1985 to October 2020. Data about clinical presentation and symptoms duration, diagnosis of VHL, presence of cyst or syringe, surgical approach, use of IONM, duration of hospital stay, follow up, McCormick grade before and after surgery were extracted. All patients signed an informed consent before surgery, approved by the Ethical Board of both Institutions.

Clinical evaluation and medical history

The modified McCormick scale was used to evaluate the neurological status before surgery, after surgery, at discharge and at follow up. It was possible to retrieve specific onset symptoms for 44 patients.

Imaging evaluation

We reviewed all available preoperative and postoperative contrast-enhanced T1-weighted MRI in order to assess tumor location (cervical, thoracic, lumbar), presence of associated cyst or syringe, extent of resection, and tumor residual or recurrence.

Surgical procedures

Surgery was performed as described elsewhere and commonly accepted [10]. After laminectomy or laminotomy, the feeding arteries were coagulated first, and the tumor-pial margin was progressively dissected to expose the tumor (Figure 1). The major draining veins were the last vessels to be sacrificed, finally resecting the tumor en bloc. In selected, more recent cases indocyanine green video-angiography (ICG-VA) was

used during surgery to better distinguish between feeding arteries and draining veins, and to confirm complete resection with absence of residual tumor at the end of the procedure[4]. No patient underwent preoperative embolization or radiosurgery.

Intraoperative Neurophysiological Monitoring (IONM)

The anesthesia protocol applied was Total Intravenous Anesthesia (TIVA). More precisely, a continuous infusion of Propofol (100-150 µg/kg/min) and Fentanyl (1µg/kg/min) was used, avoiding bolus.

Muscle MEPs were elicited by Transcranial Electrical Stimulation (TES) via corkscrew-like electrodes (Ambu® Neuroline Corkscrew, Ambu, Copenhagen, Denmark) from the scalp. Short trains of 5 to 8 square-wave stimuli of 60-200 mA intensity, 0.5 ms duration, and interstimulus interval (ISI) of 4 ms were applied at a repetition rate up to 2 Hz through electrodes placed at C3-C4 scalp sites for upper limb muscles and C1-C2 for the lower limbs, according to the 10/20 EEG system[12]. To allow for monitoring producing less intense muscle twitching, sometimes a Cz-Fz (leg muscles) or a C1-C2 montage (hand muscles) was preferred. Muscle responses were recorded via needle electrodes (Ambu® Neuroline Subdermal, Ambu, Copenhagen, Denmark) inserted in contralateral upper extremities (abductor pollicis brevis (APB), extensor digitorum longus (EXT) and biceps brachii (Biceps) and lower extremities (tibialis anterior (TA) and abductor hallucis (AHB)). Somatosensory evoked potentials (SEPs) were evoked at the level of the median and the tibial nerve (20-40 mA, 0.2-0.3 ms duration, 4.3 Hz repetition) and recorded at the scalp via corkscrew electrodes inserted in the scalp at C1'/C2' (legs) and C3'/C4'. To conclude, D-wave monitoring was performed by applying a single TES stimulus with the same montages for muscle MEPs, to record from the epidural or subdural space of the spinal cord caudal to the tumor. Signals were amplified 10.000 times and the bandwidth was filtered 1.5 to 1700 Hz. Baseline D-waves were recorded after exposing the spinal cord. IONM systems used were an Axon Sentinel-4 (AXON Systems, Inc, Hauppauge, NY, USA) or an ISIS-IOM (Inomed Medizintechnik GmbH, Emmendingen, Germany).

Literature review

We searched PubMed for previously published articles, with the terms "hemangioblastoma", "spinal", "spinal cord", "intramedullary" used in "AND" and "OR" combinations. Inclusion criteria were the following: 1) studies describing patients who were operated for the removal of spinal HBs, 2) studies reporting more than 1 patient, 3) English language. Exclusion criteria were: 1) case reports, 2) mixed series where no clear data about HBs could be extracted, 3) cases published before year 2000.

Statistical analysis

We performed a statistical analysis to evaluate and identify potential predictors of neurological outcome. Categorical factors were summarized using frequencies and percentages, while continuous variables were summarized using means and standard deviations. Chi square test and Student t test were implemented for the univariate analysis, and results were considered significant for p values < 0.05 in the context of two-tailed test. The neurological status at follow up defined by the McCormick score was the outcome variable of choice. Data were analyzed in the context of two different scenarios in which the outcome variable was dichotomized: the first aimed at assessing predictors of clinical improvement, the second at assessing predictors of either clinical stability or improvement. In the first scenario, patients were classified as having an optimal outcome if they had McCormick score of 1 and remained stable, or if they had McCormick score of 2 to 4 and improved of at least 1 point. Patients were classified as having a suboptimal outcome if a decline of one or more points was recorded on the McCormick scale or no improvement with preoperative McCormick score of 2 to 4[27]. In the second scenario, patients were classified as having an optimal outcome if they had McCormick score of 1 and remained stable or if they had McCormick score of 2 to 4 and either improved or remained stable. Patients were classified as having poor outcome if a decline of one or more points was evidenced at follow up on the McCormick scale. Factors that presented p < 0.1 in the univariate analysis were included in a multivariate logistic regression model. All statistical analysis were performed by using SPSS Windows version 26.0.

Results

Patient population

From January 1985 through October 2020, 61 patients (30 F, 30 M) underwent 69 surgeries to remove 74 spinal hemangioblastomas (37 cervical, 32 thoracic, 5 lumbar). The average age at surgery was 35 years (range 2-74 years). Based on the different time and surgeons, we divided the series into two groups: patients operated in the period 1985-2000 (historical group) and those operated in the period 2000-2020 (recent group).

Clinical and radiological features

Motor impairment was most commonly encountered (19 cases), followed by sphincter deficit (18), pain (16), and sensory impairment (11). Symptoms started on average two years before diagnosis (20.5 months, range 0-240 months). In the historical group, symptoms lasted on

average 28.8 months (range 0-240), in the recent group they lasted just more than one year (15.1 months, range 0-103 months). In 24 patients (39%) a diagnosis of VHL was made by molecular analysis. An associated cyst or syringe was found in 24 and 30 cases, respectively. Demographic data of patients, tumor characteristics, preoperative and postoperative McCormick grade are summarized in Table 1.

Surgery and resection

In 42 cases a laminectomy was performed, while laminotomy was preferred in 27 cases. In 25/69 cases (36%) intraoperative neurophysiological monitoring was used. In 4 patients affected by VHL disease, more than 1 HB was resected in a single operation (2 thoracic, 1 cervical + 1 thoracic, 2 cervical, 3 cervical, respectively). Patients were discharged after a mean period of 21 days (range 4-105 days); however, the "recent group" presented a significantly lower hospital stay compared to the "historical group" (average 13.7 vs 34.1 days, $p < 0.001$). Overall, 5 cases of relapse and 9 cases of residual tumor were registered.

Literature review

A thorough review of the literature after year 2000 identified 55 articles with a total of 1199 patients (622 males, 463 females; mean age 38.7 years) and 1432 HBs. Overall, 551 patients were affected by VHL disease. Cervical (45.6%) and thoracic (43.8%) were the most frequent locations. Use of IONM was reported in 18 studies (in 1 study only SEPs were used; in 1 study IONM was used only during positioning (Table 2).

Follow up and outcome

McCormick grading was available in all cases (69) in the preoperative setting, 43 patients in the immediate postoperative evaluation, 68 patients at discharge. Seven patients were lost at follow up, therefore recent follow up examinations were available for 62 patients. Patients were followed up for an average of 46 months (range 1-228 months). In the early postoperative period, improvement was found in 2.3% of cases, neurological condition remained stable in 67.4% of cases, and deteriorated in 30.2% of patients. At discharge, improvement was found in 4.4% of cases, neurological condition remained stable in 85.3% of cases, and deteriorated in 10.3% of patients. At the last follow up, improvement was found in 32.3% of cases, neurological condition remained stable in 51.6% of cases, and deteriorated in 16.1% of patients.

There was no statistical difference between change in McCormick score before and after surgery between VHL and non-VHL patients ($p = 0.17$). However, comparing the mean values of McCormick changes, there is a worsening trend in VHL patients (mean difference +0.06) and an improvement trend in non-VHL patients (mean difference -0.23).

When considering the first scenario, the univariate analysis showed a significant association between type of surgical approach and outcome, where laminotomy favors optimal outcome ($p = 0.03$, OR 5.4, 95% CI 1.6 – 16.7). Similarly, surgery with IONM favors optimal outcome ($p = 0.017$, OR 5.23, 95% CI 1.42 -21.7). Having a preoperative McCormick score of I or II, although not significant, showed a trend towards association to better outcome ($p = 0.08$) (Table 3).

No association was found between outcome and age, gender, VHL diagnosis, symptoms duration, presence of cyst or syringe, and HB location.

Even though the difference was close to significance ($p = 0.06$), optimal and suboptimal groups did not present a significant difference in preoperative McCormick score. A significant difference was however found in the post-op McCormick score ($p = 0.016$, 2.92 VS 1.93), mean difference of -0.9 (95% CI -1.7 - -0.19), at discharge ($p < 0.009$, 2.67 VS 1.83), mean difference of -0.8 (95% CI -1.4 - -0.2) and at follow up ($p < 0.001$, 1.34 VS 3.05), mean difference -1.7 (95% CI -2.14 - -1.2).

Univariate analysis in the second scenario confirmed a significant association between type of surgical approach and outcome, where laminectomy correlated with a poorer outcome ($p = 0.02$) (Table 3). No association was found between surgery without IONM and worse outcome ($p = 0.094$).

In the multivariate analysis for both scenarios, surgical approach was the only variable that retained significance (respectively $p = 0.01$ and $p = 0.019$). In the first scenario, preoperative McCormick score almost reached statistical significance ($p = 0.056$). In the second scenario the presence of syringe almost reached statistical significance ($p = 0.083$).

Discussion

HBs are not commonly encountered by neurosurgeons, however they are not rare, accounting for 2% to 15% of primary intramedullary spinal cord tumors in reported series. The reported male-to female ratio is 1.6:1 to 5.5:1 [13]. Similar to the literature data, the majority of the HBs in our patients occurred in the cervical and dorsal spinal cord. A reason for this may be the predominant distribution of embryonic precursor cells in these areas of the spinal cord [11, 21, 22]. Overall, onset symptoms in our series recapitulate those commonly reported in other studies: sensory and motor deficits, pain, urinary dysfunction, and occasionally bulbar symptoms.

It is well known that the postoperative neurological outcome typically correlates with the preoperative functional status in patients with intramedullary tumors, and HBs are not an exception [14, 23]. Also large tumors, and those ventrally located have been associated with a worse neurological outcome [11], possibly because of a more ventral location of corticospinal fibers.

Postoperatively, 50% to 80% of patients experience a worsening of their neurological status [13]. However, these deficits are usually transient, and patients recover to the baseline after some weeks/months. Almost one third of our patients experienced postoperative neurological worsening. Nonetheless, consistent with the reported trend, just 1 patient did not recover to the baseline at last follow up. Assessing the neurological status at the last follow up is therefore more interesting and reliable than the immediate postoperative outcome.

HBs outcome and preoperative neurological status

The importance of the neurological condition at admission has been already shown to have an impact on the final outcome [19, 23]. Although our study failed to find a clear statistical significance, our data confirm that preoperative McCormick score of I or II tend to be associated with a better outcome, compared to those patients presenting with more severely impaired neurological condition. This is particularly important in case of VHL-associated HBs. In these patients it is certainly wise to wait until spinal HB becomes symptomatic before indicating surgical removal in order to avoid unnecessary operations, but not too long in order to guarantee the best neurological outcome to the patient. There is a strong association between VHL disease and HBs, and especially spinal HBs. About one third of patients with spinal HBs are affected by VHL disease, and up to 40% of VHL-related CNS HBs develop in the spinal cord [9, 20]. The management of HBs in VHL patients can be challenging, due to the presence not only of other tumor types as pheochromocytoma, but also of multiple HBs. In 3 of our VHL-affected patients, 2 spinal HBs were resected in a single operation, and in one patient 3 spinal HBs were removed during the same surgery. These patients were admitted with severe neurological status (McCormick 3 and 4), and had a McCormick 3 at the last follow-up, confirming that the multifocality of VHL lesions can severely impact on postoperative outcome.

HBs and surgical approach

The association of surgical approach with neurological outcome in spinal surgery has been debated for a long time. Our study showed that laminotomy is significantly associated with a better outcome compared to laminectomy, both in univariate and multivariate logistic regression models. This is in contrast with some studies, which failed to show any correlation between surgical approach and neurological outcome [15]. It is not easy to find a reason to interpret this result. However, we assessed outcome using McCormick scale that is a functional scale, not a grading of neurological motor or sensory functions *per se*. Therefore, while motor and sensitive functions depend mainly on the preservation of neural pathways, mobility and functional independence can be affected also by other factors such as paraspinal muscles and osteoligamentous conditions. We hypothesize that laminotomy may guarantee a better preservation of osteoligamentous and muscular connections, thus facilitating postoperative improvement.

HBs and IONM

The use of IONM is still considered controversial. Since HBs have normally a clear border separating them from the spinal cord, monitoring is considered by some authors not useful to increase safety in surgical resection [13]. However, in the last 20 years the use of IONM during the resection of spinal HBs has become more and more common, with an increasing number of authors showing the importance of such method also in HBs removal, both for surgical strategy and for prognostic reasons [4, 6, 22, 25, 27, 15, 26].

In our results, the use of IONM was associated with optimal outcome. There are a number of reasons which may support this result, which is in line with previous literature [26]. In our clinical setting, it is common practice to abandon surgery if D-wave amplitude decreases over 50% and does not recover with corrective measures such as irrigation, papaverine and hypertension, as it has been shown to predict persistent motor deficit [19]. Another benefit may have been related to MEP monitoring. Although SEPs are generally considered useful for spinal cord preservation in scoliosis surgery, MEPs are more reliable in monitoring corticospinal tract function, particularly in the short term [8]. Even if they do not appear to be correlated with long-term outcome, they may provide timely information of initial damage to part of the motor system since a decrease of MEPs during surgery normally anticipates a reduction in D-wave amplitude. This may be very useful to modify surgical strategy and timing accordingly. A decrease of MEPs amplitudes might suggest the need of making a pause during pial dissection, or at least move to a different side of the tumor, irrigating the spinal cord with warm saline solution to allow amplitudes to recover. This strategy might potentially be beneficial to the spinal cord, which is stressed not only by tumor compression but also by the even cautious microsurgical maneuvers. In any case, it is worth noting that the univariate analysis of our data in the second scenario revealed that the absence of IONM is not associated with a poorer outcome. However, although it is not possible to say that the absence of IONM increases the odds for a poor outcome, our analysis shows that their use may increase the chances for a postoperative improvement of neurological function in the long-term follow up.

VHL vs Sporadic HBs

We showed that surgery offers high chances to improve neurological condition or at least to avoid further deterioration due to the HB. Our data suggest that VHL-patients may have a poorer outcome compared to those with sporadic HBs. This is in contrast with some published series [2, 25], but in line with others [29, 31][30], and further research is certainly needed to clarify this issue. However, we expect poorer long-term outcome in VHL patients to be due to disease progression and cumulative functional morbidity rather than the single surgical operation *per se*, as the growth of multiple HBs may multiply the risk of preoperative neurological deficits and related sequelae from cumulative surgeries, as already pointed out in other studies.

Limitations

Our study has several limitations. First, there are limitations due to the study design, which is retrospective. Second, neurological outcome was not consistently available for all patients due to losses at follow up. Third, this series is composed by patients who were operated during a long-spanned time period, when different surgical tools and devices were available. Moreover, this series includes patients treated in two different Institutions, with a possible bias due to potentially different surgical strategies.

Conclusions

Spinal hemangioblastomas are uncommon, though not rare, benign vascular tumors. Surgery can be curative if no remnants are left. Laminotomy seems to be associated with better outcome compared to laminectomy. While its absence is not associated with worse outcome, IONM seems to be associated with a better neurological outcome. Our study suggests that the more impaired the preoperative neurological condition, the worse the outcome. This finding should prompt neurosurgeons to balance very carefully the timing for surgery, especially in case of VHL-affected patients.

Declarations

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Conflict of interest. The authors declare no conflict of interest.

Availability of data and material. The corresponding author has full access to all data and material.

Code availability. Not applicable.

Authors' contributions. Alberto Feletti: conception and design of the work, analysis and interpretation of data, draft of the work, approval of the final version. Alessandro Boaro: analysis and interpretation of data, draft of the work, approval of the final version. Davide Giampiccolo: acquisition and interpretation of data, draft of the work, approval of the final version. Giorgio Casoli: acquisition of data, approval of the final version. Fabio Moscolo: acquisition of data, approval of the final version. Massimiliano Ferrara: acquisition of data, approval of the final version. Francesco Sala: design of the work, interpretation of data, critical revision, approval of the final version. Giacomo Pavesi: design of the work, interpretation of data, critical revision, approval of the final version.

Ethics approval. As this is a retrospective study, no approval was required by the Institutional Ethics Board.

Consent to participate. Consent to participate was not required because of the retrospective nature of the study, and because patients cannot be identified.

Consent for publication. Consent for publication was not required because of the retrospective nature of the study, and because patients cannot be identified.

Disclosures: the authors have nothing to disclose

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Tables

Due to technical limitations, table 1 is only available as a download in the Supplemental Files section.

Table 2. Spinal hemangioblastomas: review of the literature since year 2000. Series with more than 1 case were included.

Author	Period	Patients	Tumors	VHL	Mean Age	Sex	Level	IOM	Outcome	Follow up	McCormick
Pietilä et al., 2000 ¹³	1995-1999	15	30	13	27	1M, 14F		SEPs	6 improved, 17 stable	20 mos	No
Conway et al., 2001 ¹⁴	1973-1999	10		7				No			No
Roonprapunt et al., 2001 ¹⁵		19	19	0	32	13M, 6F	13C, 6T	Yes	13 improved, 6 stable	50 mos	No
Malis, 2002 ¹⁶	1967-1990	19	19	0			14C, 5T	Only during positioning	All recovered or improved	Minimum 8 years	No
Xu et al., 2002 ¹⁷		21							20 improved, 1 deteriorated		
Pai & Krishna, 2003 ¹⁸		2	2		26	2M	1T, 1L	No	2 improved	9.5 mos	No
Lee et al., 2003 ¹⁹	1986-2000	14	16	6	37.2	11M, 3F	8C, 7T, 1L	No	8 improved, 3 stable, 3 deteriorated	47 mos	No
Huang et al., 2003 ²⁰	1993-2003	10		5	33	3M, 7F			4 improved, 6 stable	3 mos	Yes
Van Velthoven et al., 2003 ²¹	1991-2001	22	22	18	38	14M, 14F	14C, 7T, 1L	Yes	28.6% improved, 71.4% stable	31 mos	Yes
Lonser et al., 2003 ²²	1988-1997	44	86	44	34	26M, 18F	44C, 33T, 9L	No	9% deteriorated	44 mos	Yes
Pluta et al., 2003 ²³		8	9	8	34	6M, 2F	5C, 4T		3 stable, 5 deteriorated	6 mos	
Escott et al., 2004 ²⁴		3	3	0	59	3M	1C, 2L	No	2 improved, 1 stable		No
Glasker et al., 2005 ²⁵		6	6	3	44	3M, 3F	1C, 3T, 2L	No	5 improved, 1 stable		No
Glasker & Van Velthoven, 2005 ²⁶		5	5	2	46	5F	3C, 2T	No		14 years	No
Biondi et al., 2005 ²⁷		4	4	1	43	2M, 2F	4L	No	4 improved	3 years	No
Vougioukas et al., 2006 ²⁸		5	5	5	13.6		2C, 3T	Yes	5 stable		No
Na et al., 2007 ²⁹	1994-2006	9	9	5	37.8	4M, 5F	5C, 4T	No	3 improved, 6 stable	22.4 mos	Yes
Boström et al., 2008 ³⁰	1990-2005	23		8			10C, 15T, 2L	No	5 improved, 18 stable	27 mos	Yes
Dwarakanath et al., 2008 ³¹	1992-2006	22	22		35.9	13M, 9F	15C, 1CT, 6T	No	20 improved or stable, 2 deteriorated	4.6 years	No
Shin et al., 2008 ³²	1991-2005	20	24	2	49.4	12M, 8F	C8, T12, L4	No	7 improved, 14 stable, 3 deteriorated	5.6 years	No
Pavesi et al.,	2000-	7	19	7			7C, 6T,	No	4 improved,	36.7 mos	No

2008 ³³	2008					6L			3 stable		
Kanno et al., 2008 ³⁴	2000-2002	48	74	48	33.5	21M, 27F	30C, 40T, 4L	No	83% improved or stable, 17% deteriorated	6.5 years	Yes
Wang, 2008 ³⁵	1991-2002	68	90	20	36.6	44M, 24F	50C, 32T, 8L	No	Better outcome for single lesions and cervical location compared to multiple HBs and thoracic location		No
Mandigo et al., 2009 ¹	2002-2007	15	18	2	43	7M, 8F	3C, 13T, 2L	Often	1 improved, 12 stable, 2 deteriorated	35 mos	yes
Parker et al., 2009 ³⁶	1985-2002	34	34	25	41	15M, 19F	28C, 25T, 7L	No	11 improved, 17 stable, 6 deteriorated	60 mos	Yes
Mehta et al., 2010 ⁴	1984-2008	108	218	108	33	57M, 51F	102C, 96T, 20L	No	6 improved, 86 stable, 16 deteriorated	7 years	Yes
Takai et al., 2010 ³⁷	1988-2008	35		18	39	25M, 10F	22C, 17T, 13L	No	3 improved, 16 stable, 11 deteriorated	70 mos	Yes
Clark et al., 2010 ³⁸	1995-2008	20	33	11	49	13M, 7F	19C, 9T, 5L	Yes	5 improved, 13 stable, 2 deteriorated	19 weeks	Yes
Kim et al., 2012 ³⁹	1999-2009	12	24	12	42.3	9M, 3F	6C, 14T, 4L	Yes	8 stable, 4 deteriorated	49.3 mos	Yes
Park et al., 2012 ⁴⁰	2003-2012	16	30	4	45.2	12M, 4F	12C, 14T, 2L	No	3 improved, 9 stable, 4 deteriorated	90 mos	Yes
Harati et al., 2012 ⁴¹	1997-2011	17	20	11	43	10M, 7F	13C, 5T, 2L	No	4 improved, 13 stable	57mos	Yes
Hao et al., 2013 ¹⁰	2011	7	7	2	34	6M, 1F	4C, 3T	Yes	7 stable		yes
Serban & Exergian, 2013 ⁶	2003-2009	5	5	2	40		2C, 3T	No	4 stable, 1 deteriorated		No
Sun et al., 2014 ⁴²	23 years	14	15	0	41.5	8M, 6F	9C, 3T, 1L	No	53.3% improved, 33.3% stable, 13.3% deteriorated	4 years	No
Boström et al., 2014 ⁴³	1987-2007	5	5					Yes	1 improved, 3 stable, 1 deteriorated	55 mos	Yes
Hojo et al., 2014 ⁴⁴		3	3		51	2M, 1F	1T, 2L	No			No
Deng et al., 2014 ⁸	2007-2011	92	116	32	33	58M, 33F	58C, 49T, 9L	No	38 improved, 40 stable, 14 deteriorated	50 mos	yes

Joaquim et al., 2015³	2000-2014	16	16	7	34	10M, 6F	11C, 5T	Yes (7)	2 improved, 13 stable, 1 deteriorated	48 mos	Yes
Li et al., 2016⁴⁵	2008-2013	25	25	16	37	17M, 8F	12C, 8T, 2L	No	100% McCormick I or II	21 mos	Yes
Liu et al., 2016⁴⁶	1996-2014	21	23	0	45	14M, 7F	13C, 9T	Yes (16)	9 improved, 12 long-term dysfunction	17 mos	
Westwick et al., 2016⁴⁷	2000-2010	133	133		48	62M, 71F					
Kim et al., 2016⁴⁸	2009-2014	6	6		35	5M, 1F	3C, 3T	Yes			
Prokopienko et al., 2016⁴⁹		12	12	6	34	5M, 7F	6C, 2CT, 4T	Yes	6 improved, 6 stable	5 years	Yes
Yasuda et al., 2016⁵⁰	2010-2013	11	11	1	53.9	8M, 3F	4C, 5T, 2L				Yes
Siller et al., 2017⁵¹	2000-2013	24	27	7	36.8	12M, 12F	21C, 5T, 1L	Yes	88.2% improved or stable	7.9 years	Yes
Imagama et al., 2017⁵²	1993-2013	28	28	6	43	17M, 11F	12C, 10T, 6L	Yes	Probability of good outcome: 79% if preop McCormick grade I and II. 22% if preop grade III, IV, V	10 years	Yes
Das et al., 2017⁵³	2000-2013	14	15	7	33.7	6M, 8F	8C, 5T, 1L	No	11 good functional outcome	5 years	Yes
Nemeiko et al., 2019⁵⁴	2010-2015	4			39	3M, 1F	4C				
Yousef et al., 2019⁵⁵	1997-2016	42		20	44	31M, 11F	47.6%C, 26.2%T, 9.5%CT		38 improved	20.9 mos	No
Krüger et al., 2019⁵⁶	2010-2018	18	19	16					17 improved or stable, 1 deteriorated		Yes
Sadashivam et al., 2020⁵⁷	2001-2014	15	23	8	33.8	7M, 8F	9C, 13T, 1L		80% favorable	5 years	Yes
Wang et al., 2020⁵⁸	2008-2018		3					Yes			
Chang et al., 2020⁵⁹	2005-2015	11	11	0	28.5	8M, 3F	11C	No	8 improved, 3 stable	6-48 mos	Yes
Richards et al., 2020⁶⁰	2008-2017	6	6	2							Yes
Vergauwen et al., 2020⁶¹	1996-2013	26	82	26		17M, 9F	26C, 28T, 5L	Yes			Yes
Present study	1985-2020	60	68	24	35	30M, 30F	37C, 32T, 5L	Yes (25)	20 improved, 32 stable, 10 deteriorated	46 mos	Yes

C = cervical, CT = cervicothoracic, T = thoracic, L = lumbar

Table 3. Univariate analysis of outcome predictors in scenarios 1 and 2.

variable	Scenario 1		Scenario 2	
	rate of optimal outcome (%)	p value	rate of optimal outcome (%)	p value
Gender		0.06		NS
M	78.6		82.1	
F	55.9		85.3	
VHL		NS		NS
yes	58.1		80.6	
no	69.2		84.6	
Location		NS		NS
cervical	60.7		85.7	
dorsal	73.3		86.7	
lumbar	60		60	
Laminotomy		0.009		0.02
yes	84.6		96.2	
no	52.8		75	
IOM		0.008		0.09
yes	87.5		91.7	
no	50		72.1	
Cyst		NS		NS
yes	65.2		91.3	
no	65.6		78.1	
Syringe		NS		0.008
yes	70.4		96.3	
no	54.5		68.2	
McCormick pre		0.086		NS
≤2	72.7		81.8	
>2	50		88.9	

VHL: von Hippel Lindau disease; IOM: intraoperative monitoring; NS: not significant.

Figures

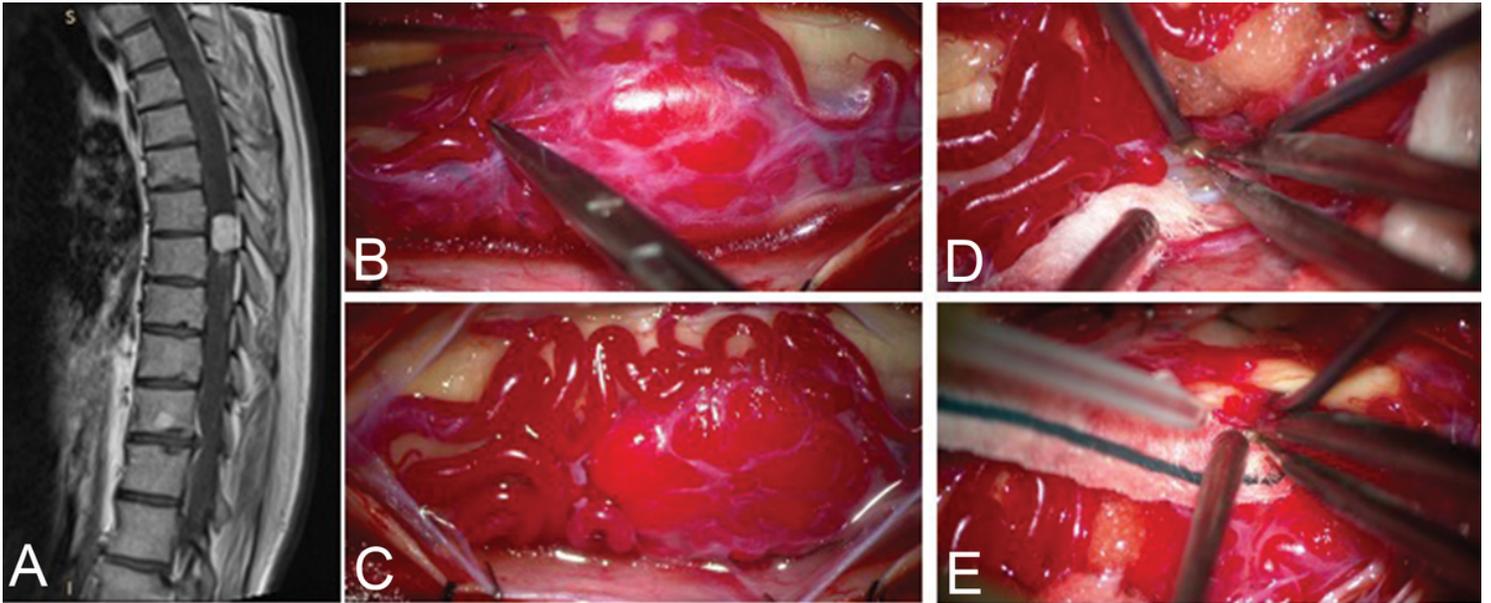


Figure 1

A) T1-weighted contrast-enhanced sagittal MRI showing the presence of a dorsal hemangioblastoma. B) Intraoperative view of arachnoid dissection. C) Evidence of the nodule and some feeders and draining veins. D) Arterial feeders are coagulated and sectioned on the ventrolateral side of the hemangioblastoma. E) Dissection of the pial layer separating the tumor from spinal cord.

Supplementary Files

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