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Neurological outcome after resection of spinal schwannoma

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ABSTRACT

Introduction: Spinal schwannoma (SS) is the most frequently diagnosed benign spinal tumor, constituting approximately 25 % of all intradural tumors. Aim of our study was to identify factors that potentially affect immediate postoperative neurological outcome, and the rate of functional recovery within 12 months.

Methods: Screening of our institutional database yielded 90 consecutive patients (mean age 57.1 years, 39 women [43.3 %]) with newly diagnosed SS between March 1997 and October 2018. We pre- and postoperatively reviewed patient charts, surgical reports, radiographic data, use of IOM, duration of symptoms, histopathology, co-morbidities, radiographic extension, surgical strategy, neurological performance (Japanese Orthopedic Association Score [JOA score] and Frankel Grade Classification).

Results: Mean duration of preoperative symptoms was 3.6 ± 1.6 months. Most common symptoms were local pain (n = 77, 85.6 %). Macroscopic complete resection was achieved in 84 patients (93.3 %). During follow-up, complete recovery from local pain was documented for 41 patients (59.7 %), from radiating pain for 41 (69.5 %; $p < 0.001$).

Postoperatively, 25 (27.7 %) patients developed a new neurological deficit (motor deficits n = 3 and sensory deficits n = 23; one patient developed both); after 12 months, however, motor deficits had abated in all patients, and 16 (69.5 %) patients had completely recovered from sensory deficits.

Use of intraoperative monitoring (IOM) was a significant predictor for good functional outcome ($p < 0.001$).

Conclusion: Resection of SS accompanied by IOM whenever feasible should be advocated. We achieved a high number of complete resections with a low rate of morbidity. New postoperative motor or sensory deficits had a very high rate of complete recovery within 12 months.

1. Introduction

Spinal schwannoma (SS) is the most frequently diagnosed benign spinal tumor, constituting approximately 25 % of all intradural spinal tumors [1–4]. According to the literature, the incidence of SS varies between 0.3 − 0.4 cases/100,000 persons per year [5]. Histologically, the majority of SS are benign with dense cellularity, whereas neurofibromatosis is marked by tumors at multiple locations [3,5]. Many SS are asymptomatic for a long time because of their slow growth rate. However, symptoms usually develop when the tumor compresses the spinal cord or nerve roots, or both, sometimes even infiltrating these structures. Surgical decision-making is usually based on clinical and radiological findings [6]. The choice of therapeutic strategy requires consideration of the topographical level of the specific compression, tumor morphology, and residual function [4]. Because schwannoma is composed of neoplastic Schwann cells wrapped around the neuron [4], complete resection of SS may necessitate the excision of the tumor-invaded nerve root; thus, permanent or transient sensory or motor deficits may develop in some cases [7]. Although diffuse tumor growth is anatomically restricted because of the dural aperture for the spinal nerve root and the intervertebral foramen [8], some SS typically grow exophytically both intra- and extraspinally.

The aim of our study was to evaluate the clinical presentation, functional outcome, and recovery rate of new deficits developed within 12 months after surgical resection of SS and to identify factors that potentially affect neurological outcome with particular focus on IOM.

2. Patients and method

Screening of our institutional database yielded 90 consecutive patients with newly diagnosed SS who had undergone surgery at the Neurosurgical Department of the University Medical Center

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Regensburg, Germany, between March 1997 and October 2018. Patients with the diagnosis of neurofibromatosis I and II were excluded because of the unpredictable and aggressive biological behavior of these lesions [9].

Patient charts, surgical reports, and radiographic data were reviewed for demographics, duration of symptoms, history of medical treatment, medication, co-morbidities, radiographic extension of the tumor, surgical approach (laminectomy, hemilaminectomy, and laminotomy), use of IOM, and pre- and postoperative neurological performance. Neurological performance was classified according to the Frankel Grade and the Japanese Orthopedic Association Score [10,11]. Pre- and postoperative motor and sensory deficits were categorized as well as bowel and bladder dysfunction. Local and radiating pain was determined by the Visual Analog Scale (VAS, grade 1 = no pain to grade 10 = maximum pain) [12]. Mean follow-up period was 23.7 ± 39.5 months (range 12–172 months). Because all patients routinely presented at our outpatient clinic for physical radiographic evaluation with magnetic resonance imaging (MRI) after 3 and after 12 months, the follow-up visits of our study patients were conducted at these time points.

Intraoperative electrophysiological monitoring (IOM) comprised D-wave, somatosensory-evoked potentials (SSEP), and motor-evoked potentials (MEP). The standardized routine use of IOM was established at our department in 2010.

The tumors were histologically classified by neuropathologists according to the criteria established by the World Health Organization [13]. The extent of resection was described in the surgical report and evaluated by means of the first postoperative MRI after 3 months. We distinguished between complete and partial removal of the tumor, with or without resection of the infiltrated nerve root. All operations were conducted microsurgically.

The study was approved by our institutional review board (18-1117-104; Ethics Committee of the University of Regensburg).

3. Statistical analysis

All data are presented using descriptive statistics; relative and absolute frequencies for categorical and median (range) for continuous data. Comparisons of pain and JOA score between admission and 3 month follow-up were done by using a Wilcoxon signed rank test. Differences between the operation method (with vs. without IOM) and the development of neurological deficits were analyzed by using a chi-squared test of independence. A p-values < 0.05 was considered statistically significant. All analyses were done with SPSS 25.0 (IBM).

4. Results

4.1. Demographics and clinical evaluation

90 patients with SS were identified, 39 women (43.3 %) and 51 (56.7 %) men. Mean age at the time of surgery was 57.1 ± 3.2 years (range 24–82 years). Mean duration of preoperative symptoms was 3.6 ± 1.6 months (range 0–6 months). The most common symptoms were local back pain (n = 77, 85.6 %), radiating pain (n = 59, 65.6 %), sensory deficits (n = 48, 53.3 %), and motor deficits (n = 20, 22.2 %). Motor deficits were subdivided in para-paresis (n = 1, 1.1 %) and mono-paresis (n = 19, 21.1 %). Loss of sphincter control was observed in 1 (1.1 %) patient and urinary retention in 3 (3.3 %) patients. Median VAS level was 4 (IQR 3–6). All clinical signs and symptoms at admission are summarized in Table 1. Histologically, all tumors were categorized as SS WHO grade I.

4.2. Tumor morphology and localization

Our search yielded 63 (70.0 %) intraspinal schwannoma and 27 (30.0 %) extraspinal schwannoma, of which 25 (27.8 %) were intra- and extraspinal hourglass (dumbbell-shaped) schwannoma. Fig. 1 shows the pre- and postoperative sagittal and axial T1 images with contrast enhancement taken after the complete SS resection at TH 12. The predominant tumor site was the lumbar spine (n = 45, 50 %) followed by the thoracic spine (n = 26, 28.6 %), the cervical spine (n = 18, 20 %), and the sacral spine (n = 1, 1.1 %). In 48 (53.3 %) patients, one spinal level was affected, in 32 (35.6 %) patients two levels, and in 10 (11.1 %) patients 3 levels. The most frequently compromised segments (n = 10, 11.1 %) were the lumbar levels L1/L2, L2/L3, and L3/L4. Details are summarized in Table 2.

Table 1
Baseline data and clinical presentation.

	n	%
Total no. of patients	90	100 %
Sex		
Women	39	43.3 %
Men	51	56.7 %
Age (y)	57.1 (24–82)	
Clinical presentation		
Local pain	77	85.6 %
Radiating Pain	59	65.6 %
Motor deficit	20	22.2 %
Sensory deficit	48	53.3 %
Sphincter impairment at first evaluation		
Yes	1	1.1 %
No	89	98.9 %
Urinary retention		
Yes	3	3.3 %
No	87	90.6 %
Mean duration of preoperative symptoms (months)	3.63 (0–6)	
Sagittal topography		
Cervical	18	20.0 %
Thoracic	26	28.6 %
Lumbar	45	50.0 %
Spinal localization		
intradural	76	84.4 %
extradural	14	15.6 %
intraspinal	63	70.0 %
extraspinal	27	30.0 %
hourglass (dumbbell shaped)	25	27.8 %

4.3. Surgery

The surgical approach was hemilaminectomy (n = 45, 50 %), laminectomy (n = 34, 37.8 %), and laminotomy (n = 7, 7.8 %). 2 (2.2 %) patients with thoracic SS were operated on by means of the transthoracical approach and another 2 (2.2 %) patients by means of the transabdominal approach (Fig. 2).

Macroscopic complete resection was achieved in 84 patients (93.3 %) and partial resection in 6 (6.7 %) patients. In 1 patient, the decision on partial resection was made intraoperatively because of deteriorating IOM. 59 (65.6 %) patients required resection of the tumor-infiltrated nerve root.

Overall surgical morbidity defined as all complications requiring revision surgery was 7.7 % (n = 7 patients). 2 (2.2 %) patients required revision surgery because of symptomatic cerebrospinal fluid (CSF) fistula, 3 (3.3 %) patients had symptomatic epidural hematoma that had to be evacuated surgically, 1 (1.1 %) patient had developed spinal instability requiring instrumented dorsal fusion, and 1 (1.1. %) patient required a second operation due to insufficient debulking.

4.4. Intraoperative monitoring and functional outcome

At 3-month follow-up, 46 (59.7 %) patients had fully recovered from local back pain, and 41 (69.5 %) patients with preoperative radiating pain were asymptomatic. 36 (75.0 %) patients with preoperative sensory deficits and 9 of the 20 (45 %) patients with motor deficits had completely recovered.

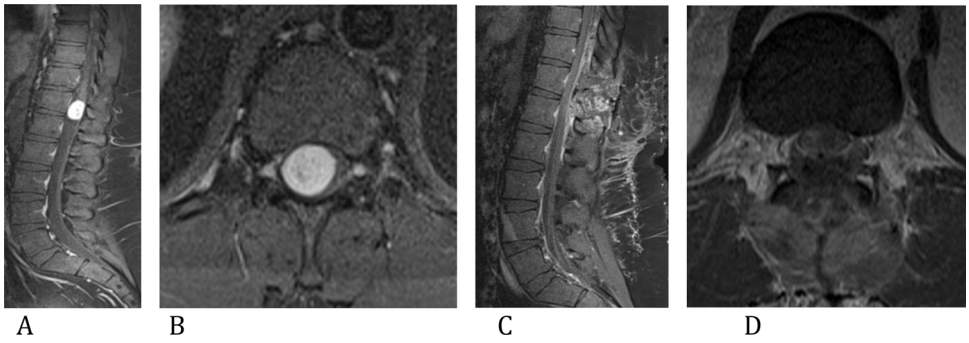

Fig. 1. Pre- (A, B) and postoperative (C, D) MRI of a patient with SS localized at Th12, contrast-enhanced sagittal and axial T1 sequence.

Table 2
Clinical outcome.

Recurrent lesion		
Yes	3	3.3 %
No	87	90.6 %
Postoperative new neurological deficit	25	27.8 %
Postoperative new neurological deficit with IOM	8	8.9 %
Postoperative new neurological deficit without IOM	17	18.9 %
Neurological status at follow-up		
Improved	45	66.6 %
Stable	23	33.4 %

At 12-month follow-up, 38 (78.1 %) patients with preoperative sensory deficits and 16 of the 20 (80 %) patients with motor deficits had completely recovered.

Pain classified by means of VAS had significantly improved from a median of 4 (IQR 3–6) at admission to a median of 0 (IQR 0–1) at 3-month follow-up ($p < 0.001$). Median JOA score had improved from 15 (IQR 9–17) from admission to 16 (IQR 16–17) at 3-month follow-up ($p = 0.001$).

Immediately after surgery, 25 (27.7 %) patients developed a new neurological deficit: new motor deficits n = 3, new sensory deficits n = 23 (one patient developed both). After 3 months, the new motor deficits had completely resolved in 2 (66.0 %) patients, and sensory deficits had significantly abated in 13 (56.5 %) patients. After 12 months, no more new motor deficits were observed, and sensory deficits had completely resolved in 16 (69.5 %) patients. However, 7 (7.7 %) patients developed new postoperative sensory deficits. The nerve root infiltrated by the tumor had to be removed in 59 (69.5 %) patients. Most of the schwannomas originated from the sensory roots (n = 58; 98.3 %), only in one patient the motor root was affected by the schwannoma (1.7 %). Out of the 59 patients of our study population in whom the infiltrated nerve root was resected, 19 patients developed a new neurological deficit (32.2 %) postoperatively, whereas only 6 patients (19.4 %) out of the 31 patients with unaffected nerve roots developed a new postoperative deficit ($p < 0.001$). In one patient (1.7 %), a rhizotomy was performed distal to the dorsal ganglion which caused refractory radicular pain, consecutively.

Out of the 90 patients in our study population, 44 patients (48.9 %) were operated with IOM and 46 (51.1 %) without IOM. A new neurological deficit was developed by 17/46 patients (37.0 %) who were operated without the use of IOM compared to 8/44 patients (18.2 %) operated with IOM ($p = 0.047$).

This effect was mainly seen in the subgroup of patients operated in the cervical spine (n = 18). While 3 of 5 patients (60 %) operated without IOM developed a new neurological deficit postoperatively,

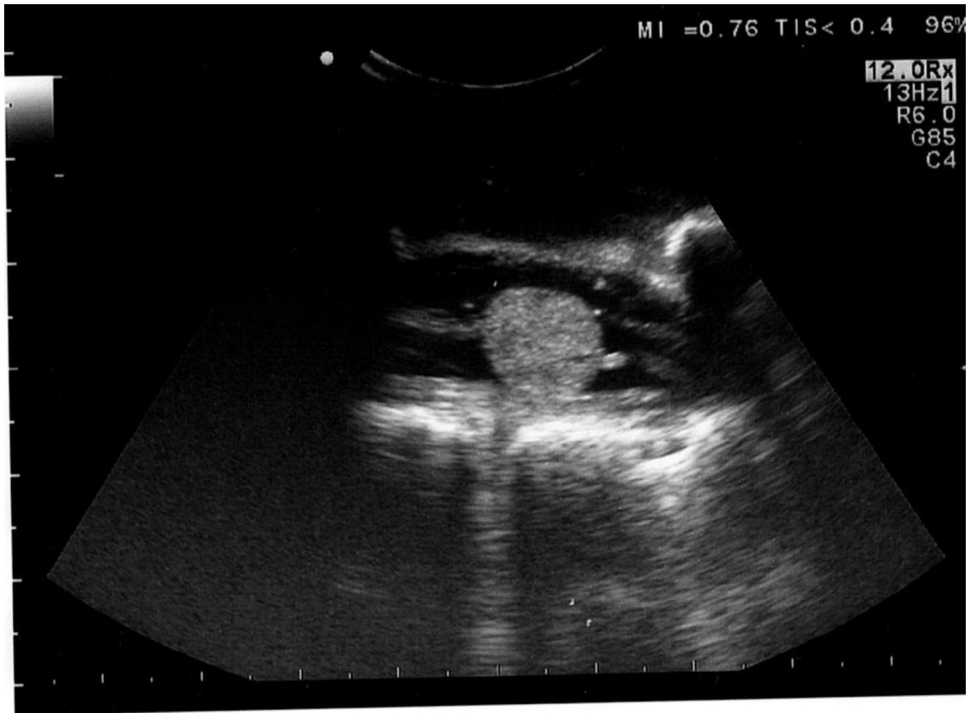

Fig. 2. Intraoperative ultrasound image of a patient with SS localized at Th12.

none was seen in the 13 patients (0 %) operated with IOM (p = 0.002).

Furthermore, those patients operated with IOM had a higher rate of improvement in the Frankel Score during follow-up at 12 months (p = 0.054, resp.).

5. Discussion

SS are important benign space-occupying lesions within the spinal canal. However, data on clinical presentation and surgical outcome are still lacking. The purpose of this study was to add more clinical knowledge about morphological and anatomical details, symptomatology, and the postoperative course of SS, including data on the influence of IOM on functional postoperative outcome.

The main findings of this study are the relatively high number of new neurological deficits after surgery, but these deficits had almost completely receded within 12 months. In addition, the use of IOM contributed to a significantly improved short-term outcome immediately after surgery as shown by the significantly improved JOA scores.

6. Epidemiology and preoperative clinical findings

In accordance with the literature, we found no significant differences between gender-related prevalence of SS, mean age in the 4th and 5th decade of life, and the majority of localizations of SS in the lumbar spine levels L1 to L4 [5–7,14].

Furthermore, up to 80 % of SS are reported to be intraspinal; approximately 15 % of SS extend through the dural aperture appear as a dumbbell mass with both intra- and extraspinal components [15,16]. These figures are also in line with our results of 84 % of intraspinal schwannomas and 27.8 % of dumbbell-shaped tumors. Intramedullary schwannoma has been rarely reported in the literature, and we also did not encounter any such case [5,16].

Analysis of surgical morbidity included only patients requiring revision surgery. The rate in our study was 7.7 %, which is comparable to the rate described in the current literature [5,17]. In contrast, Safaee et al. who also included new postoperative neurological deficits in their analysis of surgical morbidity reported a rate of > 30 % [16]. However, after 12-month follow-up, new postoperatively developed sensory deficits had persisted in only 7 (7.7 %) patients.

In summary, these findings, which are all in line with the recently reported series, show the representative status of our study population and validate the clinical symptomatology as well as the significant results concerning functional outcome within 12 months.

In our cohort, the most common symptoms were local back pain, radiating pain, sensory deficits, and motor deficits [18–20]. Vegetative deficits such as bowel and bladder dysfunction were rare. Clinical signs and symptoms led to hospital admission within 6 months after appearance, which is in line with the literature [19,20].

Local and radiating pain was mostly experienced at the site of the tumor, sometimes spreading to both limbs; pain was mostly transient but always in the same area. As supposed by some authors, initial local back pain is assumed to be caused by the disturbance of nerve conductivity because of direct or indirect irritation of the nerve root or root compression by the mass of the lesion [5]. With time, the enlarged mass leads to compression of the spinal cord and potentially affects cauda fibers, even in the case of slow tumor growth. As a late result, the integrity of the spinal column is disturbed, and myelopathy may develop. However, motor deficits rarely occur as an initial symptom, particularly in tumors in the lumbosacral region [15].

7. Extent of resection and functional outcome

We achieved complete removal of the targeted SS in 84 patients (93.3 %) and partial resection in 6 (6.7 %) patients. In the literature, rates of complete SS resection vary widely between 59 % and 95 % [5,16,21]. Total resection may be impeded for two reasons: adhesion of the tumor to the spinal cord and vulnerable nerve roots and structures directly attached to extraspinal structures such as the vertebral artery in the cervical region [15][5].

In the majority of our patients, nerve roots were removed because of tumor involvement (n = 59, 65.6 %). However, only 16 (27.1 %) patients had developed a new neurological deficit after surgery. Neurological deterioration after removal of the involved nerve roots is usually low and functionally well tolerated [22,23]. Thus, we refrained from a distinct statistical correlation of new postoperative deficits and nerve root removal in this study.

8. IOM

Neurological performance immediately after surgery differed significantly between patients operated on with and without IOM. Patients without IOM significantly more often developed new neurological deficits (p = 0.047), especially in the cervical spine (p = 0.002). In our view, the cervical roots are more sensitive and vulnerable due to their smaller diameter, and probably, utilization of IOM is protecting long fiber tracts.

Our findings are in contrast to the study of 46 consecutive cases of lumbar schwannoma by Kahramanet al. who did not report any additional motor deficits after surgery, regardless of the use of IOM [24].

In our series, 25 patients showed neurological deterioration immediately after surgery: new motor (n = 3) and new sensory deficits (n = 23). However, these new deficits had almost completely abated within 12 months.

9. Strengths and weaknesses

The study is limited by its retrospective character. Despite the rather large study population (n = 90), the low number of patients in the subgroups did not allow any distinct statistical analysis.

The study included a considerable number of patients with SS with complete clinical and radiographic data immediately after surgery as well as after 3 and 12 months. The surgical techniques did not vary during the study period.

10. Conclusion

Resection of SS with IOM significantly reduced local back pain as well as sensory and motor deficits. A large number of complete tumor resections, low surgical morbidity, and a high rate of functional recovery of new neurological deficits within 12 months support our conclusion that patients with SS should undergo surgery.

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CRediT authorship contribution statement

Christoph Hohenberger: Conceptualization, Methodology, Writing - original draft. **Julia Hinterleitner:** Data curation, Writing - original draft. **Nils-Ole Schmidt:** Supervision. **Christian Doenitz:** Software. **Florian Zeman:** Software, Formal analysis, Data curation. **Karl-Michael Schebesch:** Writing - review & editing, Supervision.

Declaration of Competing Interest

No conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.clineuro.2020.106127.

References

[1] H.H. Engelhard, J.L. Villano, K.R. Porter, A.K. Stewart, M. Barua, F.G. Barker, et al., Clinical presentation, histology, and treatment in 430 patients with primary tumors of the spinal cord, spinal meninges, or cauda equina, J. Neurosurg. Spine 13 (2010) 67–77 [Internet] [cited 2019 Nov 6] Available from: https://thejns.org/view/journals/j-neurosurg-spine/13/1/article-p67.xml.

[2] S. Safavi-Abbasi, M. Senoglu, N. Theodore, R.K. Workman, A. Gharabaghi, I. Feiz-Erfan, et al., Microsurgical management of spinal schwannomas: evaluation of 128 cases, J. Neurosurg. Spine 9 (2008) 40–47 [Internet] [cited 2019 Nov 6] Available from: http://www.ncbi.nlm.nih.gov/pubmed/18590409.

[3] S. Canbay, A.E. Hasturk, M. Basmaci, F. Erten, F. Harman, Management of thoracal and lumbar schwannomas using a unilateral approach without instability: an analysis of 15 cases, Asian Spine J. 6 (2012) 43–49 [Internet] [cited 2019 Nov 6] Available from: http://www.ncbi.nlm.nih.gov/pubmed/22439087.

[4] Factors Predicting Clinical Impairment after Surgery for Cervical Spinal Schwannoma [Internet]. [cited 2019 Nov 6]. Available from: http://www.lib.okayama-u.ac.jp/www/acta/pdf/67_6_343.pdf.

[5] J.H. Jeon, H.S. Hwang, J.H. Jeong, S.H. Park, J.G. Moon, C.H. Kim, Spinal schwannoma; analysis of 40 cases, J. Korean Neurosurg. Soc. 43 (2008) 135–138 [Internet] [cited 2019 Nov 6] Available from: http://www.ncbi.nlm.nih.gov/pubmed/19096620.

[6] S. Tish, G. Habboub, J. Jones, Q.T. Ostrom, C. Kruchko, J.S. Barnholtz-Sloan, et al., The epidemiology of central and extraventricular neurocytoma in the United States between 2006 and 2014, J. Neurooncol. 143 (May(1)) (2019) 123–127 Epub 2019 Mar 11.

[7] F. Zou, Y. Guan, J. Jiang, F. Lu, W. Chen, X. Xia, et al., Factors affecting postoperative neurological deficits after nerve root resection for the treatment of spinal intradural schwannomas, Spine (Phila Pa 1976) 41 (2016) 384–389 [Internet] [cited 2018 Nov 22] Available from: http://www.ncbi.nlm.nih.gov/pubmed/26919412.

[8] T. Jinnai, T. Koyama, Clinical characteristics of spinal nerve sheath tumors: analysis of 149 cases, Neurosurgery 56 (2005) 510–515 [Internet] [cited 2019 Nov 6] discussion 510-515. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15730576.

[9] L. Wu, T. Yang, X. Deng, C. Yang, L. Zhao, N. Yao, et al., Spinal extradural en plaque meningiomas: clinical features and long-term outcomes of 12 cases, J. Neurosurg. Spine 21 (2014) 892–898 [Internet] [cited 2019 Apr 5] Available from: http://www.ncbi.nlm.nih.gov/pubmed/25237843.

[10] A. Fujiwara, N. Kobayashi, K. Saiki, T. Kitagawa, K. Tamai, K. Saotome, Association of the Japanese orthopaedic association score with the oswestry disability index, Roland-Morris disability questionnaire, and short-form 36, Spine (Phila Pa 1976) 28 (14) (2003) 1601–1607 Jul 15.

[11] H.L. Frankel, D.O. Hancock, G. Hyslop, J. Melzak, L.S. Michaelis, Unger, et al., The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. I, Paraplegia 7 (1969) [Internet] [cited 2020 Jun 14] Available from: https://pubmed.ncbi.nlm.nih.gov/5360915/.

[12] G.A. Hawker, S. Mian, T. Kendzerska, M. French, Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP), Arthritis Care Res. 63 (2011).

[13] D.N. Louis, H. Ohgaki, O.D. Wiestler, W.K. Cavenee, P.C. Burger, A. Jouvet, et al., The 2007 WHO classification of tumours of the central nervous system, Acta Neuropathol. 114 (2007) 97–109 [Internet] [cited 2019 Nov 2] Available from: http://link.springer.com/10.1007/s00401-007-0243-4.

[14] Y.-I. Ohnishi, K. Iwatsuki, T. Ohkawa, K. Ninomiya, T. Moriwaki, T. Yoshimine, Differences between cervical schwannomas of the anterior and posterior nerve roots in relation to the incidence of postoperative radicular dysfunction, Asian Spine J. 9 (2015) 263–270 [Internet] [cited 2019 Nov 6] Available from: http://www.ncbi.nlm.nih.gov/pubmed/25901239.

[15] E. Emel, A. Abdallah, O.E. Sofuoglu, A.E. Ofluoglu, M. Gunes, B. Guler, et al., Long-term surgical treatment outcomes of spinal schwannomas: retrospective analysis of 49 consecutively operated cases, Turk. Neurosurg. 27 (2015) 217–225 [Internet] [cited 2018 Nov 22] Available from: http://www.ncbi.nlm.nih.gov/pubmed/27593781.

[16] M. Safaee, A.T. Parsa, N.M. Barbaro, P.V. Mummaneni, P.R. Weinstein, C.P. Ames, Association of tumor location, extent of resection, and neurofibromatosis status with clinical outcomes for 221 spinal nerve sheath tumors, Neurosurg. Focus 39 (2015), https://doi.org/10.3171/2015.5.FOCUS15183 [Internet] [cited 2020 Mar 6] Available from:.

[17] K. Yamada, Y. Abe, S. Satoh, Y. Yanagibashi, T. Hyakumachi, T. Masuda, Large increase in blood pressure after extubation and high body mass index elevate the risk of spinal epidural hematoma after spinal surgery, Spine (Phila Pa 1976) 40 (2015) 1046–1052 [Internet] [cited 2018 Jan 13] Available from: http://www.ncbi.nlm.nih.gov/pubmed/25768686.

[18] K. Ando, S. Imagama, Z. Ito, K. Kobayashi, H. Yagi, T. Hida, et al., How do spinal schwannomas progress? The natural progression of spinal schwannomas on MRI, J. Neurosurg. Spine 24 (2016) 155–159 [Internet] [cited 2020 Feb 27] Available from: http://www.ncbi.nlm.nih.gov/pubmed/26431071.

[19] H. Li, Y. Weng, D. Zhou, L. Nong, N. Xu, Experience of operative treatment in 27 patients with intraspinal neurilemmoma, Oncol. Lett. 14 (2017) 4817–4821 [Internet] [cited 2018 Nov 22] Available from: http://www.ncbi.nlm.nih.gov/pubmed/29085485.

[20] P. Celli, G. Trillò, L. Ferrante, Spinal extradural schwannoma, J. Neurosurg. Spine 2 (2005) 447–456 [Internet] [cited 2020 Mar 5] Available from: http://www.ncbi.nlm.nih.gov/pubmed/15871485.

[21] M. Sowash, O. Barzilai, S. Kahn, L. McLaughlin, P. Boland, M.H. Bilsky, et al., Clinical outcomes following resection of giant spinal schwannomas: a case series of 32 patients, J. Neurosurg. Spine 26 (2017) 494–500 [Internet] [cited 2020 Mar 6] Available from: http://www.ncbi.nlm.nih.gov/pubmed/28084933.

[22] M.T. Seppälä, M.J.J. Haltia, R.J. Sankila, J.E. Jääskeläinen, O. Heiskanen, Long-term outcome after removal of spinal neurofibroma, J. Neurosurg. 82 (1995) 572–577 [Internet] [cited 2019 Nov 6] Available from: http://www.ncbi.nlm.nih.gov/pubmed/7897516.

[23] S.H. Yoon, C.K. Chung, T.A. Jahng, Surgical outcome of spinal canal meningiomas, J. Korean Neurosurg. Soc. 42 (2007) 300 [Internet] [cited 2019 Apr 5] Available from: http://www.ncbi.nlm.nih.gov/pubmed/19096560.

[24] S. Kahraman, S. Gocmen, M.H. Alpsan Gokmen, G. Acka, S. Pusat, Intraoperative neurophysiologic monitoring for lumbar intradural schwannomas: does it affect clinical outcome? World Neurosurg. 124 (2019) e789–92 [Internet] [cited 2020 Feb 27] Available from: http://www.ncbi.nlm.nih.gov/pubmed/30684697.