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Original Article

Factors Predicting Clinical Impairment after Surgery for Cervical Spinal Schwannoma

Kentaro Yamane*, Tomoyuki Takigawa, Masato Tanaka, Syuhei Osaki, Yoshihisa Sugimoto, and Toshifumi Ozaki

Department of Orthopaedic Surgery, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama 700-8558, Japan

Cervical spinal schwannoma is benign, and outcomes after surgical resection are generally excellent. A surgical dilemma sometimes arises as to whether to perform total tumor removal, which carries a risk of sacrificing the nerve root, or subtotal removal, where the risk can be tumor recurrence. The purpose of this study was to identify factors with the potential to predict clinical impairment after surgery for cervical spinal schwannomas. Thirty cases of cervical schwannomas treated surgically in our institute were retrospectively reviewed; initial symptoms, tumor location, Eden classification, surgical method, functional outcome, and tumor recurrence were investigated. All permanent motor deficits were the result of resecting functionally relevant nerve roots (*i.e.*, C5-8). The rate of permanent sensory deficit was 11% after C1-4 nerve root resection, and 67% after C5-8 nerve root resection. Permanent neurological deficits occurred in 14% of patients younger than 40 years and 38% of those older than 40. Dumbbell tumors were associated with the need for total or ventral nerve root transection, as well as with a high incidence of tumor recurrence. The incidence of permanent neurological deficit was significantly higher in patients undergoing C5-8 nerve root resection, and tended to be higher in those over 40.

Key words: cervical spinal schwannoma, neurological deficit, nerve root resection, tumor resection, tumor recurrence

Schwannomas are the most frequently diagnosed benign spinal tumor. Total excision of such tumors requires resection of tumor-involved nerve roots, as schwannomas are composed of neoplastic Schwann cells that wrap around the neuron. On the other hand, subtotal tumor excision may result in tumor regrowth and reoperation. Thus, careful consideration must be given to whether a tumor can be removed totally, with or without the necessity of resecting the relevant nerve root. Because schwannomas often grow slowly, clinical recurrence is rare, even after subtotal removal of the tumor [1, 2]. Furthermore, the incidence of neurological deficit is low, even if the affected nerve root is transected to achieve total removal [3-6]. As a result, the optimal manner in which to extract cervical spinal schwannomas and treat nerve roots remains controversial. The choice of therapeutic strategy requires consideration of the level of the nerve root, the shape of tumor and the residual function. The present study was conducted to identify factors that can help predict postoperative clinical impairment in patients undergoing

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*Corresponding author. Phone:+81-86-235-7273; Fax:+81-86-223-9727
E-mail:kentaro0311@do7.enjoy.ne.jp (K. Yamane)

surgical management of cervical spinal schwannomas.

Patients and Methods

Between 1966 and 2011, 116 spinal schwannomas were treated surgically in Okayama University Hospital. Of these cases, 30 tumors located in the cervical level were included in this study. Two patients with neurofibromatosis type 1 and 1 with neurofibromatosis type 2 were excluded. The mean patient age was 48 years (range, 14–77 years), and the mean follow-up period was 39 months (range, 5–240 months). Patients included 18 males and 12 females. Twelve patients who underwent surgery before 1985 were diagnosed by x-rays and myelographs of the cervical spine. Magnetic resonance imaging (MRI) was used for diagnosis and follow-up in the 18 patients who underwent surgery after 1985. All tumors were pathologically confirmed to be schwannoma. Factors retrospectively investigated for these cases included: initial symptoms, tumor location, Eden classification [7], surgical method, functional outcome, and tumor recurrence. Motor and sensory deficits were assessed as functional outcomes. For motor deficits, manual muscle testing (MMT) 4 was defined as a mild deficit, and MMT 3 or less was defined as a severe deficit.

In our institute, total tumor removal was pursued when a tumor was confined to the spinal canal or proximal to the neural foramen. Subtotal removal was the chosen approach when a tumor extended far beyond the neural foramen and was accompanied by risk of vertebral artery injury. Nerve roots were transected when a tumor was too large to remove or debulk without further compressing the spinal cord.

Statistical analyses were performed using Fisher's exact test for comparing 2 groups; $p < 0.05$ was considered statistically significant.

Results

Initial symptoms. The most common initial manifestations were radicular symptoms (47%), followed by neck pain (33%), and gait disturbance due to myelopathy (13%); a small number of cases (3%) were asymptomatic.

Tumor location. One tumor was intramedullary (3%), 12 were intradural-extramedullary (40%), 8 were intradural-extradural (27%) and 9 were purely extradural (30%). The level of tumor-involved roots was C2 in 2 patients, C3 in 6 patients, C4 in 5 patients, C5 in 10 patients, C6 in 1 patient, C7 in 2 patients and C8 in 4 patients.

Eden classification. There were 18 dumbbell tumors (60%) in our series. Based on the Eden classification, 9 patients were diagnosed as type 2, 6 as type 3, and 3 as type 4.

Surgical method. The posterior approach was used in 28 patients (93%) and the anterior approach in 2 (7%). In the posterior approach, laminectomy was applied in 10 patients (36%) and laminoplasty in 18 (64%). No spinal instrumentations were utilized in this series. Twenty-two tumor-involved nerve roots were transected in 20 patients. Three nerve roots were transected in 1 patient because the tumor was too large to remove. The relationship between the transected nerve roots and level is shown in Fig. 1. Total removal was achieved in 16 patients (53%), and subtotal removal in 14 (47%). Only 4 of 18 patients with dumbbell tumors had total removal; in the remaining 14, tumor removal was subtotal. All patients with non-dumbbell tumors, however, achieved total tumor removal (Table 1). Of 20 patients who underwent nerve root transections, total removal of tumor was achieved in 11, and subtotal removal in 9 (Table 1).

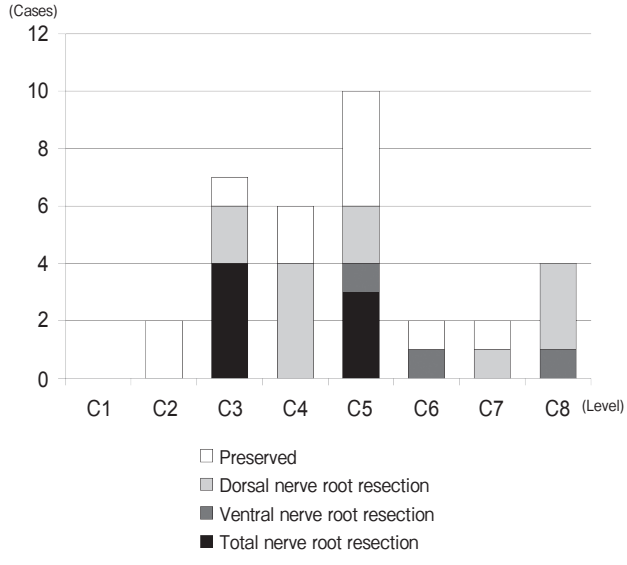

Fig. 1 Distribution of the level and surgical strategy used to manage the nerve root.

Table 1 Relationship between the shape of tumors (non-dumbbell or dumbbell), nerve root transection and the method of tumor removal

	Number of cases	Total removal		Subtotal removal	
Non-dumbbell tumors	12	12	(100%)	0	
Nerve root transection	9	9	(100%)	0	
Dumbbell tumors	18	4	(22%)	14	(78%)
Nerve root transection	11*	2*	(18%)	9	(82%)

*Including one case that required reoperation

Functional outcomes. Functional outcome after surgery is shown in Fig. 2. Of the 20 patients that underwent nerve root resection, 9 showed neurological deficits after surgery. At the final follow up, 2 of the 9 had improved, while the remaining 7 patients had permanent neurological deficits. Of these 7 patients, 2 experienced both motor and sensory deficits, while 5 had only sensory deficits. Both patients with permanent motor deficit underwent resection of the C5 nerve root. Among patients with permanent sensory deficit, the level of the resected nerve root was C4 in 1 patient, C5 in 2 patients, C7 in 1 patient and C8 in 3 patients. The rate of permanent sensory deficit was 11% after C1–4 nerve root resection, and 67% after C5–8 nerve root resection ($p < 0.05$). Permanent neurological deficit occurred in 14% of those younger than 40 years, and in 38% of those older than 40 ($p > 0.05$).

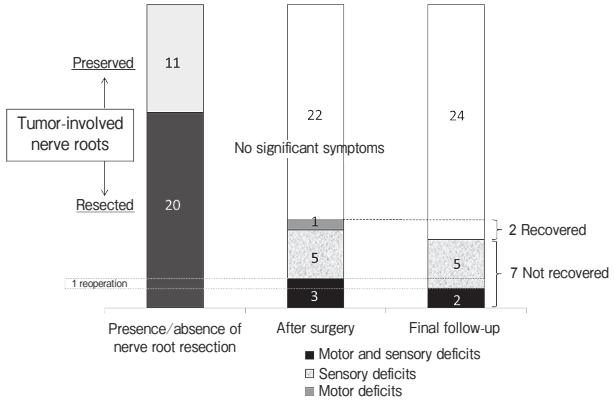

Fig. 2 Tumor-involved nerve roots were transected in 20 cases (left). Immediately after surgery, 1 case had motor deficit, 5 cases had sensory deficit and 3 exhibited both sensory and motor deficits (middle). Two cases recovered, but 7 cases showed persistent symptoms (right).

Tumor recurrence. Eighteen patients received postoperative MRI to assess for tumor recurrence. Tumor recurrence was identified in only 1 of 10 cases in which total tumor removal was achieved. Tumor enlargement was identified in 2 of 8 cases in which subtotal tumor removal was performed. One patient who initially received subtotal tumor resection required reoperation 39 months later due to worsening clinical symptoms.

Case Reports

Case 1. A 58-year-old man presented with right-hand clumsiness and gait disturbance. MRI revealed a dumbbell tumor originating from the C7 foramen (Fig. 3). Eden classification was type 2. Neurological examination revealed mild motor deficits and numbness in both distal upper extremities. The C7 dorsal nerve root was transected to achieve removal of the tumor (Fig. 4). A subtotal removal of the tumor was conducted. After the operation, the patient had anesthesia of the C7 dermatomes. There was no enlargement of the residual tumor at follow-up (Fig. 5); the sensory deficits, however, persisted.

Case 2. A 25-year-old woman developed progressive right-hand clumsiness. MRI revealed a large dumbbell tumor originating from the C5 foramen. Eden classification was type 2. Neurological examination revealed severe weakness of the right biceps, triceps, wrist extensors and wrist flexors. The tumor extended to multiple vertebral segments. The C3, C4 and C5 dorsal nerve roots and C6 ventral nerve root were transected to achieve subtotal removal of the tumor. Postoperatively, numbness in C3 and C4 dermatomes was detected, but no motor deficit was observed. Six months after surgery, the patient's preoperative motor deficits had improved. Thirty-six

months after surgery, she complained of neck pain and numbness in the right arm. Reoperation was performed because of the enlargement of the tumor. The C5 ventral nerve root was transected to achieve total removal of the tumor. Although severe weakness of the right biceps was observed after reoperation, it resolved during follow-up.

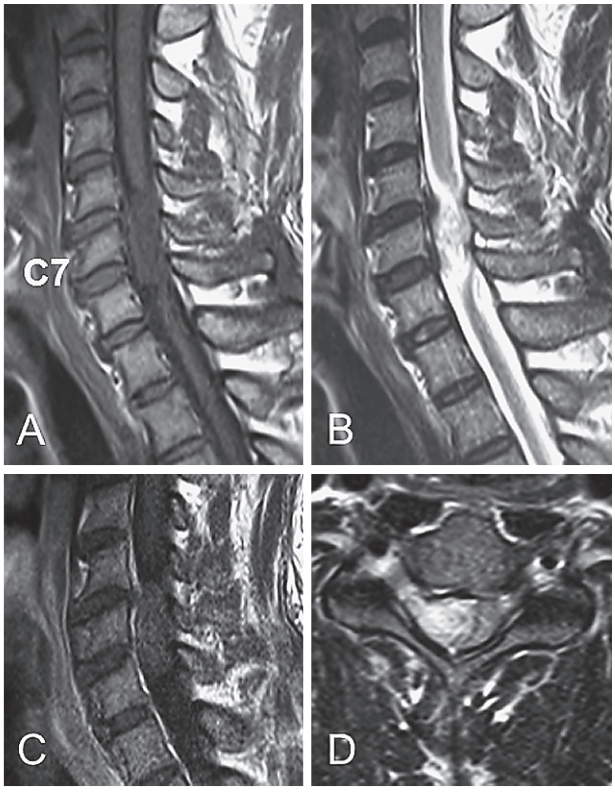

Fig. 3 T1-weighted (A) sagittal MRI showing homogeneous low signal intensity within the spinal canal at C7, and T2-weighted (B) (D) MRI showing high signal intensity. Postcontrast T1-weighted MRI (C) showing a poorly enhanced tumor.

Discussion

Postoperative neurological deficits and reoperation for tumor recurrence are suboptimal outcomes in surgery for cervical spinal schwannomas that adversely affect quality of life. While the incidence of neurological impairment is extremely low when nerve roots

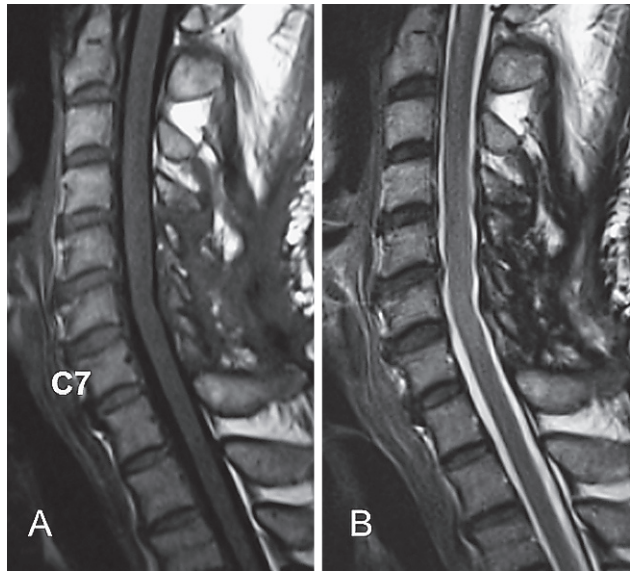

Fig. 5 T1-weighted (A) and T2-weighted (B) sagittal MRIs 1 year postoperatively, documenting no enlargement of the residual tumor.

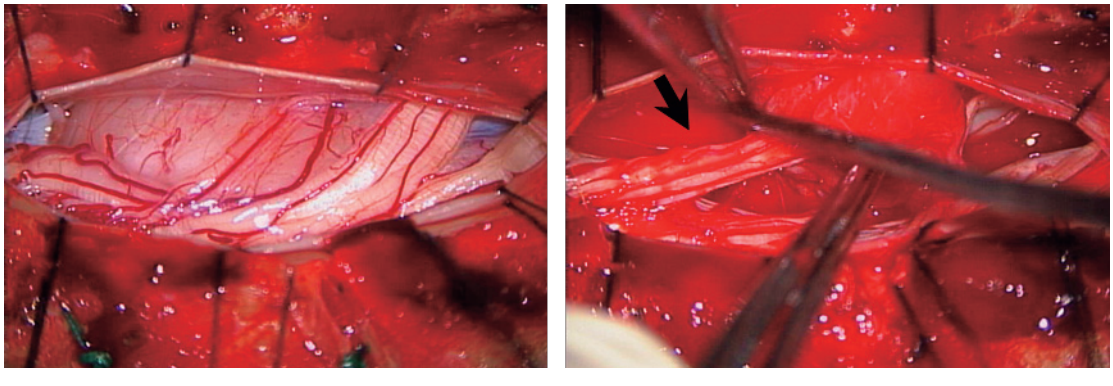

Fig. 4 Left, Intraoperative photograph showing a schwannoma within the spinal canal at C7 and pressing on the spinal cord laterally; Right, The C7 dorsal nerve root (black arrow) was transected to achieve removal of the tumor.

are preserved, resection of nerve roots can lead to neurological deficits. In previous reports [3–5, 8, 9], risk factors for neurological deficits after resection of tumors involving the nerve root seem to include functionally relevant nerve roots (C5–8), age (> 40 years) and tumor type (dumbbell). Dumbbell tumors were also associated with subtotal tumor removal and a risk of tumor recurrence.

The incidence of significant neurological deficits after resecting tumor-involved nerve roots is low, because the involved nerve root is already nonfunctional and adjacent roots have thus already begun to compensate [4, 10, 11]. Miura *et al.* described 15 patients with cervical spinal neurinomas who underwent resection of the affected nerve root in C5–8. Immediately after surgery, worsening of motor function was observed in 10 of 15 patients. At final follow-up, all but 2 patients exhibited improvement; the 2 exceptions had mild deficits [5]. Among a total of 15 patients who underwent total transections of nerve roots with cervical schwannomas, Celli described 2 patients who developed mild motor weakness, and another 2 who developed severe weakness [3]. A review of the relevant literature suggests that the permanent motor deficit rate after resecting tumor-involved nerve roots ranges from 0 to 33% [4, 6, 8]. In the present study, 6 patients underwent transection of total roots or ventral nerve roots in C5–8. Immediately after surgery, 4 had motor deficits. At the final follow-up, 2 patients had recovered, 1 showed mild motor deficit, and the other had severe deficits (Table 2).

In terms of sensory deficits, Miura *et al.* reported that 8 of 14 patients showed sensory deficits after surgery; 2 of those 8 recovered [5], while the other 6 remained symptomatic (40%). In the present study, 7 of 18 patients (39%) in whom the dorsal nerve roots were transected developed permanent sensory deficits. Moreover, continuous sensory deficits related to C5–8 nerve roots were significantly more frequent than those related to C1–4 ($p < 0.05$). The distribution of dermatomes may affect this frequency. In other words, the sensory impairments of C5–8 may have been detected at a higher rate because the dermatomes of C5–8 distribute to the upper extremities (Table 3).

The risk of developing persistent deficits after resection of tumor-involved nerve roots may vary with age [3–5]. Kim *et al.* reported that only 1 of 10 patients younger than 40 years (10%) developed permanent neurological deficits, while 6 of 21 older than 40 years (29%) did so [4]. Miura *et al.* also reported that permanent deficits were found in only 1 of 6 patients younger than 40 (17%), but were present in 7 of 9 patients older than 40 (78%) [5]. Although not statistically significant in our series, older patients (> 40 years) had a higher incidence of permanent neurological deficit, consistent with previous reports. Furthermore, permanent neurological deficit occurred in 14% of younger patients (< 40 years) and in 38% of older patients (> 40 years) (Table 4). The patient designated here as Case 1 was 58 years old. After a resection of dorsal nerve roots, he developed permanent sensory deficits. In contrast, the patient designated as Case 2, a 25-year-old female, underwent reoperation because of clinical recurrence. She showed neurological deficits after both the first and the second surgeries, but recovered during follow-up. It is possible that in comparison to older patients, younger

Table 2 Data from published reports regarding motor deficits at follow-up after resection of functionally important roots

Authors & Year	Total/ventral root resection	Number of cases	No deficits	Temporary deficits	Continuous deficits	
Kim *et al.*, 1989	C5–T1	14	11	3	0	0%
Miura *et al.*, 1998	C5–C8	15	3	7	5	33%
Celli, 2001	C5–C8	15	11*		4	27%
Nakamura *et al.*, 2012	C5–C8	25	8	11	6	24%
Present study	C5–C8	6	2	2	2	33%
	(Dumbbell tumor)	(5)	(1)	(2)	(2)	(40%)

*Number of no/temporary deficits cases was not described.

Table 3 Data from published reports regarding sensory deficit at follow-up after resection of roots

Authors & Year	Total/dorsal root resection	Number of cases	No deficits	Temporary deficits	Continuous deficits	
Kim *et al*., 1989	C5–T1	14	11	3	0	0%
Miura *et al*., 1998	C5–C8	15	7	2	6	40%
Nakamura *et al*., 2012	C1–C8	75	50	19	6	8%
Present study	C1–C4	9	7	1	1	11%
	(Dumbbell tumor)	(6)	(5)	(1)	(0)	(0%)
	C5–C8	9	2	0	6	67%
	(Dumbbell tumor)	(5)	(1)	(0)	(4)	(80%)

Table 4 Data from published reports regarding the correlation between patient age and neurological deficits after resection of roots

Authors & Year	Age	Number of cases	Continuous neurological deficits	
Kim *et al*., 1989	<40 years	10	1	10%
	>40 years	21	6	29%
Miura *et al*., 1998	<40 years	6	1	17%
	>40 years	9	7	78%
Celli, 2001	<40 years	22	0	
	>40 years		2 (Severe muscle weakness)	
Present study	<40 years	7	1	14%
	>40 years	13	5	38%

patients have more compensatory neurologic function mediated by adjacent roots. Thus, careful attention should be given to older patients when transecting nerve roots.

Subtotal removal of the tumor is a risk factor for tumor recurrence [3, 9]. When removing dumbbell tumors, it is important to take into account the method of removing the tumor and its relationship to postoperative neurological deficits. For example, tumor-related symptoms often persist when the spinal cord is insufficiently decompressed. This is why total removal is optimal in the case of non-dumbbell tumors. In the present study, total removal was completed in non-dumbbell tumors only by the posterior approach. None of the patients who underwent total tumor removal required reoperation. On the other hand, the issue of how to manage extradural components in patients with dumbbell tumors can be complex. Optimally, total tumor removal is achieved with a single approach, but single-approach surgery could restrict the surgical field and result in subtotal removal. In our series, we applied a single posterior approach, which allowed wide exposure of the spinal canal but was rather limited in terms of the extraforaminal region. Seppala *et al.* described 187 patients who were treated for spinal schwannoma [12]. Of 20 patients who received subtotal removal, 9 did not experience clinical recurrence after a median follow-up of 19 years. Only 2 of 11 patients developed radiologic recurrence and underwent reoperation. In the present study, 14 of 18 patients with dumbbell tumors underwent subtotal removal, and only one of those (7.1%) required reoperation due to clinical recurrence. Meanwhile, Schick *et al.* reported that 4 of 65 patients (6.2%) who had total removal of spinal schwannomas required reoperations due to recurrence. Our reoperation rate (7.1%) corresponded to that described in previous reports [9]. These data indicate that clinical recurrence is rare, even in the context of subtotal removal of the tumor, because

schwannomas often grow slowly [1, 2].

Few reports have described management of the nerve root in patients with dumbbell tumors. Sacrifice of the entire motor and sensory root may be required when the tumor extends throughout the root sleeve, distal to the dorsal root ganglion [13, 14]. It was for this reason that patients with dumbbell tumors in the present study required total or ventral transection of the nerve root. Five of 6 patients who had total or ventral transection of roots in C5–8 had dumbbell tumors (Table 2). Dumbbell tumors often require total or ventral nerve root transection, which leads to an increased risk of postoperative motor deficits.

Useful ways to predict the development of postoperative neurological deficits include preoperative EMG or intraoperative direct stimulation of exposed nerve roots [3, 4, 15–17]. In this series, only a few patients received both preoperative EMG and intraoperative direct stimulation, and thus we did not have adequate data for a discussion of postoperative deficits.

This study has several limitations. First, the number of patients was relatively small. Second, some cases were so old that they could only be reviewed by referring to medical records. Despite these limitations, we believe that this study has important significance for clinical practice.

In conclusion, this study investigated risk factors for postoperative clinical impairment in patients undergoing surgery for cervical spinal schwannomas. Functionally relevant nerve roots (C5–8) are a risk factor for the development of both motor and sensory deficit after resection of nerve roots; furthermore, age > 40 years tends to be a risk factor for the development of neurological deficits after resection of nerve roots. Finally, the dumbbell tumor is associated with a high requirement of total or ventral nerve root transection and a high incidence of tumor recurrence.

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