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Risk Factors for Recurrence of Surgically Treated Conventional Spinal Schwannomas: Analysis of 169 Patients from a Multicenter International Database

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Abstract

Study Design—Retrospective analysis of 169 adult patients operated for a conventional spinal schwannoma from the AOSpine Multicenter Primary Spinal Tumors Database.

Objective—To identify risk factors for local recurrence of conventional spinal schwannoma in patients who had surgery.

Summary of Background Data—Schwannomas account for up to 30% of all adult spinal tumors. Total resection is the gold standard for patients with sensory or motor deficits. Local recurrence is reported to be approximately 5% and usually occurs several years after surgery.

Methods—Rates and time of local recurrence of spinal schwannoma were quantified. Predictive value of various clinical factors was assessed, including age, gender, tumor size, affected spinal segment, and type of surgery. Descriptive statistics and univariate regression analyses were performed.

Results—Nine (5.32%) out the 169 patients in this study experienced local recurrence approximately 1.7 years post-operatively. Univariate analyses revealed that recurrence tended to occur more often in younger patients (39.33 ± 14.58 years versus 47.01 ± 15.29 years) and in the lumbar segment (55.56%), although this did not reach significance ($HR=0.96$, $p = 0.127$; and $p = 0.195$, respectively). Recurrence also arose in the cervical and sacral spine (22.22%, respectively) but not in the thoracic area. Tumors were significantly larger in patients with recurrence (6.97 ± 4.66 cm versus 3.81 ± 3.34 cm), with extent in the cranial-caudal direction posing the greatest hazard ($HR=1.321$, $p = 0.002$). The location of the tumor, whether epidural, intradural, or both ($p = 0.246$) was not significantly related to recurrence. Regarding surgical technique, over four times as many patients who underwent intralesional resection experienced a recurrence proportionally to patients who underwent *en bloc* resection ($HR = 4.178$, $p = 0.033$).

Conclusions—The pre-operative size of the conventional spinal schwannoma and intralesional resection are the main risk factors for local post-operative recurrence.

Keywords

conventional spinal schwannoma; recurrence; risk factors; surgery

Introduction

Peripheral nerve sheath tumors comprise a myriad of clinicopathologic entities. Neoplastic proliferations involving Schwann cell differentiation characterize the three main types: schwannomas (previously called neurilemmomas or neurinomas), neurofibromas, and malignant peripheral nerve sheath tumors (MPNSTs).¹ Typically, schwannomas grow as a peripheral appendage to the parent nerve.¹⁻⁵ They rarely contain cellular elements (e.g. axons) other than neoplastic Schwann cells.^{2,5} Conventional schwannomas are the most common of the four major clinicopathologic and immunohistochemical variants of schwannomas in adults. They are most often associated with the vestibular branch of cranial nerve VIII or the spinal nerves.²⁻⁴

Conventional spinal schwannomas are generally solitary, firm, oval, or lobulated encapsulated benign tumors arising from the sensory (dorsal) nerve root. They can be found anywhere along the spinal canal.³⁻⁵ Multiple schwannomas are associated with Neurofibromatosis type 2 (NF-2) and schwannomatosis.³⁻⁵ In addition, the incidence and recurrence rate of spinal schwannomas tend to be higher in NF-2 patients.^{3,6} Intradural, extramedullary schwannomas are the most common (49-83%), followed by extradural (7-27%) and transdural (1-19%), i.e. a tumor that extends through the dural root sleeve, having both intradural and extradural components. Intramedullary schwannomas are quite rare, representing less than 1% of cases.^{4,5,7-9}

Schwannomas are usually slow-growing benign tumors and initially cause non-specific symptoms such as segmental pain and paresthesia. These tumors gradually progress and can ultimately lead to some degree of paresis and myelopathy if they expand and compress the neural elements.⁵⁻⁸ They are most frequently diagnosed in the fourth through sixth decade of life.^{5,6}

Surgical treatment, in the form of decompression with or without instrumentation, should be considered in patients with initial signs of sensory and motor deficits or radiological evidence of a tumor that is enlarging. Total resection is the surgical gold standard for spinal schwannomas as it is associated with minimal morbidity and results in symptom improvement, especially in patients with few pre-operative clinical findings.^{5-7,10} However, when the tumor is in close proximity to important neural or vascular structures, total resection may not be safe despite the use of microsurgical dissection and intraoperative neurophysiological monitoring.

Recurrence of conventional spinal schwannomas is reported in less than 5% of surgical patients. Tumor recurrence typically occurs several years after initial surgical resection and appears to be associated with subtotal tumor removal.^{5,11,12} Although several surgical series have discussed recurrence, very few have reported on risk factors for the recurrence of conventional spinal schwannomas located throughout different spinal segments. This study aims to identify pre-operative clinical factors as well as surgical features associated with local recurrence of conventional spinal schwannomas following surgical resection.

Methods

We retrospectively analyzed data from 169 adult patients who underwent surgery for a single conventional spinal schwannoma confirmed by histopathological examination. Patient data was extracted from the AOSpine Multicenter Primary Spinal Tumors Database, which includes approximately 1,500 patients treated between 1981 and 2012 at 13 spine centers across North America, Europe and Asia Pacific.¹³ Collected data included demographic, diagnostic, and therapeutic information as well as local recurrence, perioperative morbidity and cross-sectional survival data. Recurrence was defined as local tumor reappearance after the definitive surgical procedure on a post-operative MRI.

The tumor size was objectively quantified by measuring its length, in centimeters, in the anterior-posterior, left-right and cranial-caudal directions. The largest of these three dimensions for each patient was taken as the size of the tumor and was analyzed separately. The surgical variable included was the surgeon's assessment of the procedure: palliative, intralesional, or en bloc. A palliative procedure referred to a limited decompression or stabilization without any oncologic intent. An intralesional resection implicated the violation of the tumor capsule, i.e. piecemeal resection, whereas en-bloc resection intended a circumferential isolation of the tumor, without violating its borders or capsule. Surgeons were given seven options to describe the type of surgery they performed: (1) palliative; (2) intralesional subtotal resection; (3) intralesional gross total resection; (4) en bloc: wide with focal intralesional transgression; (5) en bloc: wide with marginal margin – the plane of

dissection was along the reactive zone; (6) en bloc: wide with wide margin – the plane of dissection was peripheral to the reactive zone through normal tissue; and (7) unknown.

Missing data were assumed to be missing at random; Table 1 shows the sample size for each variable. Kaplan-Meier curves were plotted for categorical variables and log-rank tests were conducted to assess significance. Univariate regression analyses for continuous variables were also performed to compute hazard ratios, 95% confidence intervals and p-values. Statistical significance was defined as a p-value < 0.05. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

Results

Patient Sample

Our cohort consisted of 88 men and 81 women, with ages ranging from 18 to 84 years (mean: 46.60 ± 15.31 years). Unfortunately, the Neurofibromatosis status was not available. The average duration of symptoms before surgery was 1.70 ± 3.11 years and ranged from 17 days to 16.16 years. The majority of patients complained of pain (148 patients, 88.62%) and 33 patients (27.97%) had signs and symptoms of myelopathy at presentation. The schwannoma was most often adjacent to one (60 patients, 35.50%) or two (87 patients, 51.48%) vertebral bodies (mean: 1.85 ± 0.86 ; median: 2 vertebral bodies). However, in 19 patients (13.02%), the lesion spanned three or more adjacent levels. The most common regions of involvement were the lumbar spine (70 patients, 41.42%), followed by thoracic (41 patients, 24.26%), sacral (20 patients, 11.83%), and cervical segments (15 patients, 8.88%). The remaining 23 patients (13.62%) presented with a lesion at the cervico-thoracic (4 patients, 2.37%), thoracolumbar (10 patients, 5.92%) and lumbosacral (9 patients, 5.33%) junctions. In total, 140 patients (82.84%) had involvement in mobile and 29 (17.16%) in fixed segments of the spine. On average, the tumor was larger anterior-posteriorly (3.41 ± 3.07 cm) than in the cranial-caudal (2.82 ± 2.91 cm) or left-right (2.85 ± 2.57 cm) directions (Table 1).

All 169 patients were treated surgically and the majority were approached posteriorly (116 patients, 68.64%). Two patients (1.68%) underwent palliative surgery, while 83 (69.75%) had en bloc and 34 (28.57%) intralesional resection, for which 30 (17.75%) underwent gross total resection and 4 (2.37%) subtotal resection. Among patients who had en bloc surgery, 68 (40.24%) were qualified wide with wide margin, 11 (6.51%) were wide with marginal margin, and four (2.37%) were wide with focal intralesional margin. The dural location was extradural in 22 patients (20.95%), intradural in 50 patients (47.62%), and both intra- and extradural in 33 patients (31.43%). Nine patients (5.32%) experienced local recurrence of the tumor at an average time of 1.7 ± 1.22 years post-operatively (Table 1).

Risk factors

Patients with local tumor recurrence were on average younger (39.33 ± 14.58 years) than those without recurrence (47.01 ± 15.29 years), although this difference did not reach statistical significance (HR: 0.964, 95% C.I.: 0.919-1.011, $p = 0.127$). Gender and duration of symptoms were not significant risk factors for tumor recurrence (Table 2).

The most common segments of recurrence were in the lumbar spine (5 patients, 55.56%), followed by the cervical (2 patients, 22.22%) and sacral spine (2 patients, 22.22%). However, two out of the 15 patients (13.33%) with a cervical schwannoma experienced a recurrence whereas two out of the 20 patients (10.00%) and five out of the 70 patients (7.14%) of those with tumors in the sacral and lumbar spine respectively experienced a recurrence. There was no recurrence among patients with a cervico-thoracic, thoracic, thoraco-lumbar, or lumbo-sacral schwannoma (Table 1). When compared to the thoracic spine, tumors in sacral ($p = 0.0375$, log-rank test) and cervical ($p = 0.0167$, log-rank test) segments were more likely to recur. There were no significant differences in the risk of recurrence between patients with lesions in the cervical, sacral and lumbar spine. In addition, patients with tumors located in mobile segments were not at a higher risk than patients with tumors in fixed segments (HR: 1.491, 95% C.I.: 0.309-7.190, $p = 0.616$).

Key predictors of recurrence were variables related to the extent of the tumor. The size of the tumor was also significantly larger (6.97 ± 4.66 cm) in patients with recurrence than in those whose tumors did not recur (3.81 ± 3.34 cm) (Table 1), with larger cranial-caudal measurements posing the greatest hazard (HR: 1.321, 95% C.I.: 1.107-1.576, $p = 0.0021$) (Table 2). For every 1 cm increase in tumor size, a patient's hazard for recurrence increased by 15.7% (HR: 1.157, 95% C.I.: 1.016-1.319, $p = 0.0282$). Not surprisingly, patients with additional level involvement were 2.228 (95% C.I.: 1.223-4.057, $p = 0.0088$) times more likely to experience recurrence. However, the dural location of the tumor, whether epidural, intradural or both, was not a significant risk factors for disease recurrence ($p = 0.2463$) (Table 2).

Overall, there was no significant difference among the two intralesional and the three en bloc techniques (log-rank test, $p = 0.086$). However, surgical intervention in terms of en bloc versus intralesional procedures was a significant risk factor. Five of the eight patients with recurrence (62.50%) had an intralesional resection of the tumor (Table 2). Compared to en bloc resection, patients with an intralesional resection were at a 4.178 (95% C.I.: 0.998-17.491) times greater risk of recurrence ($p = 0.0333$, log-rank test) (Table 2).

Discussion

Conventional spinal schwannomas are benign tumors that can cause pain and significant neurological deficits due to displacement/compression of the parent peripheral spinal nerve and/or neighboring neural elements located within or in the vicinity of the spinal canal. The rates of tumor recurrence following surgical resection have been reported as 4 to 6% in previous surgical series.^{7,8,14} Despite these low rates, it is valuable to determine important predictors of local recurrence to help clinicians identify high-risk patients and encourage surgeons to routinely monitor these patients for clinical signs and symptoms, as well as radiological evidence of recurrence. In our study, the rate of recurrence was 5.32% and patients with tumor recurrence tended to be younger. Most conventional spinal schwannomas occurred in the lumbar spine; however, when location of the initial lesion was examined, there was a greater recurrence in cervical and sacral segments. In fact, two out of fifteen (13.33%) cervical and two out of twenty sacral schwannomas recurred whereas only five out of 70 (7.14%) patients with a lumbar tumor experienced recurrence. In addition,

univariate analyses showed that the major predictors of recurrence were an increased number of vertebral levels, larger overall tumor size, a greater measurement in the cranial-caudal direction, and an intralesional resection.

In other similar surgical series, recurrence was associated with malignant histopathology,^{8,15} subtotal resection,^{7,8,10,15} and gross total resection.¹⁴ Unfortunately, these studies did not specify the type of tumor resection in terms of violation of the tumor capsule (*en bloc* versus intralesional resection). Nakamura et al.¹⁶ investigated the long-term surgical outcomes of cervical dumbbell schwannomas and reported local recurrence only in cases of subtotal and partial resection. These authors distinguished surgical margins of tumor resection as (1) total resection, which included both *en bloc* (i.e. *en bloc* tumor resection including the distal affected nerve root) and gross total resection (i.e. tumor resection using Cavitronic Ultrasound Surgical Aspirator (CUSA) without resecting the distal affected nerve root and with no evidence of residual tumor on a post-operative Gadolinium-enhanced axial MRI image); (2) subtotal resection (i.e. more than 90% resection based on findings on a postoperative Gadolinium-enhanced axial MRI image); and (3) partial resection (i.e. less than 90% resection based on findings on a post-operative Gadolinium-enhanced axial MRI image).

We conducted a literature search to identify surgical case series that examined patients with histopathological features of conventional spinal schwannomas (Table 3). Our review consisted of six studies with sample sizes ranging from 35 to 181 patients and mean ages from 44.3 to 50.2 years. The average age of our patient population was 47 years, which is consistent with what has previously been reported in the literature. There was no gender predominance in our cohort (88 men and 81 women), which is similar to studies by Jeon et al.¹⁰, Asahara et al.¹⁵, and Atlas et al.¹⁷ However, in a surgical case series by Seppala et al.⁷, there was a higher incidence of schwannomas in females whereas two other series reported a greater proportion of males.^{8,14} In two multicenter Japanese studies, there was also a higher incidence of spinal schwannomas in males; however, in these studies, the histopathological features were not specified and so it is unclear whether this male predominance was in fact for conventional spinal schwannomas. Of note, the overall incidence of spinal schwannomas appears to be greater in Japan than in Western countries.^{18,19} Similarly to other surgical series, in our study the lumbar spine was the most common segment in which conventional schwannomas were found. In addition, the majority of our patients' tumors were intradural-extramedullary which is consistent with all other comparable surgical series.

Limitations and Future Directions

This is a retrospective study of data collected from 13 global centers without a standardized treatment protocol for spinal schwannomas. In addition, there was missing pre-and post-operative data (Table 1) as well as only 9 patients who experienced local tumor recurrence, which prevented performing multiple regression analysis. Further, we were unable to obtain data on a patient's NF status and thus could not evaluate the predictive value of this factor. It is well recognized that NF patients, especially those suffering from NF-2, tend to harbor schwannomas with more aggressive biological behavior and, as a result, may present with more severe clinical presentations and may deteriorate at a faster rate.^{8,20}

Furthermore, it is important to recognize the pleomorphism of presentations of conventional schwannomas. Although conventional schwannomas are histologically benign tumors, they can sometimes be very large and erode surrounding osseous structures. In primary spinal tumors, Enneking and Weinstein-Boriani-Biagini (WBB) classifications demonstrated moderate interobserver reliability and substantial to near-perfect intraobserver reliability with respect to staging and treatment decision making, but less than moderate interobserver reliability in interpreting the Enneking local tumor extension and WBB sector.²¹ While existing evidence has reported that these classification systems improve disease control and survival in patients with primary spinal bony tumors²²⁻²⁵, they are not easily applicable to spinal schwannomas. However, Sridhar et al.²⁶ have proposed a useful classification of spinal schwannomas based on radiological imaging (Table 4 and Figure 1).

This study identified several knowledge gaps and opportunities for further research related to spinal conventional schwannomas. First, patients' NF status should be assessed and NF patients should be analyzed as a distinct subset. Second, it is critical to adopt a standardized classification system for conventional spinal schwannoma based on radiological imaging, such as the classification system proposed by Sridhar et al.²⁶ Ki-67 is an immunoglobulin G class monoclonal antibody essential for cell replication²⁷. Sohn et al.²⁸ found that the Ki-67 labeling indices were significantly higher in patients with post-operative radiological evidence of local recurrence after subtotal spinal schwannoma resection. Third, molecular features, including the Ki-67 labeling index, should be examined as tumors might differ in their behavior according to their specific molecular profile, and thus have distinct risk factors for local recurrence. Screening conventional schwannomas for specific biomarkers that are known to be associated with invasive behavior and/or recurrence seem to be an area ripe for further investigation. Fourth, it is essential to standardize the definition of gross total, *en bloc* and intralesional resections, and ensure that these are supported by both post-operative histopathological examination, i.e. preservation of the integrity of the tumor capsule, and radiological imaging. Fifth, given the higher incidence of spinal schwannomas in the Asia-Pacific population and their tendency to occur in males, it would be valuable to investigate whether there are any histopathological particularities in this group of patients and whether they should be analyzed as a separate group. Sixth, the advent of stereotactic radiosurgery as an adjuvant therapy appears to offer promising results in preventing recurrence in cases of malignant histopathology¹⁷ and subtotal resection^{28,29}; this is also worth investigating. Finally, since peripheral nerve sheath tumors are not very common, creating an international multicenter prospective registry would allow for a higher powered analyses in future work.

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Figure 1. Schematic representation of Sridhar et al.²⁶ Type II, which is an intraspinal schwannoma extending over more than two vertebral segments is not shown

Table 1
General, Tumor and Surgical Characteristics

<i>General Characteristics</i>		n
Age, mean years (SD; median; range)	46.60 (15.31; 45; 18-84)	169
Sex (M/F)	88 (52.07%) / 81 (47.93%)	169
Duration of Symptoms, mean years (SD; range)	1.70 (3.11; 17 days -16.16 years)	99
Pain (Y/N)	148 (88.62%) / 19 (11.38%)	167
Myelopathy (Y/N)	33 (27.97%) / 85 (72.03%)	118
<i>Tumor Characteristics</i>		
Size, mean cm (SD; range)		
Anterior-posterior	3.41 (3.07; 0.5-19)	107
Left-right	2.85 (2.57; 0.6-14)	108
Cranial-caudal	2.82 (2.91; 0.3-13.5)	104
Tumor Level (proportion)		169
Cervical (mobile)	15 (8.88%)	
Cervicothoracic (mobile)	4 (2.37%)	
Thoracic (mobile)	41 (24.26%)	
Thoracolumbar (mobile)	10 (5.92%)	
Lumbar (mobile)	70 (41.42%)	
Lumbosacral (fixed)	9 (5.33%)	
Sacral (fixed)	20 (11.83%)	
Number of levels		169
1	60 (35.50%)	
2	87 (51.48%)	
3	13 (7.69%)	
4	5 (2.96%)	
5	4 (2.37%)	
Number of levels, mean (SD; median; range)	1.85 (0.86; 2; 1-5)	169
Dural location		105
Extradural	22 (20.95%)	
Intradural	50 (47.62%)	
Both (intra- and extradural component)	33 (31.43%)	
<i>Surgical Characteristics</i>		
Surgery Type (proportion)		155
Anterior	4 (2.58%)	
Posterior	116 (74.84%)	

<i>General Characteristics</i>		n
Circumferential	8 (5.16%)	
Other	27 (17.42%)	
Surgeon's surgical resection assessment (proportion)		119
En bloc		83
Wide with wide margin	68 (57.14%)	
Wide with marginal margin	11 (9.24%)	
Wide with focal intralesional transgression	4 (3.36%)	
Intralesional		34
Gross total	30 (25.21%)	
Subtotal	4 (3.36%)	
Palliative	2 (1.68%)	2
<i>Post-operative local recurrence</i>		
Recurrence (proportion)		169
Yes	9 (5.33%)	
No	160 (94.67%)	
Time to recurrence, mean years (SD; range)	1.69 (1.22; 74 days-4.16 years)	169
Location (proportion)		9
Cervical	2 (22.22%)	
Lumbar	5 (55.56%)	
Sacral	2 (22.22%)	
Size, mean cm (SD; range)		169
Recurrence		9
Anterior-posterior (AP)	5.40 (4.27; 1.0 – 14.0)	7
Left-right (LR)	4.17 (2.89; 1.0 – 10.0)	7
Cranial-caudal (CC)	6.13 (4.89; 1.0 – 13.0)	7
Largest of AP, LR, CC	6.97 (4.66; 1.0 – 14.0)	7
No – recurrence		160
Anterior-posterior (AP)	3.27 (2.94; 0.5 – 19.0)	100
Left-right (LR)	2.75 (2.53; 0.6 – 14.0)	101
Cranial-caudal (CC)	2.58 (2.59; 0.3 – 13.5)	97
Largest of AP, LR, CC	3.81 (3.34; 0.6 – 19.0)	101
Dural location (R / NR)		105
Extradural	3 / 19	22
Intradural	2 / 48	50
Both (intra- and extradural)	1 / 32	33
Surgeon's surgical resection assessment (R / NR)		117
En bloc		83
Wide with wide margin	2 / 66	68

<i>General Characteristics</i>		n
Wide with marginal margin	0 / 11	11
Wide with focal intralesional transgression	1 / 3	
Intralesional		34
Gross total	4 / 26	30
Subtotal	1 / 3	4
Palliative	0 / 2	2
Surgeon's Surgical Assessment (R / NR)		117
Intralesional	5 / 29	34
En-bloc	3 / 80	83

Table 2
Predictors of spinal schwannoma recurrence on univariate analyses

Predictor	Hazard Ratio (95% C.I.)	p value
General Characteristics		
Age	0.964 (0.919-1.011)	0.127
Gender (ref=male)	0.554 (0.139-2.218)	0.397
Duration of symptoms	0.999 (0.997, 1.001)	0.386
Tumor Location		
Tumor Segments (C/T/L/S)	-	0.195
Cervical vs. Thoracic	-	0.017
Cervical vs. Lumbar	0.474 (0.091, 2.462)	0.364
Cervical vs. Sacral	0.787 (0.110, 5.609)	0.810
Thoracic vs. Lumbar	-	0.096
Thoracic vs. Sacral	-	0.038
Sacral vs. Lumbar	0.665 (0.128, 3.451)	0.626
Location (ref=mobile segments)	1.491 (0.309, 7.190)	0.616
Extent of Tumor		
Number of Levels	2.228 (1.223-4.057)	0.009
Tumor Size (cm)		
Anterior-Posterior (AP)	1.131 (0.981-1.303)	0.090
Left-Right (LR)	1.171 (0.950-1.443)	0.139
Cranial-Caudal (CC)	1.321 (1.107-1.576)	0.002
Largest of AP, LR, CC	1.157 (1.016-1.319)	0.028
Dural location (Ref: Intradural)		0.246
Extradural	3.385 (0.565-20.289)	0.182
Both (intra- and extradural)	0.839 (0.075-9.364)	0.887
Surgical		
Surgical Assessment (Ref: intralesional subtotal resection)		0.086
En bloc wide with wide margin	0.124 (0.011-1.371)	0.089
En bloc wide with marginal margin	-	-
En bloc wide with focal intralesional transgression	1.090 (0.068-17.581)	0.952
Intralesional gross total	0.576 (0.064-5.169)	0.622
Surgical Assessment (ref=en-bloc resection)	4.178 (0.998-17.491)	0.033

p value of log-rank tests were used for categorical variables times greater risk of recurrence (p = 3, log-rank test)

Table 3
Recurrence of conventional spinal schwannomas: surgical case series in the literature

1 st author (Year)	# of patients (total # schwannomas) Mean/ Median Age Agerange	Ratio F:M	Spinal segments (mean age)	Postop follow-up (range)	Location	Characteristics associated with recurrence
Seppala (1995) ⁷	181 (187) Median: 480-79 ^a	104:83	C: 50 T: 57 L: 74 (conus: 34) Multiple: 6	Median 12.9 yrs (0-37.7 yrs)	ID-EM: 124 ED: 25 ED-ID: 36 ID-IM: 0 2 unknown cases	STR (11 out of 20) 2 patients required 2 nd surgery: 27 (cervical) and 8 (conus) yrs after initial surgery
Safavi-Abbasi (2008) ¹⁴	131 Mean: 47.7 7-86	52:76	C: 37 T: 34 L: 60 (conus: 37) Multiple: 2 (intradural conus L1 and L5; T12 intradural and L3 intradural and L3 intradural)		ID-EM: 89 ED: 15 ED-ID: 25 ID-IM: 2	5 recurrence Gross total resection Required 2 nd surgery: 180 (L: ID-EM); 330 (C; ED); 360 (conus; ID-EM); 420 (conus; ID- EM); 1800 (T; ID-EM) days
Conti (2004) ⁸	152 (179) Mean: 44.3 7-80	59:93	C: 33 (45.4 yo) T: 59 (48.9) L: S1-2: 87 (43.2) Multiple: 2		ID-EM: 123 ED: 11 ED-ID: 2 Dumbbell: 9 ID-IM: 2	8 recurrence STR Malignant pathology (3 out of 8 1) NF2; C 2) C 3) T
Jeon (2008) ¹⁰	38 (40 schw) 50.2 (mean) 6-74	16:22	C: 4 (58.3) T: 11 (45.7) L: 25 (49.9)	Median 15.9 mos (0-91 mos)	ID-EM: 38 ED: 2 ED-ID: 0 Recurrence: 2	STR (2 out of 6) Recurrence 12 yrs after initial surgery
Asahara (1996) ¹⁵	42 45.1 (mean) 12-79	17:25	C: 12 T: 18 L: 11 S: 1 Multiple: 2	Mean 9.7 yrs (2 – 31 yrs)	ID-EM: 26 ED: 13 ED-ID: 1 ID-IM: 2	STR (1 out of 1) Recurrence 18 yrs after initial surgery (cervical, dumbbell)
Altas (2013) ¹⁷	35 47.2 (mean) 13-76 2 malignants	15:20	C: 6 (58.3) C-T: 2 T: 4 (45.7) T-L: 10 L: 13 (49.9)		ID-EM: 30 ED: 3 ED-ID: 0 ID-IM: 2 30 total 5 subtotal, no recurrence	Malignant pathology Recurrence occurred after 2 yrs after initial surgery (T-L and lumbar)

^aThe age range was not specifically reported, data was extracted from Figure 1 which shows a bar graph of the age distribution at diagnosis. F: females; M: males; C: cervical; C-T: cervico-thoracic; T: thoracic; T-L: thoraco-lumbar; L: lumbar; ID-EM: intradural-extramedullary; ED: extradural; ED-ID: extra- and intradural (i.e. dumbbell); ID-IM: intradural-intramedullary; STR: subtotal resection

Table 4

Classification of conventional spinal schwannoma proposed by Sridhar et al.²⁶

Type	Classification
Ia	Intraspinal, intradural tumor of < 2 vertebral segments in length
Ib	Intraspinal, extradural tumor of < 2 vertebral segments in length
II	Intraspinal tumor of > 2 vertebral segments in length (giant tumor)
III	Intraspinal tumor with extension into nerve root foramen
IVa	Intraspinal tumor with extraspinal extension (dumbbell tumors) < 2.5 cm
IVb	Intraspinal tumor with extraspinal extension (dumbbell tumors) > 2.5 cm (giant tumor)
V	Tumor with erosion into the vertebral bodies, lateral and posterior extensions into myofascial planes (giant invasive tumor)