Clinical outcomes following resection of giant spinal schwannomas: a case series of 32 patients

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OBJECTIVE The objective of this study was to review clinical outcomes following resection of giant spinal schwannomas.

METHODS The authors conducted a retrospective review of a case series of patients with giant spinal schwannomas at a tertiary cancer hospital.

RESULTS Thirty-two patients with giant spinal schwannomas underwent surgery between September 1998 and May 2013. Tumor size ranged from 2.5 cm to 14.6 cm with a median size of 5.8 cm. There were 9 females (28.1%) and 23 males (71.9%), and the median age was 47 years (range 23–83 years). The median follow-up duration was 36.0 months (range 12.2–132.4 months). Three patients (9.4%) experienced recurrence and required further treatment. All recurrences developed following subtotal resection (STR) of cellular or melanotic schwannoma. There were 3 melanotic (9.4%) and 6 cellular (18.8%) schwannomas included in this study. Among these histological variants, a 33.3% recurrence rate was noted. In 1 case of melanotic schwannoma, malignant transformation occurred. No recurrence occurred following gross-total resection (GTR) or when a fibrous capsule remained due to its adherence to functional nerve roots.

CONCLUSIONS Resection is the treatment of choice for symptomatic or growing giant schwannomas, frequently requiring anterior or combined approaches, with the goals of symptom relief and prevention of recurrence. In this series, tumors that underwent GTR, or where only capsule remained, did not recur. Only melanotic and cellular schwannomas that underwent STR recurred.

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KEY WORDS cellular schwannoma; giant schwannoma; melanotic schwannoma; nerve sheath tumor; spinal tumor; oncology

Schwannomas are tumors derived from Schwann cells of the neural sheath. Approximately 95% of schwannomas are benign, encapsulated, and slow growing. Within the spine, they can be extradural, intradural extramedullary, or rarely intramedullary, and can cause spinal cord and nerve root compression. Schwannomas occur sporadically or as part of a hereditary disorder, in particular neurofibromatosis Type 2 or schwannomatosis. Sporadic schwannomas most commonly occur in the 2nd through 5th decade of life, but can occur at any age with an equal prevalence in men and women.14

Giant schwannomas of the spine are classified as an intraspinal tumor of at least 2 vertebral bodies in length or with an extraspinal extension of at least 2.5 cm.17 Here, we have also included giant paraspinal schwannomas of at least 2.5 cm. Giant schwannomas most commonly present in the lumbar or sacral regions but are also found in the cervical and thoracic regions.1,10,11,13,21,24 The most common symptoms are back pain, radiculopathy, muscle weakness, sensory deficit, difficulty with ambulation, and bladder/bowel dysfunction, which are the result of spinal cord or nerve root compression.

Giant schwannomas without associated symptoms or radiographic growth can be observed. Surgery is the treatment of choice for symptomatic or growing schwannomas, and the surgical approach to giant schwannomas of the spine is focused on prevention of recurrence and symptom relief. Gross-total resection (GTR) is often curative and can be achieved safely in the majority of cases. However, GTR may be hindered by intimate involvement

ABBREVIATIONS EMG = electromyography; GTR = gross-total resection; MPNST = malignant peripheral nerve sheath tumors; SRS = stereotactic radiosurgery; STR = subtotal resection.

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of functional nerve roots or the spinal cord. In these cases, fibrous capsule or tumor may be left to preserve neurological function. The role of residual fibrous capsule in recurrence is uncertain and may not indicate subtotal resection (STR) of the actual tumor, but rather residual fibrous tissue without neoplastic potential. Subtotal resection may predispose the tumor to recurrence, but due to the slow growth of these tumors, it can be sufficient to provide long-term relief of symptoms. The current study examines the outcomes of surgical treatment of giant paraspinal schwannomas, examines factors associated with recurrence, and delineates technical considerations for the surgical approach and excision of these tumors.

**Methods**

Between September 1998 and May 2013, 32 patients with giant schwannomas of the spine, defined as extending at least 2 vertebral levels intraspinally or 2.5 cm extraspinally, were identified. Patients with giant spinal and paraspinal schwannomas with at least 12 months of follow-up were included. Patients with schwannomas smaller than 2 vertebral bodies intraspinal or 2.5 cm extraspinally were excluded, as were 4 cases of schwannomas in the brachial plexus with no spinal canal involvement and 14 cases with less than 12 months of follow-up. A retrospective chart and image review was performed. This study was approved by the institutional review board of Memorial Sloan Kettering Cancer Center.

Tumor size was measured from the most immediate preoperative MR or CT imaging available. All but 1 tumor measurement was confirmed through image review. All patients were diagnosed and followed postoperatively with MRI, with the exception of 1 patient who was diagnosed preoperatively with CT and 3 patients who were followed postoperatively with CT.

**Approach Considerations**

In each case, the surgical approach was dictated by the location and size of the tumor. Tumors located entirely or partially within the spinal canal were accessed through the midline posterior approach. Preference was always given to removing the portion of the tumor located within the spinal canal because the intraspinal tumor component was the most likely to be or become symptomatic in the future. When the posterior approach was used, every effort was made to maximize the excision of the paraspinal tumor through the same posterior approach. In cases in which a very significant portion of the tumor could not be removed using the posterior approach, an additional anterior approach was used to complete the tumor excision. Tumors without extension into the spinal canal were accessed using an anterior approach tailored to the level of the tumor: neck dissection for cervical tumors, thoracotomy or thoracoscopy for thoracic tumors, and laparotomy, laparoscopy, or retroperitoneal approaches for lumbar tumors. In anteriorly located tumors with intrafornaminal extension, without significant tumor volume in the spinal canal, the paraspinal tumor was excised and followed into the foramen. In cases in which complete foraminal tumor excision was not possible through the anterior approach, residual foraminal tumor was left behind and observed in asymptomatic cases. Posterior instrumented stabilization was used when facetectomy was undertaken to access the paraspinal tumor component.

In cases in which anterior approaches were employed, the operations were performed in conjunction with surgeons who specialize in the region-specific approaches, such as head and neck, thoracic, and abdominal surgeons. Upper or lower neck dissections provided exposure of anterior cervical tumors. Intrathoracic tumors were approached using thoracotomy or thoracoscopy. Paraspinal lumbar tumors were approached using the retroperitoneal approach. Open laparotomy or laparoscopy was used to approach presacral tumors. Recent operations used the less invasive techniques such as thoracoscopy and laparoscopy. Excision of one of the thoracic schwannomas was performed with robotic assistance (da Vinci Surgical System, Intuitive Surgical), as previously reported.

**Surgical Technique**

Neurophysiological monitoring was used in all cases. Surgery for tumors located in the cervical or thoracic spinal canal was conducted using spinal cord monitoring with somatosensory and motor evoked potentials. Free-running electromyography (EMG) was used during lumbar surgery. A nerve stimulator was used to delineate motor nerve roots.

In tumors located in the spinal canal, a laminectomy spanning the length of the tumor with additional half-level exposure above and below the tumor was carried out. Intraoperative ultrasonography was used to confirm the location of the tumor prior to dural incision. A straight midline dural incision was used to expose the tumor and the spinal cord. In tumors with significant foraminal and paraspinal extension, a horizontal incision along the root sleeve was also performed with its starting point at the vertical incision.

Once the tumor was exposed, blunt dissection around the capsule was performed to free the tumor of adherent surrounding structures. In cases in which nerve roots were suspected to be adherent to the capsule, a nerve stimulator was used to determine whether the adherent structure was a functional motor nerve root. Once stimulation helped delineate a safe entry zone on the tumor surface, the area was coagulated using bipolar forceps and sharply incised. An ultrasonic aspirator was used to internally decompress the tumor. Piecemeal tumor resection was carried out. Once portions of the capsule were entirely free of surrounding structures, these free segments of the capsule were sharply sectioned from the remaining tumor. The steps of internal debulking and capsule sectioning were repeated until either the entire tumor along with the capsule was safely removed or until only small portions of the capsule that were adherent to the adjacent nerve roots remained. If stimulation of the nerve root adherent to the tumor did not elicit an EMG response, the root was sectioned with the assumption that it only had a sensory function. The proximal and distal root attachments were sectioned to fully remove the tumor. Upon completion of tumor excision, the midline dural incision and the nerve root sleeve incisions were closed in a watertight fashion using a running suture.
Bovine pericardial dural substitute was used in instances when the dura could not be reapproximated without excessive tension and in T-shaped incisions. In cases of extradural tumors treated with rhizotomy, every effort was made to perform the rhizotomy proximal to the dorsal root ganglion to avoid postoperative neuropathic pain.

Results

Patient Population

The study included 32 patients with giant schwannomas of the spine. The median age was 47 years (range 23–83 years, mean ± SD 50 ± 17.6 years). Of the 32 patients, 9 were female (28.1%) and 23 were male (71.9%). None of the patients had neurofibromatosis or schwannomatosis.

Patients most commonly presented with nonradicular pain (n = 21, 65.6%). Radiculopathy was present in 9 patients (28.1%). There was sensory deficit or paresthesia in 12 patients (37.5%), and motor weakness in 6 patients (18.8%). Four patients (12.5%) had difficulty with ambulation, and one patient (3.1%) presented with bowel or bladder dysfunction. The tumors were an incidental finding in 4 patients (12.5%).

Tumor Characteristics

Eleven tumors were located at the level of the sacrum (34%), and the remaining tumors were evenly distributed among the cervical, thoracic, and lumbar regions (7 tumors/22% per region).

The patients included in this case series had tumors with a maximum dimension between 2.5 cm and 14.6 cm with a median size of 5.8 cm (mean 6.88 ± 3.56 cm). Preoperative growth was documented in 7 (21.9%) of the cases. Five (15.6%) were intradural, and 13 (40.6%) were characterized as dumbbell-shaped. Spinal cord compression was present in 12 cases (37.5%) with all but 1 case being moderate to severe. Bone remodeling was documented in 16 cases (50.0%).

All tumors were confirmed as schwannomas on pathological analysis. Eighteen patients (56.3%) were biopsied before surgery. Twenty-one (65.6%) of the specimens were tested for S100 protein immunoreactivity, and all were positive. Three cases (9.4%) were described as melanotic, and 6 cases (18.8%) were described as cellular on histological examination. One of the melanotic and 1 of the cellular schwannomas were also plexiform. Six tumors were evaluated with Ki-67 staining.

Tumor Resection

The posterior approach was the most common surgical approach, used in 16 cases (50.0%). A posterior approach was used in conjunction with a laparotomy, anterior neck dissection, or retroperitoneal approach in 3 cases. There were 8 retroperitoneal cases (25.0%), including 1 with posterior dissection, and 3 transperitoneal cases (9.4%). A thoracotomy was performed in 3 patients (9.4%), including 1 thoracoscopic resection. A laparotomy was performed in 3 patients (9.4%), including 1 laparoscopic resection and 1 in conjunction with a posterior approach. One patient (3.1%) underwent a lateral neck dissection, and 1 patient (3.1%) underwent an anterior neck dissection follow-

ing posterior dissection. Instrumentation was placed in 10 cases (31.3%). The lateral extracavitary and costovertebral approaches were not used in any of the surgeries.

Combined approaches were used in 3 cases. One case was a cervical case. A C6–7 tumor was removed via a posterior approach with a hemilaminectomy and foraminotomy exposing and dissecting laterally; noteworthy was the fact that the tumor did not breach the dura medially. After removal of the intraforaminal component with preservation of motor function, C5–T1 instrumented fusion was performed. The patient was then repositioned and a transverse incision, made for a posterior sternocleidomastoid approach, was used to locate the remaining tumor that was adherent to the brachial plexus. Intraoperative monitoring precluded a complete resection, as significant motor responses were elicited. The next case was a lumbar tumor, an L1–2 tumor with a 15-cm paraspinal mass, in which surgery was initiated posteriorly with a 3-level laminectomy, posterior instrumented fusion, facetectomy, and intrathecal decompression. This was followed by repositioning and completion of surgery through an open retroperitoneal approach. During this approach the inferior vena cava, ureters, and kidney were visualized and protected, the tumor was identified, and an intrathecal decompression was achieved. The third combined approach was a large sacral mass filling the entire pelvis. A midline incision was made from the umbilicus to the symphysis pubis, and the abdominal cavity was entered. The sigmoid colon, ureter, and bladder were mobilized and protected, and the presacral space was dissected, immobilizing the iliac vessels. Due to an inability to completely protect the iliac vessels, the adherent tumor was intraspinally decompressed. Next, a posterior approach was performed via a midline incision, S1–3 laminectomy, and removal of the remaining visible tumor.

As these tumors are typically benign, the risks and benefits of each approach are weighed, and the elected surgical approach is based on the tumor location and extent with consideration also given to the safest approach with the least expected morbidity. Illustrative cases and approach considerations are presented in Fig. 1.

Tumor Resection

GTR was achieved in 19 patients (59.4%). Based on intraoperative findings, 6 patients (18.8%) had only residual fibrous capsule left, while 7 patients (21.9%) underwent STR of the tumor. STR was performed in these 7 cases when risk of vascular injury or neurological deficits was high as suggested by intraoperative nerve monitoring. Rhizotomy was performed when, according to intraoperative monitoring, the involved/adherent nerve root could be sacrificed without causing significant neurological deterioration. This is typically applicable, as these tumors mostly arise from sensory roots. On postsurgery MRI, 12 patients (37.5%) showed enhancement on their imaging, suggesting residual capsule or tumor.

Complications

Five patients (15.6%) had a complication following surgery. Two patients with sacral schwannomas had wound
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Infections, 1 treated with only antibiotics and another requiring debridement. One patient developed chemical meningitis and symptomatic communicating hydrocephalus that was treated with a right ventriculoperitoneal shunt. Another patient developed Guillain-Barre syndrome 10 days postoperatively, leading to respiratory distress requiring a tracheostomy and dysphagia requiring a feeding tube. One patient had a subacute gastrointestinal obstruction after a midline laparotomy.

Functional Outcomes

Functional outcomes were determined by physical examination findings and patient reporting. Long-term follow-up of these 32 patients showed improvement of nonradicular pain, radiculopathy, motor weakness, sensory deficit, ambulation, and bowel and bladder function (Fig. 2). At last follow-up, nonradicular pain remained the most common symptom, with 9 patients (28.1%) complaining of neck, back, hip, or extremity pain. Complete resolution of radiculopathy in all patients was observed by last follow-up.

In 2 patients (6.3%), a thoracic rhizotomy was performed. In 1 patient with a T7–8 rhizotomy, no postoperative motor or sensory deficit was noted. In another patient with a T7 rhizotomy, only temporary numbness in a T7 distribution was reported.

Tumor Recurrence

The median follow-up time was 36.0 months (mean 41.4 ± 28.6 months, range 12.2–132.4 months). In this study, 3 patients (9.4%) experienced tumor recurrence, as determined by MRI and follow-up. The median time between the index surgery and recurrence was 27.5 months (mean 37.5 ± 32.5 months, range 11.2–73.9 months). Overall, no patients who underwent GTR or had only a residual fibrous capsule experienced recurrence. No conventional schwannomas recurred. Two of the recurrences were cellular schwannomas. One recurrence was a melanotic schwannoma, which underwent malignant transformation. Overall, 33.3% of melanotic (1 of 3) and cellular (2 of 6) tumors recurred. Three (42.9%) of the 7 patients with STR had evidence of recurrence on MRI. Recurrence was treated with radiation therapy, a second resection, or a combination of radiation and surgery. Additionally, 3 patients had stable nodules at other spinal or systemic sites.

Adjuvant Therapy

In our case series, 3 patients (9.4%) received radiation therapy. One patient with melanotic schwannoma was given stereotactic radiosurgery (SRS) at 2700 cGy in 3 fractions approximately 3.5 months after surgery in addition to p32 brachytherapy intraoperatively. In 1 patient with cellular schwannoma, recurrence was identified at 27 months postoperatively and treated with SRS at 3000 cGy in 5 fractions. In the third patient, also with melanotic schwannoma, who underwent an initial resection at a different institution, SRS at 2700 cGy in 3 fractions was given 3 weeks after surgery to prevent recurrence. In this case, the patient developed multiple metastases, which were treated with further SRS and a targeted drug therapy (pazopanib).

Discussion

Schwannomas are benign, encapsulated tumors of the nerve sheath. Due to their benign nature, schwannomas can grow to a significant size before causing symptoms through mass effect. They can be found incidentally, as was the case for about 20% of patients in this study.
Schwannomas of the spine can be classified as extradural, intradural extramedullary, or, rarely, intradural intramedullary. These tumors can occur within or outside the spinal canal, as well as spanning the neural foramen with both intraspinal and extraspinal components, so-called dumbbell tumors. In this study, we focused on giant spinal schwannomas, which extend at least 2 vertebral bodies intraspinally or at least 2.5 cm extraspinally.

Resection and Recurrence
The primary goals of giant schwannoma resection are to prevent recurrence and to relieve the patient’s symptoms. When possible, GTR is essentially curative with superior outcomes to STR. Excision of the large paraspinal tumor component often requires anterior approaches. Increasing experience with thoracoscopic, laparoscopic, and robot-assisted surgery has decreased the invasiveness of these approaches. No patient in this study experienced recurrence following GTR. When the tumor’s fibrous capsule is adherent to functional nerve roots or the spinal cord, leaving residual capsule is preferable to causing neurological deficit. Thoracic rhizotomy may be performed to achieve GTR as deficits are minimal, only sensory, and generally do not impact a patient’s quality of life after surgery. In this case series, none of the patients with residual fibrous capsule experienced recurrence or required further treatment. The lack of recurrence in cases in which tumor capsule was left behind confirms that the residual capsule does not confer a significant recurrence risk, and, in cases in which capsule removal poses a risk of injury to the surrounding structures, the capsule can be left behind. Conversely, STR predisposes to recurrence with more than 40% local recurrence in this study. Of note, all the recurrences happened after STR of melanotic or cellular schwannomas and did not occur after STR of conventional schwannomas. In the literature, STR has been suggested to predispose to recurrence, including in melanotic and cellular schwannoma.

Notably, the cohort presented in this study is a fairly heterogeneous group of Schwann cell tumors in regard to their location (i.e., cervical, thoracic, lumbar, and sacral), and surgical removal at each tumor location is inherently different. In our opinion, the concepts and treatment paradigms remain the same for all groups. Regardless of location, when surgical removal is indicated, the goal is for a maximal, safe (neurological-preserving) resection. In the authors’ experience, when the tumor is adherent to functional nerve roots, major vessels, or vital organs, a maximal, intralesional decompression without the need for aggressive capsule excision is warranted with long-term follow-up for growth of the residual tumor.

Histology
Conventional schwannomas contain neoplastic Schwann cells with spindle-shaped nuclei surrounded by a fibrous capsule. The tumor is composed of hypercellular Antoni A regions with palisading nuclei and associated Verocay bodies and paucicellular Antoni B regions. In cellular schwannomas, hypercellular Antoni A tissue without Verocay bodies predominates. Cellular schwannomas share histological similarities with malignant peripheral nerve sheath tumors (MPNSTs), a distinction important for diagnosis and treatment. Melanotic schwannoma is a rare variant with Schwann cells containing cytoplasmic deposits of melanin. Melanotic schwannomas have the potential for malignant transformation, leading to poorer prognosis, and they must be differentiated from metastatic melanoma. Psammomatous melanotic schwannomas are associated with Carney complex, a rare genetic disorder characterized by schwannomas, skin pigmentation abnormalities, endocrine neoplasms, and myxomas. A further variant of schwannoma is plexiform, typified by a multinodular tumor that follows a nerve plexus, which can also be mistaken for an MPNST in children.

Within this cohort of giant spinal schwannomas, there was a particularly high occurrence of cellular (18.8%) and melanotic (9.4%) schwannoma. Few previous reports have documented the specific prevalence of these histological variants. In 1 case series from the Mayo Clinic, cellular schwannoma accounted for 4.6% of benign peripheral nerve tumors. In the study by Fletcher et al., cellular schwannoma represented 2.83% of all peripheral nerve tumors and 9.8% of all benign schwannomas. For melanotic schwannoma, only about 100 cases have been reported in the literature. In this case series, we observed a much higher rate of both cellular and melanotic schwannoma, suggesting that these variants may be more common among giant schwannoma.

In this case series, all recurrences occurred following STR of melanotic or cellular schwannomas. There were no recurrences of conventional schwannomas. There was only 1 patient with cellular or melanotic schwannoma with STR in which there was no recurrence, but this patient is less than 2 years postoperative (16.59 months of follow-up) and is still being followed up.

The recurrence and metastasis rates for melanotic schwannoma are not well established. Killeen et al. documented a recurrence rate of 24% in a report of 2 cases and a literature review of 34 melanotic schwannomas. In this study, the metastasis rate was not reported, but STR was correlated with poorer prognosis. In a report of 5 cases and a literature review of 57 cases of melanotic schwannoma by Vallat-Decouvelaere et al., 15% had recurrences and 26.3% had metastasis. Zhang et al. reported on 13 cases and observed an 18.2% recurrence rate and 9.1% metastasis rate. In this study, we observed a 33.3% recurrence and metastasis rate for giant melanotic schwannoma. One of the 3 cases of melanotic schwannoma reported here experienced recurrences following 2 STR surgeries with metastases at the time of the second recurrence. Although recurrences have almost exclusively occurred following STR, malignant melanotic schwannoma that recurred following GTR has been reported. Leptomeningeal spread, drop-down metastases, and systemic melanotic schwannoma metastases have been reported.

With cellular schwannoma, moderately high local recurrence rates have been reported, but no definite case of metastasis has been documented. In Casadei et al., a recurrence rate of 23.4% was reported in a review of 47 patients with at least 1 year of follow-up. In the study of White et al., 8.6% of 35 patients with at least 1 year of follow-up ex-
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The histological appearance of schwannoma appears to correlate with tumor behavior and clinical outcome. Therefore, it is important to distinguish between conventional and atypical schwannomas. The 3 main variants of schwannoma are cellular, melanotic, and plexiform, all of which are represented in this case series. These variants are frequently confused with other neoplastic conditions, most notably MPNST for cellular or plexiform schwannomas and melanoma for melanotic schwannomas. These histological similarities may contribute to confusion and suboptimal clinical treatment. The notable recurrence risk after STR of cellular and melanotic giant schwannomas emphasizes the importance of maximal excision of these tumors. However, because recurrence and residual tumor progression can generally be effectively managed with additional surgery or radiation, intentional neurological sacrifice should still be avoided, even in these cases with increased risk of recurrence.

Adjuvant Therapy

Because schwannomas are generally benign, radiation and systemic therapy is rarely used. Radiation therapy and targeted systemic therapy may be considered in recurrent and metastatic disease. In this case series, SRS was used to treat recurrence in 1 patient and metastasis in another patient, as well as to prevent recurrence in 2 cases of melanotic schwannoma. The use of SRS to treat residual and recurrent schwannoma has been previously reported. Intraoperative p32 brachytherapy was used in 1 case of melanotic schwannoma. In another case of melanotic schwannoma, metastases were treated systemically with a tyrosine kinase inhibitor (pazopanib). When considering adjuvant radiation or systemic therapy, the potential short- and long-term side effects must be balanced with the immediate presentation of disease. Because radiation and systemic therapies can carry risks, including carcinogenesis, adjuvant therapy is reserved for clinically aggressive tumors.

To date, there is no sensitive method of predicting grade or histology of Schwann cell tumors prior to tissue diagnosis. With melanocytic schwannomas, possible clues can arise when a hyperintense signal, consistent with melanosis, appear within the tumor. Regardless of tumor histology and grade, the goal of surgery remains uniform, i.e., maximal tumor resection with preservation of neurological function. Postoperatively, once the histological diagnosis is finalized, adjuvant radiation or close observation serve as reasonable strategies for residual atypical tumors and tumors with unfavorable histological types.

Study Limitations

The limitations of our study include the relatively small cohort of patients and the retrospective nature of data collection. Because 2 of the recurrences in this study occurred after 12 months, it is possible that some recurrences were not captured in our follow-up period. Conversely, patients who were excluded due to less than 1 year of follow-up may have been asymptomatic and less likely to have recurred. The reported data may underrepresent the true recurrence rate of the cohort because the median time to tumor recurrence in this series was 27.5 months. This may be particularly relevant to cellular and melanotic schwannomas that are represented in small numbers. Also, as a national cancer referral center, the patient population may be skewed to include more aggressive disease.

Conclusions

Resection is the treatment of choice for giant schwannomas with the goals of symptom relief and prevention of recurrence. Complete excision of these tumors frequently requires anterior approaches and a multidisciplinary surgical team. In this study, resection led to improvement of preoperative symptoms in every case. As a cohort, there was improvement in nonradicular pain, radiculopathy, motor weakness, sensory deficit, ambulation, and bowel and bladder function following resection. GTR is highly effective for the prevention of recurrence. When a fibrous capsule was adherent to functional nerve roots or the spinal cord, it was left, and this did not predispose the tumor to recurrence. Conversely, local recurrence following STR was more than 40% and only occurred in patients with nonconventional schwannomas. For melanotic and cellular variants, there was a considerably higher rate of recurrence than for the remainder of the cohort (33.3% vs 0%, respectively). In melanotic schwannoma, malignant transformation is also possible and should be considered if rapid tumor growth or rapid progression of symptoms is observed. Overall, giant schwannomas of the spine are predominantly benign and slow growing, with an excellent response to resection and a good prognosis.

References


**Disclosures**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

**Author Contributions**

Conception and design: Laufer, Boland, Bilsky. Acquisition of data: Sowash. Analysis and interpretation of data: Laufer, Sowash, Barzilai, Kahn, McLaughlin. Drafting the article: Sowash. Critically revising the article: Laufer, Barzilai, Bilsky. Reviewed submitted version of manuscript: Laufer, Barzilai, Bilsky. Approved the final version of the manuscript on behalf of all authors: Laufer. Administrative/technical/material support: Barzilai. Study supervision: Laufer.

**Supplemental Information**

**Previous Presentations**

This paper was previously presented by Madeleine Sowash in poster form at the Summer Fellowship Program Poster Session at Memorial Sloan Kettering Cancer Center in August of 2014.

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