Efficacy analysis of percutaneous cannulated paravertebral approach for microscopic resection of intraspinal schwannomas: A case series

SHAOBO YANG and NIANHUA WANG

Department of Neurosurgery, Changde Hospital, Xiangya School of Medicine, Central South University (The First People's Hospital of Changde City), Changde, Hunan 415000, P.R. China

Received August 25, 2025; Accepted March 13, 2026

DOI: 10.3892/etm.2026.13155

Abstract. The present study aimed to describe the surgical technique and to evaluate the clinical feasibility of a percutaneous cannulated paravertebral approach for microscopic resection of intraspinal schwannomas. A retrospective case series analysis was conducted using clinical data from six patients treated between January 2019 and December 2021. Demographic characteristics, clinical presentation, tumor location, operative parameters and follow-up outcomes were reviewed and descriptive statistical analysis was performed. The mean operative time was 130.8±32.9 min (range, 100-190 min), the mean intraoperative blood loss was 60±32.2 ml (range, 30-100 ml) and the mean length of hospital stay was 10.5±2.0 days (range, 8-12 days). In the present small cohort gross total resection was confirmed on postoperative imaging. During a follow-up period of 38-60 months, subjective improvement in presenting symptoms was reported, with no radiological evidence of tumor recurrence or clinically apparent spinal instability. As a consequence, the percutaneous cannulated paravertebral approach may be technically feasible in selected patients with small, single-level intraspinal schwannomas.

Introduction

Intraspinal tumors account for 10-15% of all central nervous system tumors (1). Among these lesions, schwannomas are the most common benign intraspinal tumors and typically originate from schwann cells of the spinal nerve roots. Although histologically benign, they may cause progressive neurological dysfunction due to sustained compression of the spinal cord, cauda equina or nerve roots (2-4). Clinical manifestations may include back pain, radicular pain, sensory disturbance, motor weakness and, in advanced cases, bladder or bowel dysfunction on tumor size and location. Prolonged neural compression may result in irreversible neurological deficits, underscoring the importance of timely diagnosis and surgical intervention for symptomatic patients (5,6).

Surgical resection remains the primary treatment option for intraspinal schwannomas, aiming to achieve adequate neural decompression while preserving the spinal stability and neurological function (7). Total laminectomy, laminoplasty and hemilaminectomy, as conventional posterior approaches, provide sufficient surgical exposure. However, these approaches may increase the risk of paraspinal muscle injury, posterior ligamentous disruption and potential postoperative spinal instability, particularly in multilevel or lumbar cases (8-10).

Minimally invasive spinal techniques have seen growing applications with the advances in surgical instrumentation and imaging guidance, in selected cases (11). Tubular retractor-assisted paraspinal approaches limit muscle dissection and posterior bony resection while maintaining an adequate operative corridor for microscopic tumor resection (12).

The present study retrospectively reviewed six patients with intraspinal schwannomas who underwent microscopic tumor resection via a percutaneous cannulated paravertebral approach. The present study aimed to describe the surgical technique and to assess its clinical feasibility in carefully selected cases.

Materials and methods

Study design and patients. The present study was designed as a retrospective case series and was conducted at the Department of Neurosurgery, The First People's Hospital of Changde City, Changde, China). Clinical data from patients treated between January 2019 and December 2021 were reviewed. The institutional ethics committee approved the study (approval no. YX-2024-005-01), and all patients provided written informed consent.

Correspondence to: Dr Nianhua Wang, Department of Neurosurgery, Changde Hospital, Xiangya School of Medicine, Central South University (The First People's Hospital of Changde City), 188 Wuling Road, Changde, Hunan 415000, P.R. China
E-mail: wnhlch1981@163.com

Key words: percutaneous cannulated paravertebral approach, intraspinal schwannomas, minimally invasive surgery, surgical techniques

Inclusion and exclusion criteria. Patients were retrospectively screened from the institutional medical record system. All patients who underwent surgical treatment for intraspinal tumors at the First People's Hospital of Changde City between January 2019 and December 2021 were initially identified, and those who underwent tumor resection using the percutaneous cannulated paravertebral approach were further evaluated according to predefined eligibility criteria. Patients were considered eligible for inclusion if they met the following criteria: i) preoperative magnetic resonance imaging (MRI) findings suggesting an intradural extramedullary tumor with imaging characteristics consistent with schwannoma; ii) lateralized tumor growth, allowing safe exposure through a unilateral paravertebral corridor; iii) tumor diameter ≤2 cm; iv) involvement of a single spinal segment; and v) the primary surgical objective being tumor resection rather than decompression for spinal canal stenosis. Patients were excluded if the tumor was large (>2 cm), involved multiple spinal levels, had significant ventral extension or vascular characteristics that might increase operative risk within a limited surgical corridor. In addition, patients were excluded if they had severe comorbidities precluding surgery, a history of surgery at the same spinal level, pregnancy or lactation or underwent surgery for indications other than tumor decompression. During the study period, all patients who underwent surgery for intraspinal tumors were screened, and 6 patients meeting the predefined criteria were ultimately included in this case series.

Clinical and imaging evaluation. Demographic characteristics, presenting symptoms and symptom duration were recorded. All patients underwent preoperative MRI with and without contrast to assess tumor location, size and relationship to adjacent neural structures. Preoperative X-ray and computed tomography (CT) examinations were performed to evaluate spinal alignment and stability. Standardized functional or neurological scoring systems, such as the visual analog scale (VAS) for pain assessment, the Japanese Orthopaedic Association (JOA) score for neurological function evaluation and the McCormick scale for functional grading, were not routinely recorded in a structured or standardized manner during the study period; therefore, such data were not available for consistent retrospective extraction.

Histopathological examination and immunohistochemistry. Resected tumor tissues were fixed in 10% neutral-buffered formalin at room temperature for 24 h and embedded in paraffin. Sections were cut at a thickness of 4 μm. For hematoxylin and eosin (HE) staining, sections were deparaffinized, rehydrated through graded ethanol, stained with hematoxylin and eosin at room temperature and examined using a light microscope. For immunohistochemistry (IHC), antigen retrieval was performed in citrate buffer (pH 6.0) at 95˚C for 15 min. Sections were blocked with 5% bovine serum albumin (Beijing Solarbio Science & Technology Co., Ltd.) for 30 min at room temperature, followed by incubation with anti-S-100 primary antibody (1:200; cat. no. ZM-0224; Beijing Zhongshan Jinqiao Biotechnology Co., Ltd.) overnight at 4˚C. After washing, sections were incubated with a HRP-conjugated secondary antibody (1:500; cat. no. PV-6001; Beijing Zhongshan Jinqiao Biotechnology Co., Ltd.) for 30 min at room temperature. Immunoreactivity was visualized using DAB, and sections were counterstained with hematoxylin. Images were captured using a light microscope (Olympus BX50 microscope; Olympus Corp.).

Surgical methods. All patients received general anesthesia with endotracheal intubation and were positioned prone on a soft sponge pad. To prevent perineum compression, the lower abdomen was elevated. Neurophysiological monitoring electrodes were placed during positioning, using a C-arm X-ray machine to identify the incision site 2-2.5 cm from the midline and parallel to it. A skin incision of 1.8-2.2 cm was made, followed by the separation of subcutaneous and fascial layers and the insertion of an introducer sheath measuring 1.4-1.8 cm. Blunt separation of muscle layers was facilitated by Kocher's forceps, with the introducer sheath chosen based on the tumor's longitudinal axis. During surgery, repositioning of the introducer sheath occurred as needed. Under microscopic visualization, the ligamentum flavum and soft tissues overlying the spinous process and interspinous space were carefully separated using blunt dissection. The corresponding spinous process was excised by a grinding drill system, followed by the removal of the yellow ligament within the spinal canal. The dura mater was exposed and delicately incised with microscissors. The tumor was carefully isolated from adjacent nerves and spinal cord and excised in parts under neurophysiological monitoring. The dura mater was intermittently sutured, followed by the extraction of the surgical channel sheath. Hemostasis ensued after repositioning the paraspinal muscles. The fascia, subcutaneous tissue and skin were sutured in sequence.

Statistical analysis. Only descriptive statistical analyses were performed because of the small sample size and retrospective descriptive design. Continuous variables are presented as mean ± standard deviation with ranges. Inferential statistical testing was not conducted, as the present study was not designed for hypothesis-testing analyses.

Results

Surgery. A total of six patients (two men and four women) with a mean age of 45.5±14.2 years (range, 30-69 years) were included in the present study. Tumor location was thoracic in two patients and lumbar in four patients. All patients underwent microsurgical tumor resection using the percutaneous cannulated paravertebral approach under general anesthesia with neurophysiological monitoring. Minor intraoperative adjustments of the tubular working channel were performed according to tumor location and anatomical exposure; however, no major variations in the surgical technique were required between patients.

The mean operative time was 130.8±32.9 min (range, 100-190 min), the mean intraoperative blood loss was 60±32.2 ml (range, 30-100 ml) and the mean length of hospital stay was 10.5±2.0 days (range, 8-12 days). Gross total resection was confirmed by postoperative MRI in all cases. The mean follow-up duration was 51±8.4 months (range, 38-60 months). Postoperative symptom improvement was reported during follow-up in this cohort. No radiological evidence of tumor

Table I. Demographic and clinical characteristics of patients with schwannomas.

Patient number	Age/sex	Duration of symptoms, months	Lesion location	Pathological results	Surgery date	Follow-up time, months
1	69/M	120	L1-L2	Schwannoma	December 2019	60
2	42/F	0.5	L5-S1	Schwannoma	January 2020	59
3	52/F	36	T5-T6	Schwannoma	August 2020	52
4	33/F	1	L3	Schwannoma	August 2020	52
5	47/F	6	L5	Schwannoma	March 2021	45
6	30/M	1	T10-T11	Schwannoma	October 2021	38

M, male; F, female.

Table II. Preoperative symptoms, neurological signs and postoperative outcomes.

Patient number	Symptoms	Preoperative signs	Postoperative symptoms	Postoperative signs
1	Back and left lower limb pain	Left lower limb muscle strength grade 3	None	Left lower limb muscle strength grade 4
2	Numbness in the left lower limb	Left lower limb muscle strength grade 3	None	Left lower limb muscle strength grade 4
3	Back pain	None	None	None
4	The right lower limb pain	Right lower limb muscle strength grade 3	None	Right lower limb muscle strength grade 4
5	Right hip and sacrococcygeal pain	None	None	None
6	Back pain	None	None	None

Pain scores are not presented because standardized pain assessment tools were not uniformly recorded in routine clinical practice during the study period.

Table III. Operative parameters and perioperative outcomes.

Patient number	Site of laminectomy	Amount of bleeding, cc	Surgical time, min	Length of hospital stay, days
1	L1	30	100	12
2	L5	30	130	12
3	T5	50	100	8
4	L3	50	135	8
5	L5	100	130	11
6	T10	100	190	12

recurrence or clinically apparent spinal instability was identified (Tables I-III).

Case 1. A 69-year-old man with a >10-year history of recurrent low back pain, aggravated by left lower limb pain over the preceding 2 months, was diagnosed with a schwannoma at the L1-L2 level. The tumor was microsurgically excised via a percutaneous tubular retractor-assisted paravertebral approach. Postoperative contrast-enhanced MRI demonstrated complete resection, and three-dimensional CT reconstruction confirmed a limited laminotomy. HE staining and IHC staining demonstrated features consistent with schwannoma, including diffuse S-100 positivity (Fig. 1A-I). At 60-month follow-up, sustained symptomatic improvement was observed, with no radiological evidence of tumor recurrence.

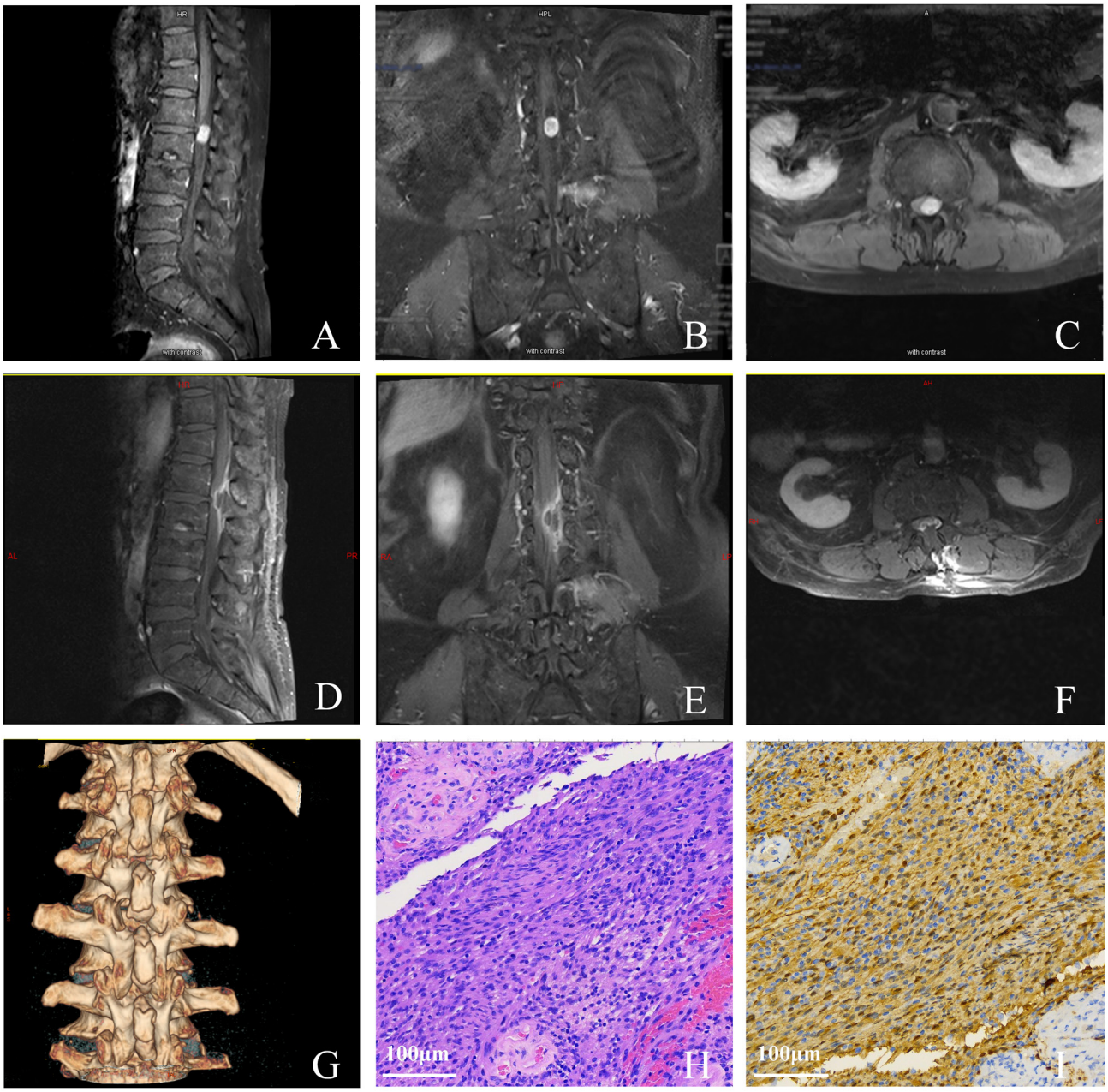

Figure 1. Representative imaging and pathological findings from Case 1. A 69-year-old man with a >10-year history of recurrent low back pain, aggravated by left lower limb pain during the preceding 2 months, was diagnosed with a schwannoma at the L1-L2 level. (A) Preoperative sagittal T1-weighted contrast-enhanced MRI. (B) Preoperative coronal T1-weighted contrast-enhanced MRI. (C) Preoperative axial T1-weighted contrast-enhanced MRI. (D) Postoperative sagittal T1-weighted contrast-enhanced MRI. (E) Postoperative coronal T1-weighted contrast-enhanced MRI. (F) Postoperative axial T1-weighted contrast-enhanced MRI. (G) Three-dimensional CT reconstruction illustrating the percutaneous tubular retractor-assisted laminotomy (posterior view). (H) Histopathological examination (x20) showing densely packed spindle cells arranged in fascicular and interlacing patterns, with indistinct borders, eosinophilic fibrillary cytoplasm and elongated, wavy nuclei, consistent with schwannoma. (I) Immunohistochemical staining demonstrating diffuse S-100 protein expression (x20).

Case 2. A 42-year-old woman presented with left lower limb numbness for 2 weeks, accompanied by aggravated pain during the preceding week. Preoperative imaging suggested a schwannoma at the L5-S1 level. Microsurgical tumor resection was performed using the percutaneous tubular retractor-assisted paravertebral approach. Postoperative contrast-enhanced MRI confirmed gross total tumor removal, and CT reconstruction revealed no postoperative hemorrhage. HE staining and IHC staining demonstrated features consistent with schwannoma, including diffuse S-100 protein positivity (Fig. 2A-I). At the 59-month follow-up, the patient's symptoms had markedly improved, and no tumor recurrence was observed on imaging.

Case 3. A 52-year-old woman presented with a 3-year history of persistent back pain. Preoperative imaging suggested a schwannoma located at the T5-T6 level. The tumor was removed microsurgically via the percutaneous tubular retractor-assisted paravertebral approach. Postoperative contrast-enhanced MRI confirmed gross total resection, and three-dimensional CT reconstruction demonstrated partial laminotomy. HE staining and IHC staining confirmed schwannoma with diffuse S-100

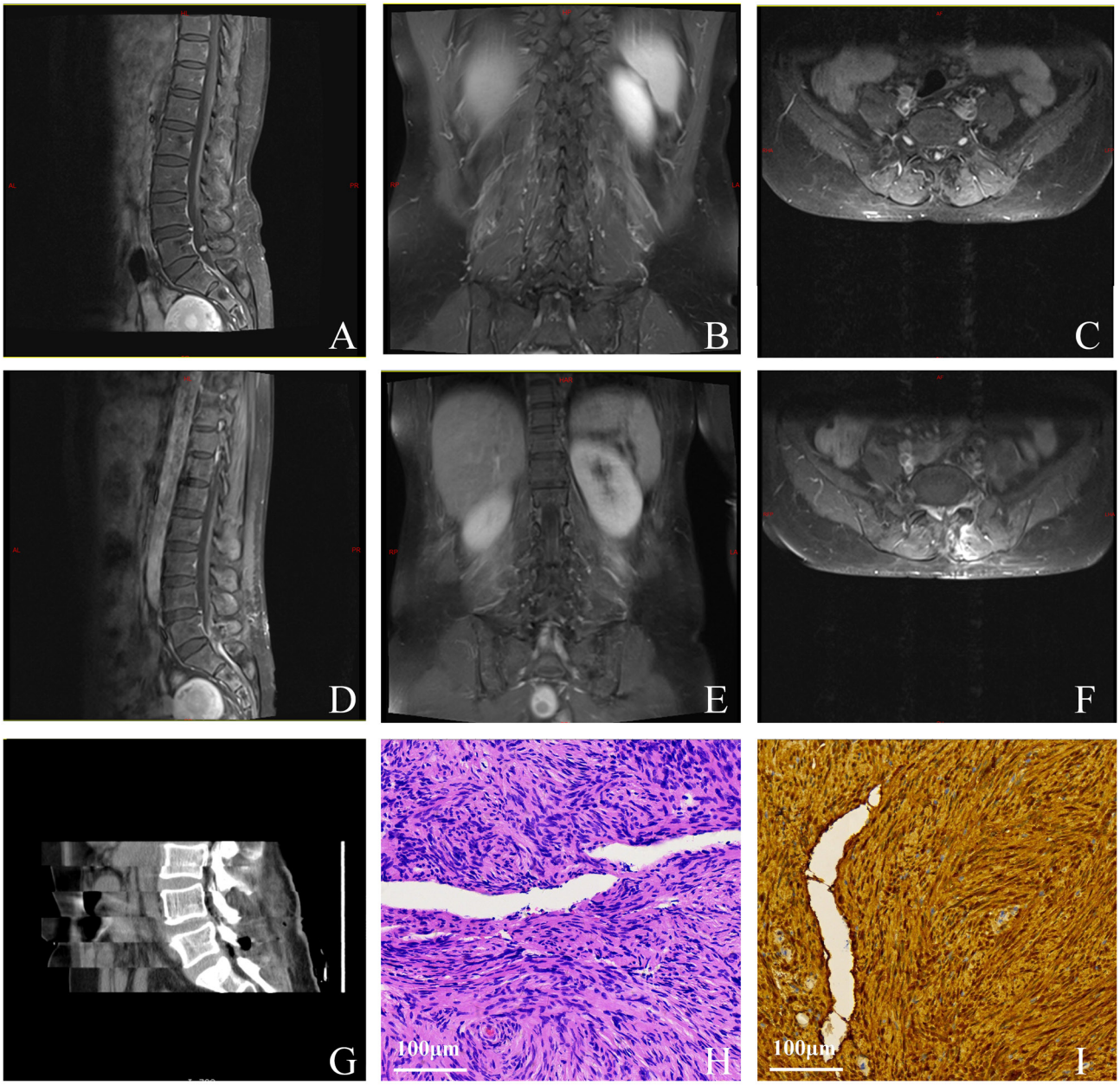

Figure 2. Representative imaging and pathological findings of Case 2. A 42-year-old woman presented with numbness in the left lower limb for 2 weeks with worsening pain during the preceding week and was diagnosed with a schwannoma at the L5-S1 level. (A-C) Preoperative contrast-enhanced MRI showing the lesion in (A) sagittal, (B) coronal and (C) axial views. (D-F) Postoperative contrast-enhanced MRI confirming gross total tumor resection. (G) Postoperative CT scan confirming the absence of delayed postoperative hemorrhage. (H) Histopathological staining showing spindle-shaped tumor cells arranged in fascicles (x20). (I) Immunohistochemical staining showing diffuse S-100 protein positivity (x20).

protein expression (Fig. 3A-I). At 52-month follow-up, the patient's symptoms improved, with no evidence of tumor recurrence.

Case 4. A 33-year-old woman presented with a 1-month history of intermittent right lower limb pain. Imaging examinations indicated a schwannoma at the L3 level. Microsurgical tumor removal was performed through the percutaneous tubular retractor-assisted paravertebral approach. Postoperative contrast-enhanced MRI confirmed gross total tumor resection, and three-dimensional CT reconstruction demonstrated limited laminotomy. HE staining and IHC staining confirmed schwannoma with diffuse S-100 protein positivity (Fig. 4A-I). At 52 months of follow-up, the patient's symptoms had improved, and no tumor recurrence was detected on imaging.

Case 5. A 30-year-old woman presented with right buttock and sacrococcygeal pain for 6 months. Preoperative imaging suggested a schwannoma at the L5 level. The tumor was resected microsurgically using the percutaneous tubular retractor-assisted paravertebral approach. Postoperative contrast-enhanced MRI confirmed gross total tumor resection, and CT reconstruction demonstrated partial removal of the vertebral canal wall. HE staining and IHC staining confirmed schwannoma with diffuse S-100 protein positivity (Fig. 5A-I). At the 45-month follow-up, the patient's

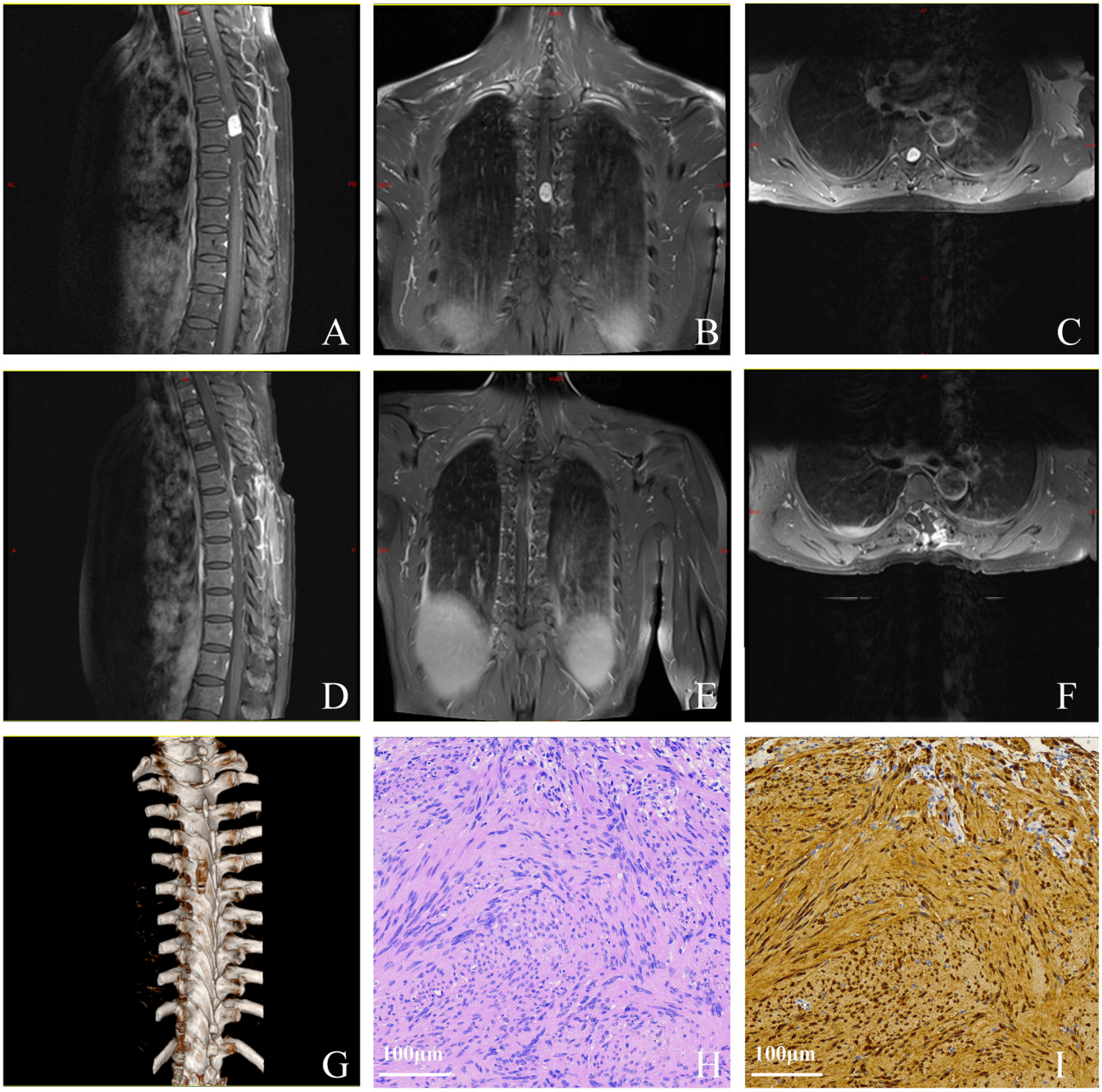

Figure 3. Representative imaging and pathological findings of Case 3. A 52-year-old woman with a 3-year history of back pain was diagnosed with a schwannoma at the T5-T6 level. (A-C) Preoperative contrast-enhanced MRI showing the lesion in (A) sagittal, (B) coronal and (C) axial views. (D-F) Postoperative contrast-enhanced MRI confirming complete tumor removal. (G) Three-dimensional CT reconstruction demonstrating partial laminotomy using the tubular retractor system. (H) Histopathological staining showing densely arranged spindle cells with elongated nuclei (x20). (I) Immunohistochemical staining showing diffuse S-100 protein expression (x20).

symptoms had notably improved, with no evidence of tumor recurrence.

Case 6. A 30-year-old man with a 1-month history of back pain was diagnosed with a T10-T11 schwannoma. Microsurgical resection of the intraspinal extramedullary tumor was performed using a percutaneous tubular retractor-assisted paraspinal approach. Preoperative contrast-enhanced MRI demonstrated a well-defined enhancing lesion, and postoperative MRI confirmed complete tumor removal. Three-dimensional CT reconstruction displayed a limited laminotomy achieved through the tubular corridor. Histopathological and immunohistochemical analyses confirmed the diagnosis of schwannoma with diffuse S-100 protein expression (Fig. 6A-I). At 38 months follow-up, the patient remained symptom-free, with no radiological evidence of recurrence or spinal instability.

Discussion

Schwannomas account for ~8% of all nervous system tumors; however, their reported incidence varies depending on anatomical location and the nerves involved. Tumors arising from the facial and vestibular nerves are the most frequently encountered (13,14). Consequently, surgical resection remains the primary treatment modality for spinal schwannomas (15).

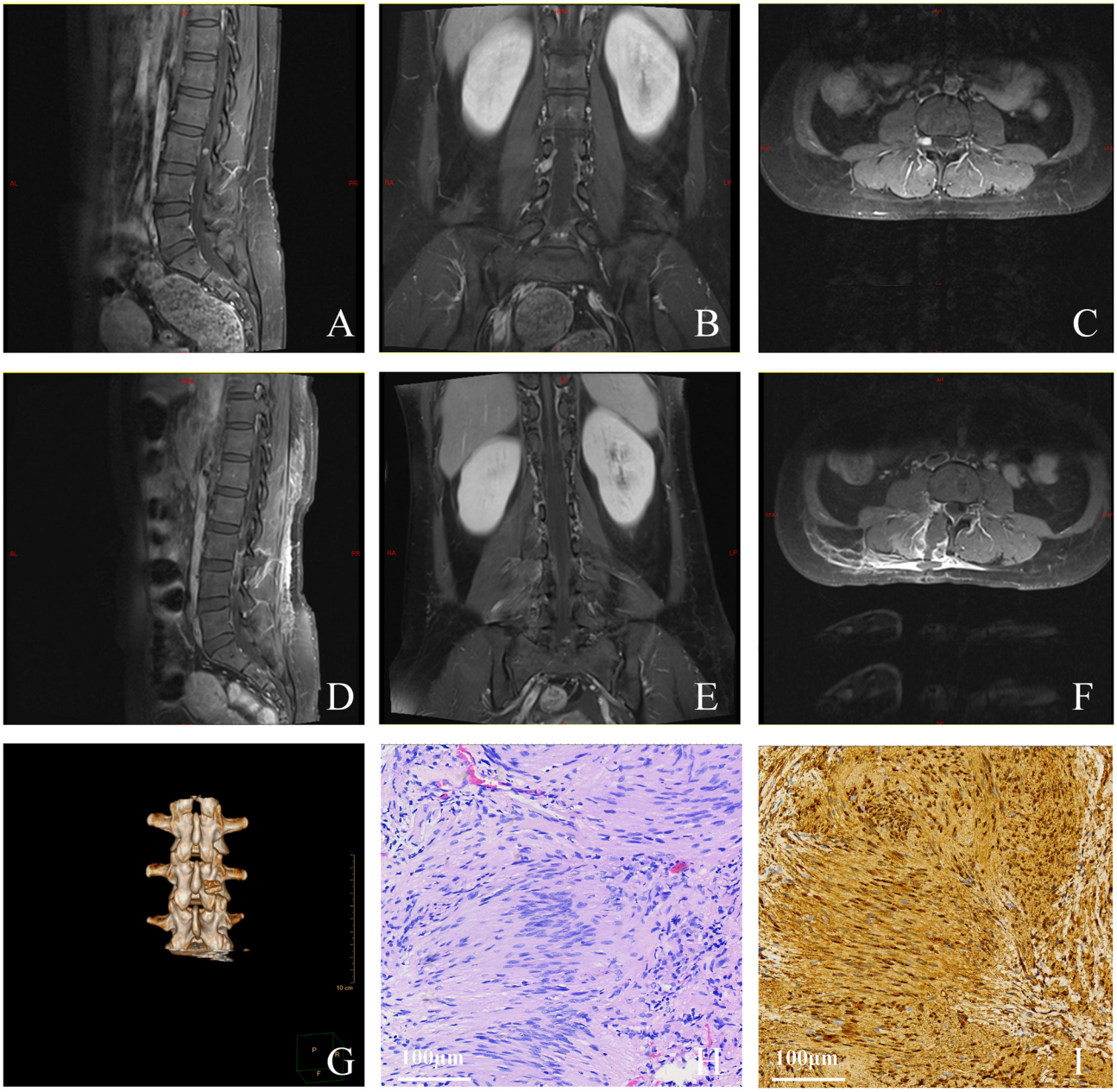

Figure 4. Representative imaging and pathological findings of Case 4. A 33-year-old woman presented with intermittent right lower limb pain for 1 month and was diagnosed with a schwannoma at the L3 level. (A-C) Preoperative contrast-enhanced MRI showing the lesion in (A) sagittal, (B) coronal and (C) axial views. (D-F) Postoperative contrast-enhanced MRI confirming gross total tumor resection. (G) Three-dimensional CT reconstruction showing limited laminotomy through the minimally invasive tubular approach. (H) Histopathological staining demonstrating spindle-shaped tumor cells arranged in interlacing fascicles (x20). (I) Immunohistochemical staining demonstrating diffuse S-100 protein positivity (x20).

The principal objectives of surgical management are maximal safe tumor removal, preservation of spinal stability and protection or recovery of neurological function. Conventional posterior approaches, including total laminectomy and unilateral hemilaminectomy, have been widely employed to achieve these objectives (16).

With the increasing adoption of minimally invasive spinal surgery, alternative posterior approaches employing tubular or fixed-channel systems have been introduced for selected intraspinal tumors. These techniques are designed to minimize soft tissue disruption and limit posterior bony resection while ensuring adequate exposure for tumor resection (17). The present study is a retrospective case series, and the following discussion is based on descriptive observations rather than comparative or causal inference. The present study reported the technical application of a percutaneous cannulated paravertebral approach and its associated clinical outcomes in a highly selected series of patients.

Clinical presentation. The clinical manifestations of intraspinal tumors are mainly determined by compression of neural structures. Radicular pain is often the initial symptom, which is more pronounced at night or in the supine position. As the lesion enlarges, sensory deficits and motor weakness may develop, and in advanced cases, bladder or bowel dysfunction can occur due to involvement of autonomic pathways (17). In

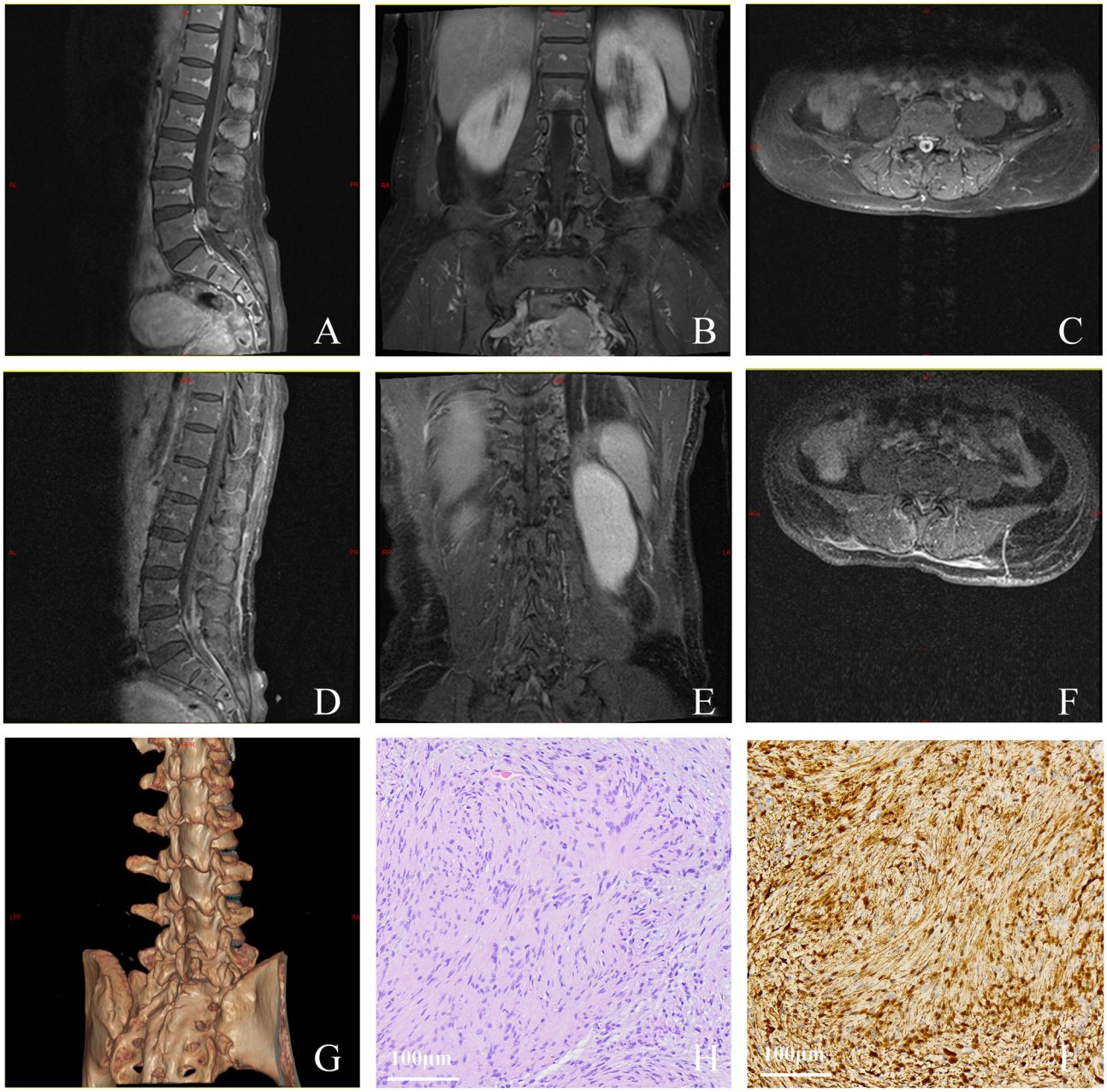

Figure 5. Representative imaging and pathological findings of Case 5. A 30-year-old woman presented with right buttock and sacrococcygeal pain for 6 months and was diagnosed with a schwannoma at the L5 level. (A-C) Preoperative contrast-enhanced MRI showing the lesion in (A) sagittal, (B) coronal and (C) axial views. (D-F) Postoperative contrast-enhanced MRI confirming complete tumor resection. (G) Three-dimensional CT reconstruction demonstrating partial removal of the vertebral canal wall via the tubular surgical approach. (H) Histopathological staining showing spindle-shaped tumor cells with eosinophilic cytoplasm arranged in fascicles (x20). (I) Immunohistochemical staining showing diffuse S-100 protein expression (x20).

the current cohort, lumbar back pain was the most frequently reported symptom, followed by lower limb pain or sensory disturbance. These clinical features are consistent with previously reported presentations of extradural or intradural extramedullary schwannomas (18,19).

Spinal stability and surgical approach. Developing minimally invasive spinal techniques has provided alternative strategies for addressing certain limitations of conventional open surgery, particularly with respect to reducing intraoperative blood loss and limiting disruption of posterior spinal structures. In 1983, Denis (20) proposed the widely accepted three-column theory of spinal injury, which remains fundamental for understanding spinal stability. One of the classical surgical approaches for intraspinal tumors is total laminectomy, first described by Gowers in 1888. This technique involves the removal of the ligamentum flavum, interspinous ligaments, spinous process, and bilateral laminae to achieve sufficient exposure of the lesion (1,21). With advances, internal fixation systems were introduced to address concerns regarding postoperative instability.

The posterior column of the lumbar spine, including the facet joints and associated ligaments, is crucial for segmental stability and preventing spondylolisthesis. Disruption of these elements can lead to abnormal flexion or anterior vertebral translation, resulting in spinal instability (22). In total, 5-10%

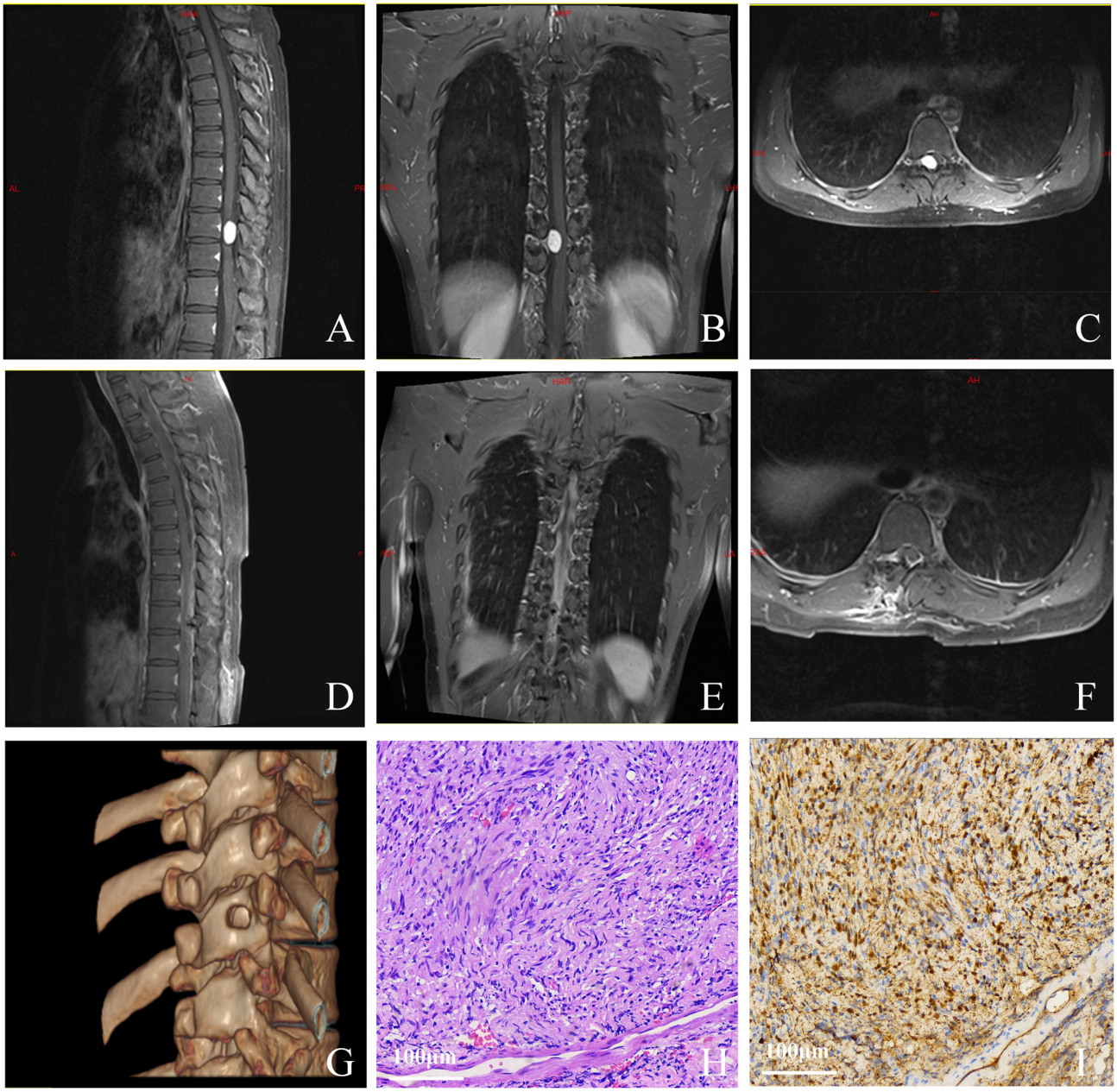

Figure 6. Representative imaging and pathological findings from Case 6. A 30-year-old male presented with a 1-month history of back pain and was diagnosed with a schwannoma at the T10-T11 level. (A) Preoperative sagittal T1-weighted contrast-enhanced MRI. (B) Preoperative coronal T1-weighted contrast-enhanced MRI. (C) Preoperative axial T1-weighted contrast-enhanced MRI. (D) Postoperative sagittal T1-weighted contrast-enhanced MRI. (E) Postoperative coronal T1-weighted contrast-enhanced MRI. (F) Postoperative axial T1-weighted contrast-enhanced MRI. (G) Three-dimensional CT reconstruction demonstrating the laminotomy performed via the percutaneous tubular retractor (posterior view). (H) Histopathological staining (x20) showing densely packed spindle cells arranged in fascicular and interlacing patterns, with indistinct borders, eosinophilic fibrillary cytoplasm, and elongated, wavy nuclei, consistent with schwannoma. (I) Immunohistochemical staining demonstrating diffuse S-100 protein expression (x20).

of patients undergoing total laminectomy required secondary surgical intervention for postoperative instability (19). Consequently, several modified posterior approaches have been developed to limit posterior column injury (23).

Semi-laminectomy, introduced in the 1980s, aims to reduce damage to posterior elements while ensuring adequate surgical exposure. This approach involves a unilateral incision, limited laminar resection, preservation of contralateral soft tissues, retention of the spinous process, contralateral lamina and ligamentum flavum. The general aim of minimally invasive surgery for intraspinal tumors is to limit paraspinal muscle injury, preserve spinal stability and mobility and provide sufficient operative visualization (24). Microchannel-assisted surgery could be performed without radiographic evidence of postoperative instability in appropriately selected patients (25).

Comparison with conventional posterior approaches. Clinically, conventional posterior approaches, such as total laminectomy and hemilaminectomy, remain established approaches for the resection of intraspinal tumors (26,27). However, extensive posterior element removal may be associated with postoperative complications such as paraspinal muscle atrophy, cerebrospinal

fluid leakage and delayed spinal instability, particularly in multilevel or lumbar procedures (28-30). Reported rates of postoperative instability and secondary fixation vary across studies, reflecting differences in tumor characteristics, surgical extent and follow-up duration (31).

Hemilaminectomy and other modified posterior approaches have been introduced to reduce these risks by limiting posterior column disruption. However, they still involve detachment of paraspinal muscles and partial removal of stabilizing structures. In this context, minimally invasive posterior approaches have been increasingly explored as a means of reducing approach-related morbidity, without replacing conventional techniques (32,33). In the present case series, no clinically apparent postoperative instability was observed during follow-up. However, this finding, based on a small, non-comparative cohort, should not be interpreted as evidence of superiority over traditional approaches.

Technical characteristics of the percutaneous approach. The percutaneous approach is analogous to keyhole techniques in cranial surgery and is designed to expose and resect lesions through a limited surgical corridor. It is characterized by a small skin incision and preservation of midline ligamentous structures, which may reduce paraspinal muscle disruption in selected cases. A non-expandable tubular channel provides targeted lesion access without extensive detachment of the surrounding paraspinal musculature, thereby limiting muscle-related disruption (34). As previously reported, spinal biomechanical integrity is largely preserved when laminar resection does not exceed 50% (35). These findings provide a theoretical rationale for limiting posterior element removal in minimally invasive posterior approaches for selected cases.

Surgical experience and technical observations. Based on the diagnosis and treatment of the present cohort, some technical considerations were identified during the percutaneous paravertebral approach. First, accurate preoperative localization is essential. Fluoroscopic guidance using a C-arm should be performed repeatedly to confirm the target level before incision and after placement of the tubular sleeve to avoid level misidentification. Second, a skin and muscle incision of 2.0-2.5 cm is created, followed by gentle muscle dilation to minimize sleeve-related muscle injury. Third, after a limited hemilaminectomy and removal of the ligamentum flavum, controlled vertical adjustment of the tubular sleeve may facilitate adequate exposure of the operative field while minimizing manipulation of the facet joint. Fourth, following dural opening, bilateral dural suspension can be used to expand the subdural working space within the confined corridor. Fifth, given the limited operative space, initial intradural tumor decompression is often necessary before mobilization of the lesion. After decompression, intraoperative neurophysiological monitoring can help identify the functional nerve root associated with the tumor. If no myoelectric activity is detected, resection of the involved nerve is considered. If myoelectric activity is found, careful microsurgical dissection of the tumor from the nerve root is recommended, particularly for small lesions. Sixth, after tumor removal, careful inspection for active bleeding is required, as blind spots may exist within the restricted operative field, necessitating adjustment of the viewing angle. Seventh, watertight dural closure in a restricted working space requires specialized instruments and technical experience. During withdrawal of the tubular sleeve, attention should be paid to achieve adequate hemostasis of the paraspinal musculature. Routine muscle suturing is not required.

Recent developments in spinal oncology have emphasized careful patient selection and refinement of surgical techniques to balance adequate tumor resection with preservation of neurological function and spinal stability (12). In particular, contemporary surgical practice increasingly favors minimally invasive strategies aimed at reducing approach-related tissue disruption while maintaining sufficient visualization and operative safety. Bibliometric analyses of oncologic surgery have demonstrated a progressive shift toward precision-oriented and minimally invasive techniques designed to reduce perioperative morbidity and facilitate functional recovery (36).

Within this evolving context, the percutaneous paravertebral approach evaluated in the present study represents a technical adaptation intended to minimize paraspinal muscle injury and preserve posterior ligamentous structures. However, the applicability of this technique remains dependent on tumor size, location and anatomical characteristics. Accordingly, the present findings should be interpreted as preliminary observations derived from a highly selected cohort rather than definitive evidence supporting broader clinical adoption.

Limitations and clinical implications. The percutaneous approach for intraspinal tumor surgery has been reported to produce favorable clinical outcomes in selected cases under microscopic visualization (37). With continued advances in surgical instruments and imaging technology, the percutaneous paravertebral approach may represent a potential alternative surgical option for selected patients. The strict inclusion criteria in the present study, including small tumor size, single-level involvement and predominantly extradural location, likely contributed to the observed outcomes, and selection bias cannot be excluded. However, its application is inherently limited by the restricted operative corridor and exposure range. Therefore, this technique is generally not suitable for large intraspinal tumors, intramedullary lesions or vascular tumors, underscoring the importance of strict patient selection.

In addition, successful application of this approach requires proficiency in microsurgical techniques within confined spaces and a thorough understanding of spinal anatomy and biomechanics, which entails a substantial learning curve (38). In the present cohort, the percutaneous paravertebral approach was associated with limited disruption of paraspinal muscles and ligaments, and postoperative outcomes were assessed based on clinical symptoms and radiological findings. Standardized functional or neurological outcome measures were not collected, representing an important limitation of the present study. A further limitation is the absence of standardized quantitative pain assessment data. During the study period, structured pain scoring systems were not routinely recorded in clinical documentation; therefore, postoperative pain outcomes were evaluated qualitatively based on clinical records. Moreover,

the small sample size and a maximum follow-up duration of 60 months further restrict the strength of the conclusions. Accordingly, these findings should be regarded as exploratory and hypothesis-generating rather than confirmatory. Future studies with larger cohorts, standardized outcome assessments and longer follow-up are required to more clearly define the clinical role of this technique in managing intraspinal tumors.

In conclusion, the percutaneous cannulated paravertebral approach was applied for the microscopic resection of small, single-level intraspinal schwannomas in the present retrospective case series. Gross total resection was achieved in all cases without radiological evidence of recurrence observed during follow-up. Although these findings suggest that this technique is feasible in selected patients, further prospective studies are required to better define its safety profile and clinical applicability.

Acknowledgements

Not applicable.

Funding

No funding was received.

Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

SY and NW conceptualized the study. SY conducted the literature search, drafted the initial manuscript and prepared the figures. NW provided supervision, revised the manuscript and finalized the final version of the manuscript. SY and NW confirmed the authenticity of all the raw data. All authors have read and approved the final version of the manuscript.

Ethics approval and consent to participate

The present study involving human participants was reviewed and approved by the Ethics Committee of The First People's Hospital of Changde City. All patients/participants provided their written informed consent to participate in this study. Ethics approval no. YX-2024-005-01.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. Soriano Sánchez JA, Soto García ME, Soriano Solís S, Rodríguez García M, Trejo Huerta P, Sánchez Escandón O, Flores Soria ER and Romero-Rangel JAI: Microsurgical resection of intraspinal benign tumors using non-expansile tubular access. World Neurosurg 133: e97-e104, 2020.
2. Bin R, Lin C, Wang J, Deng J, Chen Z and Yang B: Efficacy of posterior laminectomy approach for treating intraspinal neurilemmoma. Chin J Spine Spinal Cord 22: 688-692, 2012.
3. Romano N, Federici M and Castaldi A: Imaging of cranial nerves: A pictorial overview. Insights Imaging 10: 33, 2019.
4. Hyun SJ and Rhim SC: Giant cauda equina schwannoma with dystrophic calcifications: Case report and review of the literature. J Korean Neurosurg Soc 51: 105-108, 2012.
5. Weber C, Gulati S, Jakola AS, Habiba S, Nygaard ØP, Johannesen TB and Solheim O: Incidence rates and surgery of primary intraspinal tumors in the era of modern neuroimaging: A national population-based study. Spine (Phila Pa 1976) 39: E967-E973, 2014.
6. Li Y, Yang X, Zhou H, Zheng J, Hui X, Li H and Liu Y: Lateral ventricle ectopic schwannoma: Case report and literature review. Front Oncol 13: 1090509, 2023.
7. Birkenbeuel J, Vu K, Lehrich BM, Abouzari M, Cheung D, Khosravi P, Sahyouni R, Ziai K, Moshtaghi O, Sahyouni S and Djalilian HR: Medical malpractice of vestibular schwannoma: A 40-year review of the united states legal databases. Otol Neurotol 40: 391-397, 2019.
8. Moran C and Bolger C: Operative techniques for cervical radiculopathy and myelopathy. Adv Orthop 2012: 916149, 2012.
9. Palmisciano P, Ferini G, Watanabe G, Conching A, Ogasawara C, Scalia G, Bin-Alamer O, Haider AS, Passanisi M, Maugeri R, *et al*: Surgical management of craniovertebral junction schwannomas: A systematic review. Curr Oncol 29: 4842-4855, 2022.
10. Yuan C, Wang J, Zhou Y and Pan Y: Endoscopic lumbar discectomy and minimally invasive lumbar interbody fusion: A contrastive review. Wideochir Inne Tech Maloinwazyjne 13: 429-434, 2018.
11. Skovrlj B, Belton P, Zarzour H and Qureshi SA: Perioperative outcomes in minimally invasive lumbar spine surgery: A systematic review. World J Orthop 6: 996-1005, 2015.
12. Ahn Y: Current techniques of endoscopic decompression in spine surgery. Ann Transl Med 7 (Suppl 5): S169, 2019.
13. Ledbetter LN and Leever JD: Imaging of intraspinal tumors. Radiol Clin North Am 57: 341-357, 2019.
14. Wu YL, Chang CY, Hsu SS, Yip CM, Liao WC, Chen JY, Liu SH and Chen CH: Intraspinal tumors: Analysis of 184 patients treated surgically. J Chin Med Assoc 77: 626-629, 2014.
15. Li T, Wang G, Bai H, Zou H, Gong F, Yang R, Zhan Y, Yao S, Wang Y, Department of Neurosurgery, General Hospital of Southern Theatre Command: Diagnosis and microsurgical treatment of intraspinal schwannomas. Chin J Minim Invasive Neurosurg 26: 123-126, 2021.
16. Wang N, Cheng J, Leng H, *et al*: Clinical effect of microsurgical resection of subdural extramedullary tumors via hemilaminec tomy. J Int Neurol Neurosurg 47: 172-175, 2020.
17. Chowdhury F, Haque M, Kawsar K and Alam S: Removal of cervical spinal tumor with large inferio-lateral extension through anterolateral (interscalene and transforaminal) approach. J Neurosci Rural Pract 4: 357-360, 2013.
18. Zhai P, Wu H, Tong L, Wang Y and Sun Z: Posterior paramedian approach combined with a novel inverted V-shaped surgical access for intraspinal schwannomas: A retrospective case series study. J Orthop Surg Res 18: 358, 2023.
19. Ogose A, Kawashima H, Hatano H, Ariizumi T, Sasaki T, Yamagishi T, Oike N, Inagawa S and Endo N: The natural history of incidental retroperitoneal schwannomas. PLoS One 14: e0215336, 2019.
20. Denis F: The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine (Phila Pa 1976) 8: 817-831, 1983.
21. Lei D, Zhou Y, Yao D, Zhang F, Wang X, Jiang X, Xiong N and Zhao H: Efficacy of unilateral hemilaminectomy for intraspinal tumor resection: A systematic review and meta-analysis. Ann Palliat Med 10: 984-999, 2021.
22. Duan Y, Ma J, Miao S, Zhang J, Deng J and Wu H: Comparison of total laminectomy and pedicle screw internal fixation with ultrasonic- and microscopic-assisted laminectomy replantation for tumors of the lumbar spinal canal: A retrospective study of 60 cases from a single center. Med Sci Monit 27: e931768, 2021.
23. Onyia CU and Menon SK: Laminectomy versus laminoplasty in the surgical management of long-segment intradural spinal tumors: Any difference in neurological outcomes? Asian J Neurosurg 13: 1128-1133, 2018.
24. Gowers WR and Horsley V: A case of tumour of the spinal cord. Removal; recovery. Med Chir Trans 71: 377-430, 1988.

25. Chen C, Cai G, Zhang W, Fu C, Zhang H, Wang R, Chen Z, Wang C and Shi S: Efficacy analysis of paraspinal approach by percutaneous tubular retractor system for microsurgical resection of space-occupying lesions in cervical spinal canals. Chin J Neurosurg 31: 1018-1022, 2015.
26. Newman WC, Berry-Candelario J, Villavieja J, Reiner AS, Bilsky MH, Laufer I and Barzilai O: Improvement in quality of life following surgical resection of benign intradural extramedullary tumors: A prospective evaluation of patient-reported outcomes. Neurosurgery 88: 989-995, 2021.
27. Dobran M, Paracino R, Nasi D, Aiudi D, Capece M, Carrassi E, Lattanzi S, Rienzo AD and Iacoangeli M: Laminectomy versus unilateral hemilaminectomy for the removal of intraspinal schwannoma: Experience of a single institution and review of literature. J Neurol Surg A Cent Eur Neurosurg 82: 552-555, 2021.
28. Ma Y, Mao L, Liu G, Hu L and Chen K: Research progress on the posterior midline lumbar spinous process-splitting approach. Orthop Surg 17: 990-998, 2025.
29. West JL, De Biase G, Abode-Iyamah K, Nottmeier EW, Deen HG, Chen SG, Huynh T, Fox WC, Bydon M, Miller DA and Clendenen SR: Initial results of precision treatment of postoperative cerebrospinal fluid leak with ultrasound-guided epidural blood patch. World Neurosurg 153: e204-e212, 2021.
30. Cohen PR and Dorros SM: Lumbar stenosis spinal surgery-associated cerebrospinal fluid leak without headache: An autobiographical case report. Cureus 14: e25253, 2022.
31. Nong L, Zhou D, Xu N, Du R and Jiang X: Lamina replacement with titanium plate fixation improves spinal stability after total lumbar laminectomy. Comput Methods Biomech Biomed Engin 18: 1753-1759, 2015.
32. Mladenov K, Kunkel P and Stuecker R: Hemivertebra resection in children, results after single posterior approach and after combined anterior and posterior approach: A comparative study. Eur Spine J 21: 506-513, 2012.
33. Zhang J, Shengru W, Qiu G, Yu B, Yipeng W and Luk KD: The efficacy and complications of posterior hemivertebra resection. Eur Spine J 20: 1692-1702, 2011.
34. Chen CM, Yu XG and Wang S: Tubular access spine surgery: A new concept of minimal invasive spine surgery. Zhonghua Yi Xue Za Zhi 100: 244-246, 2020 (In Chinese).
35. Li J, Huang S, Ju Y and Wang B: A comparison of unilateral hemilaminectomy and total laminectomy for the removal of intraspinal tumors. Chin J Nervous Mental Dis 33: 139-142, 2007.
36. Wu Z, Chen Y, Yu G and Ma Y: Research trends and hotspots in surgical treatment of recurrent nasopharyngeal carcinoma: A bibliometric analysis from 2000 to 2023. Asian J Surg 47: 2939-2941, 2024.
37. Raynor RB, Pugh J and Shapiro I: Cervical facetectomy and its effect on spine strength. J Neurosurg 63: 278-282, 1985.
38. Zong S, Zeng G, Du L, Fang Y, Gao T and Zhao J: Treatment results in the different surgery of intradural extramedullary tumor of 122 cases. PLoS One 9: e111495, 2014.