

Posterolateral Sulcus Approach for Spinal Intramedullary Tumor of Lateral Location: Technical Note

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Abstract

Posterolateral sulcus (PLS) approach of the spinal cord, being equivalent to the dorsal root entry zone myelotomy, may offer the satisfactory exposure of the spinal intramedullary tumor if applied appropriately. Eight consecutive patients with spinal intramedullary tumors of lateral location underwent the surgery of PLS approach in our institute. There were 6 male and 2 female patients, ranging in age from 34 to 72 years (mean, 57 years). PLS approach was indicated for the intramedullary tumor situated laterally in the spinal cord and that do not contact the posterior or lateral surfaces on magnetic resonance (MR) images before surgery. Total removal of the tumor was achieved in 6 cases except of 2 cases of anaplastic astrocytoma. All 6 patients with total removal of the tumor demonstrated the modest or mild deterioration of motor function on the approach side early after surgery, which resolved within 1 month after surgery. Average grade of the modified McCormick functional schema was 3.5 before surgery and improved to 3.0 at 3 months after surgery. These 6 patients demonstrated satisfactory pain relief early after surgery. Average grade of the sensory pain scale was 2.7 before surgery and improved to 1.7 at 3 months after surgery. PLS approach can be one of the surgical choices to the spinal intramedullary tumors, if applied appropriately. Better indication for PLS approach may be the tumors of the uneven location within the spinal cord associated with moderate or severe local pain.

Key words: cavernous malformation, dorsal root entry zone, metastasis, posterior lateral sulcus, spinal intramedullary tumor

Introduction

In the surgical approach for spinal intramedullary tumors, posterior median sulcus approach is preferably used for most gliomas such as ependymomas or astrocytomas, whereas lateral myelotomy from the point at which the lesion can be recognized under the microscope may be suitable for most vascular tumors such as hemangioblastomas or cavernous malformations.^{1–11,13,16} Here, we report the utility of posterolateral sulcus (PLS) approach, being equivalent to the dorsal root entry zone (DREZ) myelotomy, in the selected cases of spinal intramedullary tumors of lateral location. Although PLS approach to the spinal intramedullary tumors was not an altogether new approach, it may offer the satisfactory exposure of the tumor if applied appropriately after careful selection.^{1,2,10,11,16} We retrospectively analyzed the surgical outcome of the consecutive 8 patients, and

discuss its technical constraints and disadvantage as well.

Materials and Methods

I. Patient population

Eight consecutive patients with spinal intramedullary tumors of lateral location underwent the surgery of PLS approach in our institute. There were 6 male and 2 female patients, ranging in age from 34 years to 72 years (mean, 57 years). All patients underwent comprehensive evaluation before surgery. The neurological condition before and after surgery was assessed based on the modified McCormick functional schema and sensory pain scale (Table 1).^{4,9,15}

Onset of the symptom was acute (Patient 1), progressive (Patient 2, 3, 7, 8) or gradual (Patient 4, 5, 6). All patients presented with some degree of pain or dyesthesia of local distribution, impairing quality of life (QOL). The location of the tumors was cervical (4 cases) or thoracic (4 cases). Follow-up

period after surgery ranged from 1 month to 47 months (mean, 11.5 months). Clinical characteristics of all patients is summarized in Table 2.

II. Diagnostic imaging before surgery

PLS approach was indicated for the intramedullary tumors situated laterally in the spinal cord and that do not contact the posterior or lateral surfaces on magnetic resonance (MR) images before surgery

Table 1 Modified McCormick functional schema and sensory pain scale

Grade	Definition
1	Neurologically normal; mild focal deficit not significantly affecting limb function; mild spasticity or reflex abnormality; normal gait
2	Presence of sensorimotor deficit affecting function of involved limb; still functions & ambulates independently; mild gait difficulty; mild pain or dysesthesia, slightly impairing QOL
3	Presence of sensorimotor deficit affecting function of involved limb; still functions & ambulates independently; moderate gait difficulty; moderate pain or dysesthesia, fairly impairing QOL
4	More severe neurological deficit; requires cane/brace for ambulation or significant bilateral upper-extremity impairment; may or may not function independently
5	Severe deficit; requires wheelchair or cane/brace w/bilateral upper-extremity impairment; usually not independent

Grade	Definition
1	No symptoms
2	Mild pain or dysesthesia, slightly impairing QOL
3	Moderate pain or dysesthesia, fairly impairing QOL
4	Severe pain or dysesthesia, significantly impairing QOL

QOL: Quality of life.

Table 2 Clinical characteristics of 8 consecutive patients

Patient	Age	Sex	Spine level	Tumor deviation	Onset	Intramedullary hemorrhage	Tumor removal	Pathology
1	34	M	C2	Left	Acute	+	Total	Cavernous malformation
2	67	M	C2	Right	Progressive	-	Total	Metastasis
3	46	F	Th4	Right	Progressive	-	Partial	Anaplastic astrocytoma
4	72	M	C3	Right	Gradual	-	Total	Subependymoma
5	68	M	Th4	Left	Gradual	+	Total	Cavernous malformation
6	67	F	Th10	Right	Gradual	+	Total	Fibrosis with hyalinization
7	65	M	Th12	Right	Progressive	-	Total	Metastasis
8	37	M	C2	Left	Progressive	-	Biopsy	Anaplastic astrocytoma

(Fig. 1B). In case if the MR images before surgery clearly suggested the central or subpial growing of the tumor, then PLS approach was not applied (Fig. 1A, C). When conventional MR images such as T₁- or T₂-weighted images failed to determine the tumor location in the axial plane, precise location of the tumor was assessed using contrast-enhanced constructive interference in steady-state (CISS) MR imaging or myelographic MR imaging using true fast imaging with steady-state precession (TrueFISP) sequences.

III. Surgical technique

The patient was placed in the lateral oblique (45 degrees) position under general anesthesia.^{4,8,13)} The side of the tumor location was placed to the upper side. The patient's thorax was elevated to 15 degrees and the head was maintained in neutral flexion without any rotation. All pressure points were securely padded to avoid any venous congestion or peripheral nerve injury. This was particularly comfortable for the surgeon and met the need for spinal immobilization and absence of abdominal pressure as well. Transcranial motor evoked potentials (MEPs) was routinely set up as the intraoperative neurophysiological monitoring.

Laminectomy was performed in the usual manner of en bloc fashion. The laminectomy was made long enough to expose the entire lesion and widened to the medial pedicular surface. The dura mater was opened with preserving the arachnoid membrane. The arachnoid membrane was also opened with care not to avoid the damage at the points of arachnoid adherence or vascular connection. The vascular pattern or overswelling of the spinal cord was inspected first in comparison with MR images before surgery (Fig. 3A, 5A). The linear incision along the PLS was made just on the tumor location after careful inspection of dorsal nerve roots. The dorsal nerve roots are attached to the spinal cord along a shallow vertical groove of PLS, which

naturally continues to the posterolateral tract of Lissauer (Fig. 2). The opening was made using a diamond knife (Fig. 3B, 5B). Crossing vessels were coagulated with the microbipolar at very low power levels under continuous saline irrigation. The myelotomy was extended rostrally or caudally by meticulously splaying the spinal tissue using a microdissector (Fig. 3C, 5C). Meticulous dissection of the posterolateral tract of Lissauer revealed the cleavage plane between the dorsal and lateral columns with the microvasculature of the spinal cord (Fig. 2). The cleavage plane led to the substantia gelatinosa at the posteromedial aspect of the dorsal horn of gray matter. After the tumor was encountered, the gentle dissection of the tumor-cord interface was continued in the longitudinal plane over the extent of the tumor (Fig. 3D, 5D). Stay sutures, usually of 8-0 monofilament nylon, were usually sewn between the pia and the dura mater to keep the spinal cord incision gently open. The microcoagulation of the tumor surface was used to shrink back the surface of the tumor and draw it away from the spinal cord surface, with preservation of the fine vessels and

without current spread or heating of the adjacent spinal tissue. To protect the adjacent dorsal and lateral columns, the tumor or capsule was removed segmentally or in one piece carefully. In the case of cavernous malformation, the surrounding hemosiderin stained tissue was not resected. When the removal was complete, there was usually little or no need for further hemostasis (Fig. 3E, 5E). Entire procedure was accomplished in a field with no significant bleeding as much as possible. The pial stay sutures were then removed. The shape of the spinal cord was restored by suturing the pial edges together (Fig. 3F, 5F). Arachnoid membrane was then closed with the dura mater, in order to reduce the chance of postoperative arachnoid adhesion. Resected laminae were constructed as lift-up style of cervical spine or on-lay style of thoracic spine using titanium mini-plate and screws.^{4,13)}

Results

Total removal of the tumor was achieved in 6 cases except of 2 cases of anaplastic astrocytoma. In 2 cases

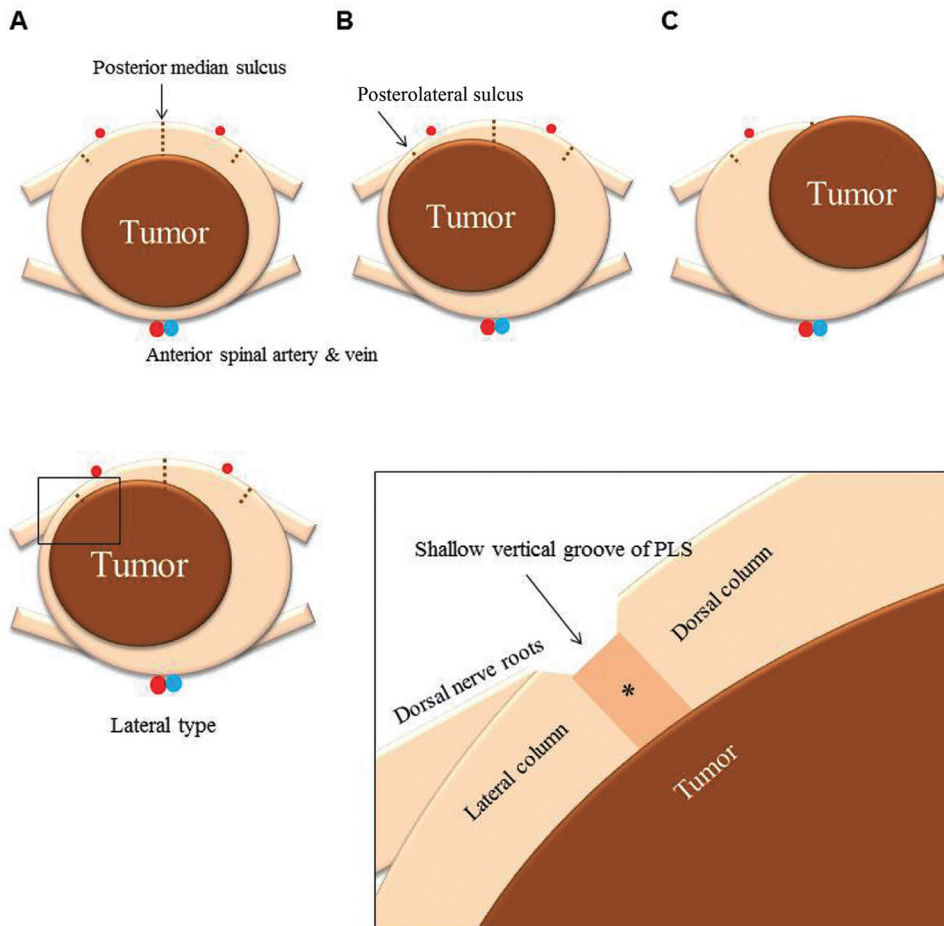


Fig. 1 Diagram illustrating the three types of spinal intramedullary tumor in the axial plane. A: Central type, B: Lateral type, and C: Subpial type.

Fig. 2 Higher magnification of boxed area in diagram of lateral type showing the surgical dissection route via posterolateral sulcus (PLS) approach. Meticulous dissection of the posterolateral tract of Lissauer (*) revealed the cleavage plane between the dorsal and lateral columns with the microvasculature of the spinal cord.

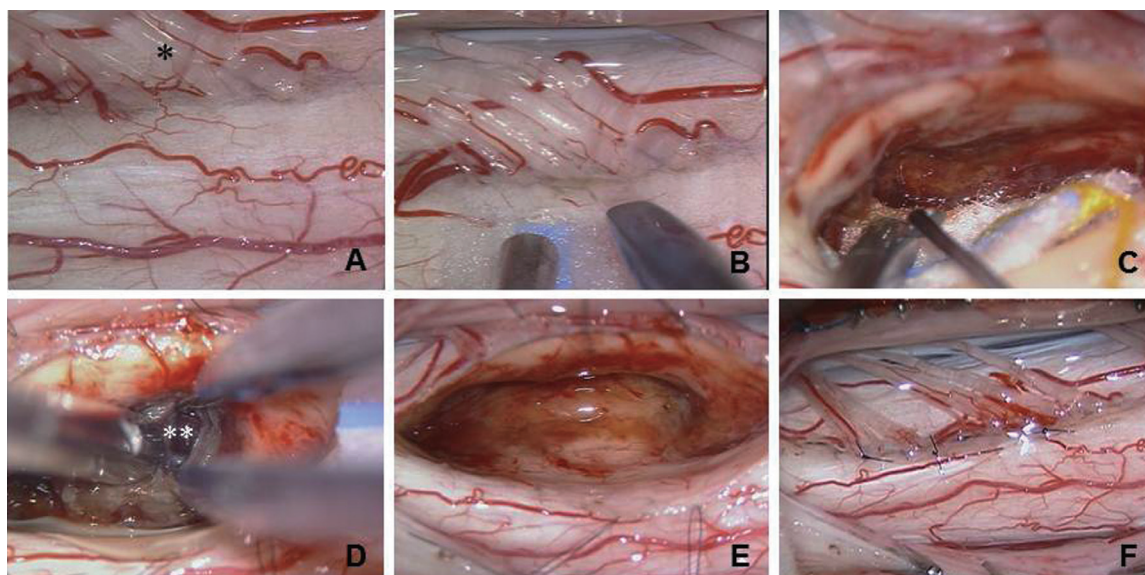


Fig. 3 Intraoperative photographs in Patient 1 demonstrating the surgical steps by posterior lateral sulcus approach. **A:** The spinal cord appeared a little bit swollen. C3 dorsal nerve roots on the left side (*) were identified. **B:** The opening of the posterior lateral sulcus was made using a diamond knife. **C:** The myelotomy can be extended rostrally or caudally by meticulously splaying the spinal tissue using a microdissector. **D:** Careful dissection within the spinal cord revealed the tumor (**)-cord interface with the surrounding hemosiderin stained tissue. **E:** There was little or no need for further hemostasis after the complete removal of the tumor. **F:** The shape of the spinal cord was restored by suturing the pial edges together.

of anaplastic astrocytoma, radical resection of the tumor was not possible because there was no clear tumor-cord interface. Pathological examination of the tumor revealed 2 cases of cavernous malformation accompanying intramedullary hemorrhage, 2 cases of metastasis from renal cell carcinoma, 2 cases of anaplastic astrocytoma, 1 case of subependymoma, and 1 case of unknown pathology of fibrosis with hyalinization accompanying intramedullary hemorrhage. There was no surgical mortality. There has been neither clinical nor radiological evidence of local recurrence after surgery during the follow-up period.

Functional outcome

All 6 patients with total removal of the tumor demonstrated the modest or mild deterioration of motor function on the approach side early after surgery, which resolved within 1 month after surgery in all cases. Average grade of the modified McCormick functional schema was 3.5 before surgery and improved to 3.0 at 3 months after surgery. These 6 patients also demonstrated pain relief early after surgery. Average grade of the sensory pain scale was 2.7 before surgery and improved to 1.7 at 3 months after surgery. It was rare for us to encounter the significant worsening of proprioception associated with dorsal column dysfunction after surgery,

Table 3 Functional outcome

Patient	Gait		Local pain	
	Preop.	Postop.	Preop.	Postop.
1	2	1	3	1
2	5	4	2	1
4	2	2	2	2
5	3	3	4	2
6	4	4	2	2
7	5	4	3	2
Mean	3.5	3.0	2.7	1.7

although objective and accurate assessment was not provided. Surgical outcome of these 6 patients is summarized in Table 3.

Illustrative Cases

Patient 1: A 34-year-old male was admitted with the chief complaint of acute motor-weakness on the left side. He also had severe dysesthesia on the right side. The symptom was more apparent on the upper extremities compared to lower extremities. Neurological examination on admission showed

Brown-séquad syndrome on the left side with mild spasticity. Assessment of neurological condition before surgery suggested Grade 2 of the modified McCormick functional schema and Grade 3 of the sensory pain scale. MR imaging of the cervical spine revealed extensive enlargement and intramedullary mixed signal of the spinal cord at C2 to C3 on T₂-weighted MR images (Fig. 4A). T₂*-weighted gradient-echo MR images showed mixed low signal within the spinal cord, which was consistent with blood degradation products and deviated to left side and on T₂-weighted images (Fig. 4B). Imaging diagnosis before surgery was the intramedullary hemorrhage associated with cavernous malformation.

The patient underwent the C2 to C3 osteoplastic laminotomy for the evacuation of the intramedullary hemorrhage and total resection of the tumor 3 weeks after the onset. The spinal cord appeared a little bit swollen (Fig. 3A). A PLS approach of the spinal cord on the left side revealed the intramed-

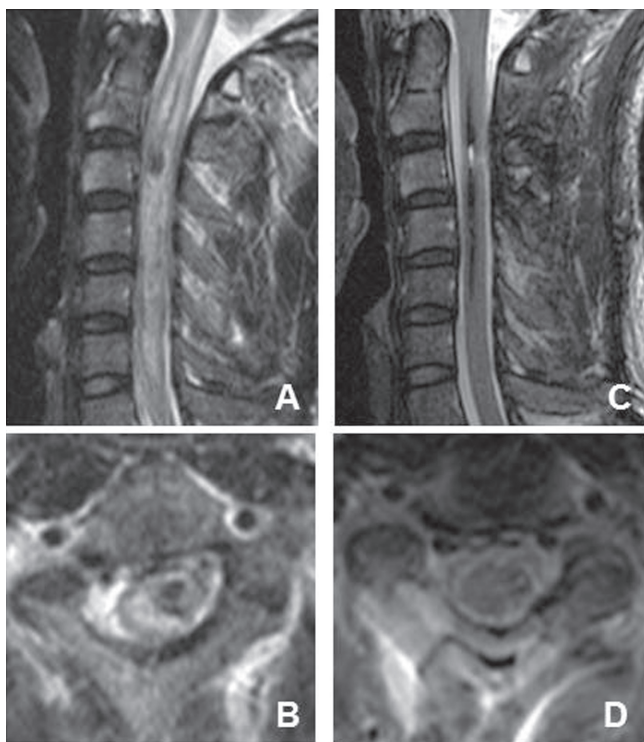


Fig. 4 Patient 1. T₂-weighted magnetic resonance (MR) images before surgery demonstrating the extensive enlargement and intramedullary mixed signal of the spinal cord at C2 to C3 (A), which was consistent with blood degradation products and deviated to left side and on T₂-weighted images (B). T₂-weighted MR images at 2 months after surgery demonstrating satisfactory recovery of intramedullary signal of the spinal cord (C, D).

ullary hemorrhage. Careful dissection within the spinal cord revealed the tumor-cord interface with the surrounding hemosiderin stained tissue (Fig. 3C, D). The tumor was removed segmentally. The surrounding hemosiderin stained tissue was not resected to avoid the damage of spinal tissue. When the removal was complete, there was little or no need for further hemostasis (Fig. 3E). Histological examination of the tumor verified the diagnosis of cavernous malformation.

No apparent deterioration of neurological condition was noted early after surgery. T₂-weighted MR images at 2 months after surgery revealed satisfactory recovery of intramedullary signal of the spinal cord (Fig. 4C, D). Assessment of neurological condition at 3 months after surgery suggested Grade 1 of the modified McCormick functional schema and Grade 1 of the sensory pain scale.

Patient 2: A 67-year-old male was admitted with the chief complaint of 1 month history of progressive motor-weakness on the right side. He finally developed tetraparesis and was unable to stand himself. The symptom was more apparent on the upper extremities compared to lower extremities. His medical past history included a surgical treatment of renal cell carcinoma and its brain metastasis. Neurological examination on admission showed the spastic tetraparesis. Assessment of neurological condition before surgery suggested Grade 5 of the modified McCormick functional schema and Grade 2 of the sensory pain scale. MR imaging of the cervical spine revealed extensive enlargement and intramedullary high signal of the spinal cord with tumor formation at C2 on T₂-weighted MR images (Fig. 6A). Enhanced T₁-weighted MR images showed well-enhanced tumor within the spinal cord, which was deviated to right side on T₂-weighted axial images (Fig. 6B). Imaging diagnosis before surgery was the intramedullary metastasis possibly from renal cell carcinoma.

The patient underwent the C1 laminectomy and C2 to C3 osteoplastic laminotomy for the total resection of the tumor. The spinal cord appeared a little bit swollen (Fig. 5A). A PLS approach of the spinal cord on the right side revealed the intramedullary tumor. Careful dissection within the spinal cord revealed the tumor-cord interface with the surrounding edematous tissue (Fig. 5C, D). The surrounding edematous tissue was protected to avoid the damage of spinal tissue. When the removal was complete, there was little or no need for further hemostasis (Fig. 5E). Histological examination of the tumor verified the diagnosis of intramedullary metastasis from renal cell carcinoma.

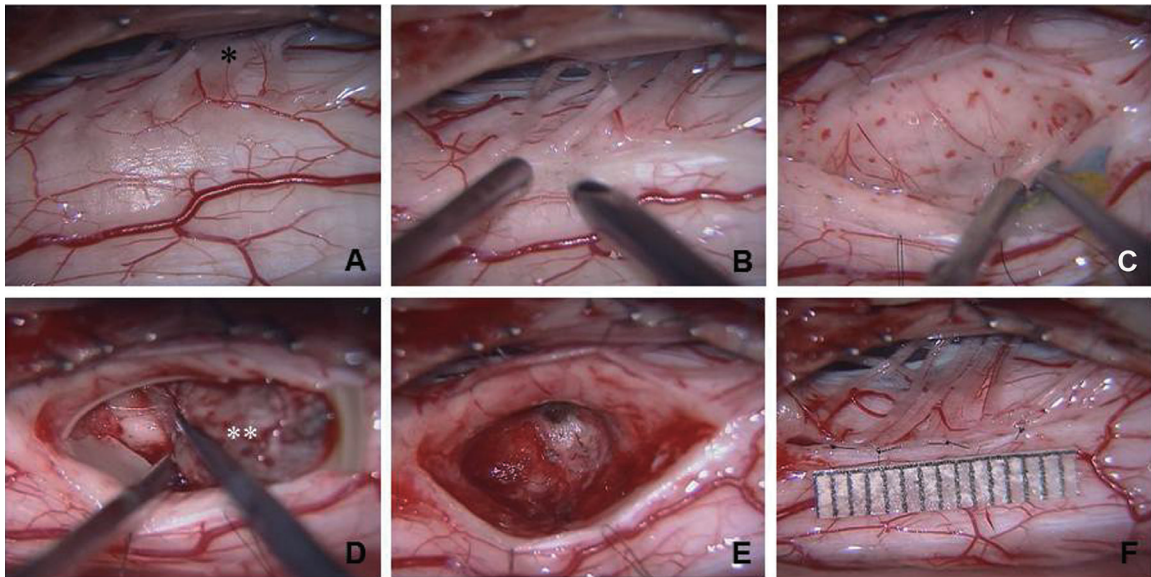


Fig. 5 Intraoperative photographs in Patient 2 demonstrating the surgical steps by posterior lateral sulcus approach. **A:** The spinal cord appeared a little bit swollen. C3 dorsal nerve roots on the right side (*) were identified. **B:** The opening of the posterior lateral sulcus was made using a diamond knife. **C:** The myelotomy can be extended rostrally or caudally by meticulously splaying the spinal tissue using a microdissector. **D:** The gentle dissection of the tumor-cord interface was continued in the longitudinal plane over the extent of the tumor (**). **E:** There was usually little or no need for further hemostasis after the complete removal of the tumor. **F:** The shape of the spinal cord was restored by suturing the pial edges together.

Mild deterioration of motor-weakness on the right side was noted early after surgery, but gradually improved within 1 month after surgery. T₂-weighted MR images at 1 month after surgery revealed satisfactory recovery of intramedullary signal of the spinal cord (Fig. 6C, D). The patient was referred to urological department and started to receive target therapy for renal cell carcinoma after surgery. Assessment of neurological condition at 3 months after surgery suggested Grade 4 of the modified McCormick functional schema and Grade 1 of the sensory pain scale.

Discussion

PLS approach, being equivalent to DREZ myelotomy, refers to the surgical method that selectively destroys the posterolateral aspect of the spinal cord, corresponding to the area where dorsal roots enter the spinal cord itself.^{12,14} DREZ myelotomy was originally aimed at undercutting the lateral part of the dorsal roots and cutting into the matter of spinal cord as a surgical resolution for chronic pain and spasticity.¹⁴ The surgical procedure was then modified with deeper destruction of the spinal cord as a surgical resolution for control of medically refractory chronic severe pain syndrome.¹² The presumed rationale

for DREZ myelotomy is the surgical destruction of deafferentation-related spontaneous hyperactivity of spinal cord neurons located in the most superficial Rexed layers of the gray matter that are involved in processing of nociceptive information. DREZ myelotomy selectively destroys Rexed laminae I through V and the Lissauer's tract while preserving the adjacent dorsal and lateral columns. Destruction of the area of presumed abnormal hyperactivity by DREZ myelotomy resulted in the elimination of the deafferentation pain.

Although PLS approach to the spinal intramedullary tumors was not an altogether new approach, it may offer the satisfactory exposure of the tumor if applied appropriately after careful selection.^{1,2,10,11,16} Ideally, the myelotomy should be made over the length of the entire lesion to facilitate its complete removal. During the tumor resection, the micro-coagulation of the tumor surface may shrink back the surface of the tumor and draw it away from the spinal cord surface, with preservation of the fine vessels and without current spread or heating of the adjacent spinal tissue. This kind of surgical technique may help expose the adjacent feeding vessels and the tumor-cord interface. Mitha et al. (2011) proposed that its closer proximity to eloquent tracts may warrant the use of a CO₂ laser during

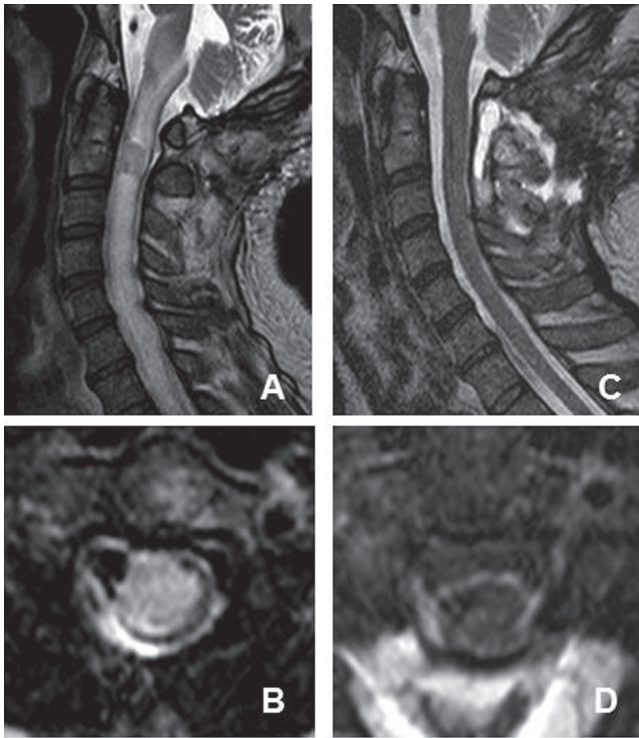


Fig. 6 Patient 2. T₂-weighted magnetic resonance (MR) images before surgery demonstrating the extensive enlargement and intramedullary high signal of the spinal cord with tumor formation at C2 (A), which was deviated to right side on T₂-weighted axial images (B). T₂-weighted MR images at 1 month after surgery demonstrating satisfactory recovery of intramedullary signal of the spinal cord (C, D).

the tumor resection.^{10,11)} The CO₂ laser facilitates less retraction by causing shrinkage of the lesion, making it easier to define the plane between the lesion and surrounding spinal cord tissue. In the case of cavernous malformation, the surrounding hemosiderin stained tissue was not resected to avoid the significant damage of the spinal tissue. When an associated venous malformation was observed, it was not coagulated because it may still function in the venous drainage to normal spinal cord tissue.

Better indication for PLS approach may be the tumors of the uneven location within the spinal cord associated with moderate or severe local pain. Ependymoma may not be successfully resected using PLS approach, because ependymoma originally grows from central to periphery within the spinal cord. In our case series, 2 patients demonstrated moderate pain of Grade 3 and 1 patient developed severe pain of Grade 4 before surgery. It can be presumed that the tumor of uneven location within the spinal cord

is related to processing of nociceptive information, and generate the deafferentation-related spontaneous hyperactivity of spinal cord neurons. After surgery, all patients obtained the acceptable relief of pain. Local pain distributing the spinal level of the tumor may be one of the reference points to determine the surgical approach for intramedullary tumor. It was rare for us to encounter the significant worsening of proprioception associated with dorsal column dysfunction after surgery, although objective and accurate assessment was not provided in the present study. The desirable advantages of PLS approach was less chance of neurological deficits related to the dorsal column damage compared to the standard posterior median sulcus approach and acceptable pain relief. The disadvantage of PLS approach was more chance of neurological deficits related to the lateral column damage compared to the standard posterior median sulcus approach, especially the damage of corticospinal tract on the tumor side. In our case series, although small number of cases, early recovery of motor function on the tumor side was obtained.

Although surgeons should be aware of its disadvantages related to the approach itself as well as the surgical indications and advantages, PLS approach can be optional for the selected cases of spinal intramedullary tumors of lateral location. PLS approach can provide direct access to the tumor with the minimum damage of spinal normal tissue, if applied appropriately after careful selection. Better indication for PLS approach may be the tumors of the uneven location within the spinal cord associated with moderate or severe local pain.

Conflicts of Interest Disclosure

No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript. Authors made declaration of conflict of interest to the JNS Office.

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