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Morphological Patterns of the Anterior Median Fissure in the Cervical Spinal Cord Evaluated by Computed Tomography After Myelography

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Objective: Computed tomography following myelography (CTM) revealed an unusual flow of contrast dye into the anterior median fissure (AMF) in a patient with cervical spondylotic myelopathy. Since then, several AMF configurations have been observed on CTM. Therefore, we evaluated morphological patterns of the AMF on CTM and investigated the significance and mechanisms of contrast dye flow into the AMF.
Methods: Morphological patterns of the AMF on CTM were examined in 79 patients. Group A (24 patients) underwent surgery because of symptomatic cervical myelopathy. Group B (43 patients) had no clinical symptoms but showed spinal cord compression on CTM. Group C (12 patients), who showed neither clinical symptoms nor cord changes, underwent CTM for lumbar lesion evaluation. AMF patterns were classified into 4 types according to their configurations on CTM (reversed T, Y, V, and O types).
Results: In group B, the reversed T type and Y type appeared significantly more often near the compressed portion ($p<0.001$). A similar tendency was seen in group A. The V and O types were most frequently observed in group C ($p<0.001$).
Conclusion: On CTM, contrast dye tends to flow into the AMF of the cervical cord when the spinal cord is compressed. We speculate that there may be 3 possible mechanisms for this phenomenon: deformation of the epipial layer of the AMF due to cervical cord compression, AMF dilatation due to atrophy of the anterior funiculus or anterior horn, and temporary AMF dilatation when it becomes an alternative route for cerebrospinal fluid circulation.

Keywords: Computed tomography, Myelography, Anterior median fissure, Spinal cord, Cervical spondylosis

INTRODUCTION

Computed tomography following myelography (CTM) plays an important role in the accurate diagnosis of various lesions in the spinal canal lesions that cannot be diagnosed by magnetic resonance imaging (MRI).[1,2] In our clinic, almost all admitted patients suffering from spinal lesions are examined by CTM, during which we have noted unusual flow patterns of contrast dye into the anterior median fissure (AMF). We therefore meticulously investigated the morphological patterns of the AMF on CTM of patients with or without symptomatic cervical myelopathy as well as the meaning and mechanisms of contrast dye flow into the AMF.

MATERIALS AND METHODS

A total of 24 patients with cervical spondylotic myelopathy (CSM) who underwent surgery in our clinic from January 2015 to December 2015 were defined as the CSM group (group A). In our clinic, the patients with lumbar spine disease who are also suspected of cervical spine disease are examined on CTM in the cervical region. During the same period, 43 patients with lumbar lesions showing cervical cord compression without clinical symptoms were defined as the asymptomatic group (group B). Finally, 12 patients with lumbar lesions with no cervical cord compression were defined as the control group (group C).

Cervical spinal cord compression on CTM was defined that the subarachnoid space decreased or disappeared and the spinal cord was deformed. In 79 patients, the morphological patterns of AMF in the cervical spinal cord were evaluated at the C2, C2/3, C3, C3/4, C4, C4/5, C5, C5/6, C6, C6/7, C7, and C7/Th1 levels (Fig. 1). The morphological AMF patterns at each level of the cervical spinal cord were then classified into 4 types: reversed T, Y, V, and O types (Fig. 2). Two board-certified spinal neurosurgeons of the Japanese Society of Spinal Surgery, who did not participate in data collection of the present study, interpreted the images.

For the statistical analysis, the t-test was used to assess age. Fisher exact test was used for all of the other statistical assessments. This study was approved by the Institutional Review Board of Fujieda Heisei Memorial Hospital (FHR 30-2). Informed consent was obtained from all patients included in this study.

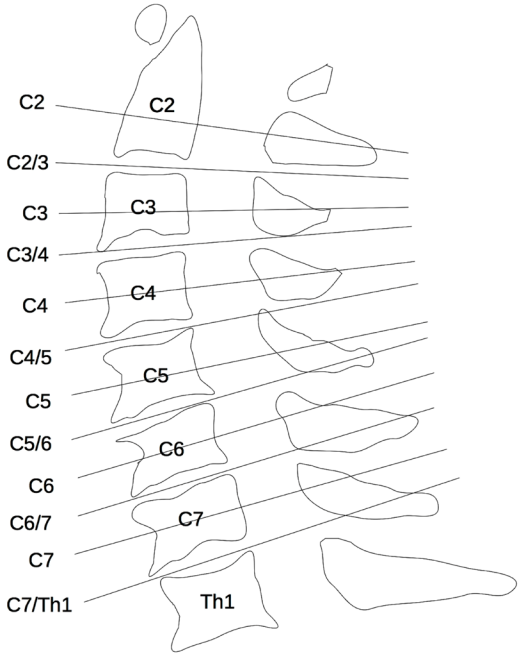

Fig. 1. The 12 evaluated cervical spinal levels: C2, C2/3, C3, C3/4, C4, C4/5, C5, C5/6, C6, C6/7, C7, and C7/Th1.

RESULTS

The average age of the patients, their sex, and the total number and distribution of the morphological AMF patterns of each patient group are shown in Table 1. Group C tended to be slightly younger than the patients in groups A and B, but the differences did not reach statistical significance ($p = 0.09$ and $p = 0.11$, respectively). Fig. 3 shows the morphological AMF patterns and the amount of cord compression at each cervical level in the 3 groups. In group A, cervical cord compression oc-

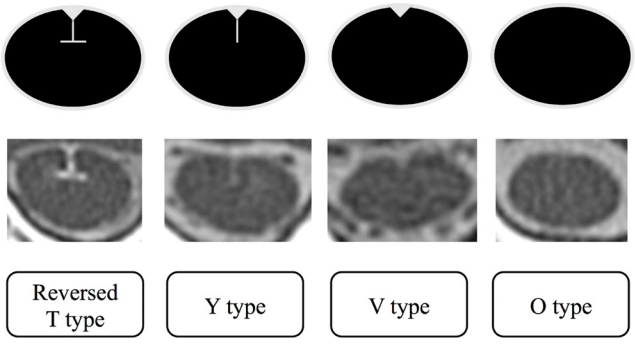

Fig. 2. Morphological patterns of the anterior median fissure.

Table 1. Patients' characteristics and total number and distribution of the morphological pattern of the anterior median fissures in each group

Variable	Group A (CSM)	Group B (asymptomatic)	Group C (control)
No. of patients	24	43	12
Mean age (yr)	71.2	70.0	64.4
Sex, male:female	16:8	26:17	7:5
Total slices	288	475	144
AMF morphological type (n)			
Reversed T	5	1	0
Y	35	117	3
V	107	196	75
O	141	161	66
Reversed T type and Y type (%)	13.9	24.8	2.1

$p < 0.001$, groups A and B, groups B and C, and groups A and C.
CSM, cervical spondylotic myelopathy; AMF, anterior median fissure.

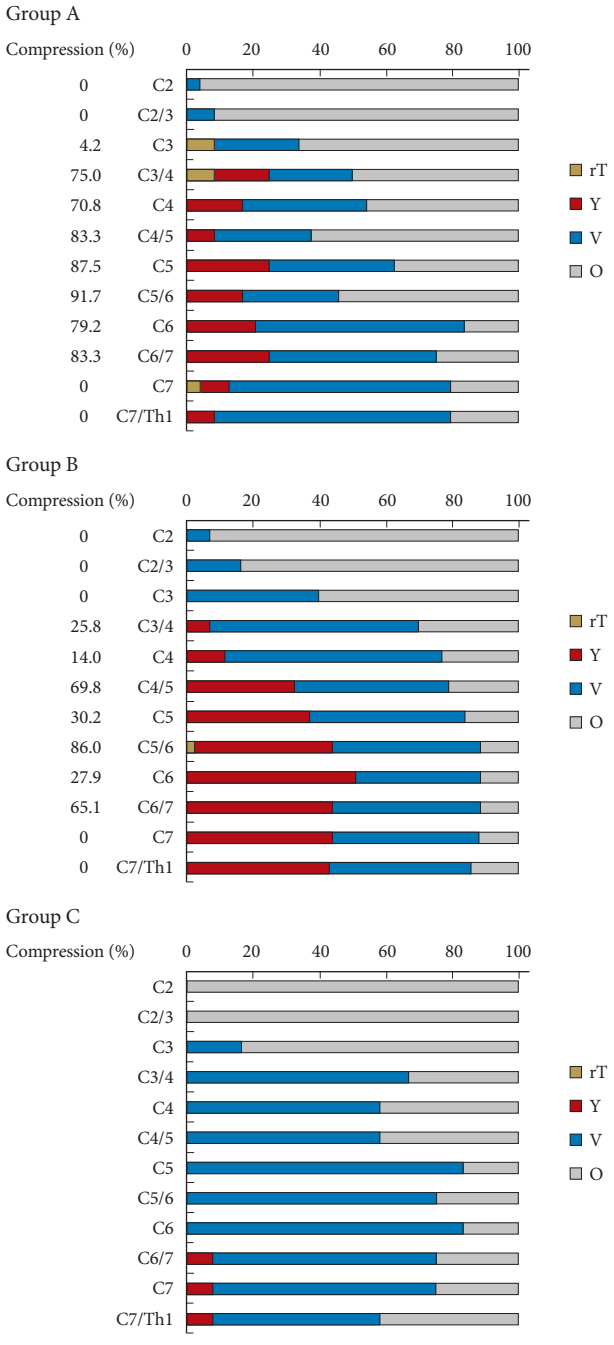

Fig. 3. Morphological anterior median fissure patterns and the degree of cord compression at each cervical level in the 3 groups. Group A, cervical spondylotic myelopathy group; group B, asymptomatic group; group C, control group.

curred mostly at the C5/6 level (91.7%), followed by the C5 and C4/5 levels. The reversed T type or Y type AMF pattern was detected between C3/4 and C6/7. In group B, the reversed T type was seen at the C5/6 level in only 1 patient. Y type was observed in large numbers at lower cervical levels. In group C, the Y type pattern was seen at the C6/7, C7, and C7/Th1 levels in only 1 patient each. Most of the patients in group C showed a V or O type pattern. In all 3 groups, O type was detected mostly at the C2, C2/3, and C3 levels. Overall, the reversed T and Y types were seen at significantly higher frequencies than the other types in both group B (24.8%, $p < 0.001$) and group A (13.9%, $p < 0.001$). The V and O types were most often observed in group C.

The interesting case in which preoperative CTM revealed unusual contrast dye flow into the AMF (which led us to initiate the present study) is herein described. The patient was a 68-year-old man. Three months before his admission, he experienced numbness and clumsiness of his hands and weakness of his legs. MRI showed severe cervical cord compression at the C3/4 level (Fig. 4A). On CTM of the cervical spinal cord, contrast dye was clearly seen to flow into the AMF (reversed T type flow in the present study) (Fig. 4B). C3–4 laminoplasty was performed with good clinical improvement. Postoperative CTM showed a marked decrease in contrast dye flowing into the AMF (Fig. 4C). This representative case shows that the patterns of AMF on CTM can change according to the degree of spinal cord compression.

DISCUSSION

1. Normal Anatomical Structure of the AMF

The fine anatomy of the AMF and the presence of cerebrospinal fluid (CSF) in it has not been well investigated, although Mii et al.[3] studied the anatomy of the AMF in detail for many years. According to their studies and other authors' papers, the current anatomical structure of AMF can be understood as follows (Fig. 5). The spinal pia mater is composed of 2 layers: an outer (epipial) layer and an inner (intima pia) layer.[4] The epipial layer is composed of collagen fibers, which bulge (linea splendens) to surround the whole circumference of the anterior spinal artery and vein. This layer enters the AMF from the linea splendens, forming the anterior median septum. The central arteries and veins from the anterior spinal artery and vein run into the anterior median septum, flowing from the tip of the anterior median septum into the spinal cord substance.[5]

2. Patterns of Contrast Dye Flow Into the AMF on CTM

The epipial layer has a mesh-like structure that allows contrast dye to pass through it.[6] The intima pia, composed of reticular fibers, lines the whole circumference of the spinal cord. These anatomical structures permit some space between the epipial layer and the intima pia, where the CSF can potentially

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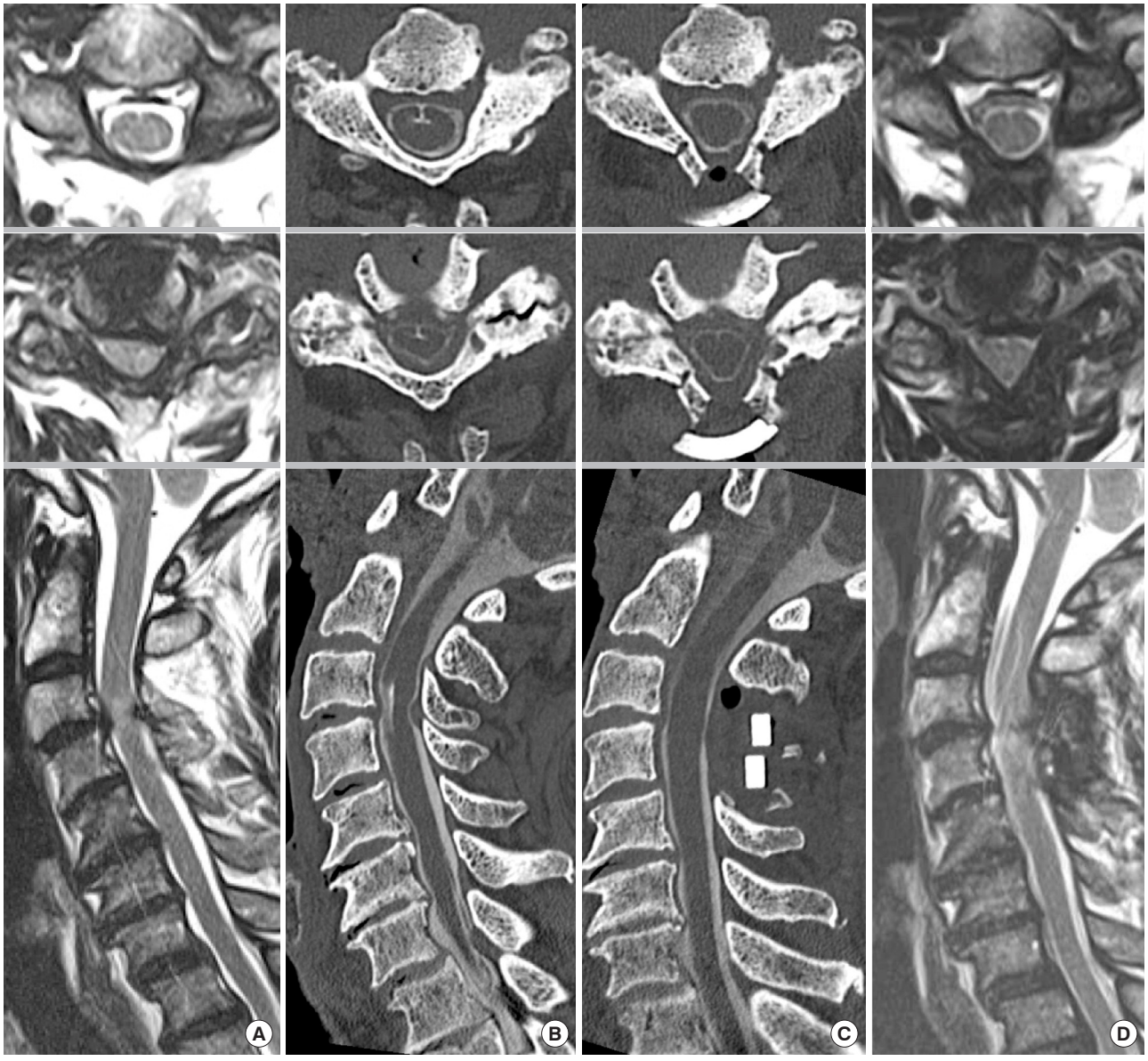

Fig. 4. Magnetic resonance imaging (MRI) and computed tomography scans after myelography (CTM) of the illustrative case. (A) MRI preoperatively. (B) CTM preoperatively, 15 minutes after injection of contrast dye. (C) CTM postoperatively, 15 minutes after injection of contrast dye. (D) MRI postoperatively. Upper panel: Axial sections show the greatest dye flow sites. Middle panel: Axial sections of the most compressed sites. Lower panel: Sagittal sections.

flow. The morphological patterns of AMF on CTM in the present study were divided into 4 types, which are defined according to their actions as follows. O type is present when no contrast dye flows into the AMF. With the V type, contrast dye flows only into the entry portion of the AMF. With the Y type, contrast dye flows into the vertical portion of the AMF. With the reversed T type, contrast dye flows into the recessed portion of the AMF between the commissure and anterior funiculus (Fig. 6). V type and Y type sometimes can be seen with MRI, but the reversed T type can only be seen with CTM. Although this recessed portion has not been described in detail, either anatomically or radiologically, the anatomical study of Mii et al.[3] and the morphological pattern of the reversed T type AMF in the present study strongly suggest the presence of such a recess. According to its anatomical structure, we named this recess the "commissuro–funicular recess."

3. Mechanisms of Contrast Dye Flow Into the AMF

The epipial layer covers the most superficial layer of the AMF, which is almost closed under normal conditions.[7] In the pres-

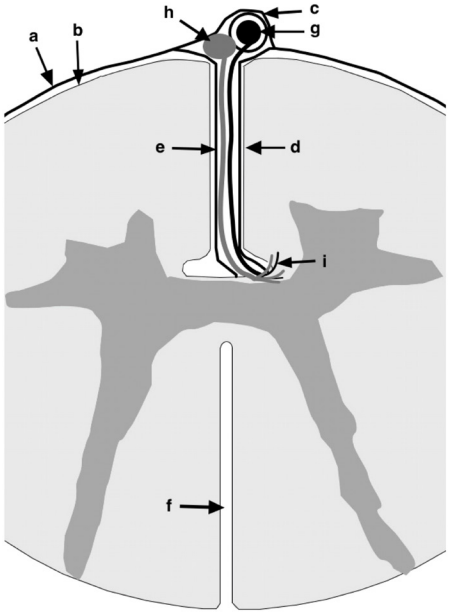

Fig. 5. Anatomy of the anterior median fissure. a, outer layer of the pia mater (epipial layer); b, inner layer of the pia mater (intima pia); c, linea splendens; d, anterior median fissure; e, anterior median septum; f, posterior median sulcus; g, anterior spinal artery; h, anterior spinal vein; i, central artery.

ent study, the reversed T and Y types were rarely seen in group C. In contrast, these reversed T and Y types are seen more frequently in groups A and B than in group C. This finding suggests that contrast dye can flow into the AMF when the spinal cord is compressed with or without the patient having clinical symptoms.

There are three possible mechanisms by which the contrast dye flows into the AMF. First, a deformation of the epipial layer due to spinal cord compression may permit the contrast dye to flow easily into the AMF. The epipial layer has a mesh-like structure, and the inflow of the contrast dye is originally possible, but it may be easier to pass by deforming the epipial layer. The spinal cord compression has the potential to deform not only the spinal cord itself but also the epipial layer and open the mesh-like structure. The deformation of the epipial layer may be reversible, as shown by postoperative CTM in the illustrative case, which revealed decreased contrast dye in the AMF. More meticulous clinical observations and experimental studies are thus needed to confirm the reversibility of the deformation of the epipial layer.

A second possible mechanism of contrast dye flow into the AMF is AMF dilatation due to atrophy of the anterior horn or anterior funiculus. In fact, spinal cord atrophy and intramedullary hyper signal intensity were seen with postoperative T2-weighted image MRI in the representative case. However, atrophy of the spinal cord seems irreversible, so this hypothesis cannot explain the fact that the contrast dye into the AMF decreased after decompression surgery, as also shown in the representative case.

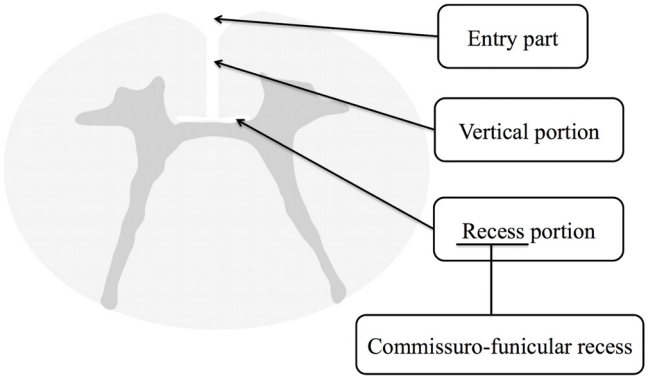

Fig. 6. Parts of the anterior median fissure.

The third possibility to explain contrast dye flow into the AMF could be that a dilated AMF may become an alternative route for CSF circulation when the normal subarachnoid space is compressed by epidural mass and others. Since there is almost no subarachnoid space at the site of the narrowest stenosis, almost no CSF around the spinal cord and in the AMF can be confirmed, but CSF may flow into the AMF through the mesh-like structure and may rather be trapped on the upper and lower side of the narrowest part. Therefore, it is considered that there is a deviation between the site where the AMF is imaged and the site of the narrowest stenosis. The pressure effect of CSF may play an important role in dilatation of the AMF.

4. Limitations of the Study

Regarding postoperative changes in AMF, CTM was performed postoperatively in only 1 patient. Thus, more postoperative CTM data must be collected and analyzed to investigate the precise mechanisms of dye flow into the AMF. For other limitations, CTM of the cervical portion were studied at a neutral or extended position, whereas it should be examined in the same position. Finally, the relation between the morphological AMF pattern and clinical symptoms were not investigated. In fact, since there was no significant difference between groups A and B in this study, it seems that the pattern of the AMF changes with the presence or absence of compression to the last. More meticulous study that collects more CTM and experimental research data must be done to investigate the clinical significance of contrast dye flow into the AMF. Despite these

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limitations, the present study could be an important first step to clarify this interesting phenomenon of contrast dye flowing into the AMF.

CONCLUSION

Morphological AMF patterns in the cervical spinal cord can be divided into 4 types (reversed T, Y, V, and O types) on CTM. The contrast dye tends to flow into the AMF when the cervical spinal cord is compressed. We speculated that there are three possible mechanisms that could explain contrast dye flow into the AMF: deformation of the epipial layer due to spinal cord compression; AMF dilatation due to atrophy of the anterior funiculus or anterior horn; temporary AMF dilatation due to its being used as an alternative route for CSF circulation. Although it is clinically rare, a spinal anterior approach is performed, and it is possible that CTM can serve as an aid for the image evaluation of the AMF approach.

CONFLICT OF INTEREST

The authors have nothing to disclose.

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REFERENCES

1. Machino M, Yukawa Y, Ito K, et al. Dynamic changes in dural sac and spinal cord cross-sectional area in patients with cervical spondylotic myelopathy: cervical spine. Spine (Phila Pa 1976) 2011;36:399-403.
2. Yoshii T, Yamada T, Hirai T, et al. Dynamic changes in spinal cord compression by cervical ossification of the posterior longitudinal ligament evaluated by kinematic computed tomography myelography. Spine (Phila Pa 1976) 2014;39:113-9.
3. Mii K, Shimizu S, Mishima D. Description of the microsurgical anatomy and intramedullary tumor resection in the anterior part of the spinal cord. No Shinkei Geka 2016;44:19-28.
4. Millen JW, Woollam DH. On the nature of the pia mater. Brain 1961;84:514-20.
5. Zhang ZA, Nonaka H, Hattori T. The microvasculature of the spinal cord in the human adult. Neuropathology 1997;17:32-42.
6. Nicholas DS, Weller RO. The fine anatomy of the human spinal meninges. A light and scanning electron microscopy study. J Neurosurg 1988;69:276-82.
7. Shimizu S, Mii K, Mishima D, et al. Patients with spinal ependymomas attached to the anterior median septum are at risks for postoperative functional impairment: a correlating analysis. Spinal Surgery 2013;27:153-60.