Clinical Imaging 55 (2019) 100–106

Contents lists available at ScienceDirect

Clinical Imaging

journal homepage: www.elsevier.com/locate/clinimag

Neuroradiology

Magnetic resonance imaging spectrum of spinal meningioma

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ARTICLE INFO

Keywords:
Meningioma
Spine
Magnetic resonance imaging

ABSTRACT

Purpose: To evaluate magnetic resonance (MR) imaging findings of spinal meningioma and to determine the radiological subtypes based on the MR imaging findings and their respective clinical features.

Material and methods: Data for 105 patients with surgically treated and histopathologically diagnosed spinal meningiomas at our hospital between May 1, 2003 and May 1, 2017 were evaluated in this study. Two radiologists reviewed the characteristics of spinal meningiomas on MR images and categorized the spinal meningiomas into subtypes based on MR imaging findings.

Results: Most spinal meningiomas showed higher signal intensity than that of the spinal cord but lower than that of the subcutaneous fat on T2-weighted images (WI). 56 cases (54%) showed adjacent spinal cord signal changes. Meningiomas could be categorized according to MR imaging findings into type A: dural-based tumors with a homogeneous signal intensity and intense contrast enhancement (81 cases, 77%); type B: round or oval-shaped tumors with an internal hypointense portion on T2-weighted images (18 cases, 17%); type C: en plaque tumors (three cases, 3%); and type D: tumors with unusual findings and a heterogeneous appearance (three cases, 3%). All type C patients showed spinal cord signal changes.

Conclusions: Spinal meningioma showed slightly high signal intensity rather than high signal intensity on T2-weighted images. Spinal cord signal changes were present in more than half of the cases. Clinical differences were observed among the different MR imaging types.

1. Introduction

Spinal meningioma is the second most common spinal cord tumor, accounting for approximately 25% of the primary spinal tumors [1,2]. This tumor frequently occurs in middle-aged women and can cause symptoms such as sensory and motor deficits and gait disturbance. It usually manifests as solitary and sporadic lesions, but multiple meningiomas are often associated with neurofibromatosis type II [2,3]. Histopathologically, there are several subtypes, and the surgical outcomes may differ depending on the subtype [4,5].

The imaging modality of choice for the evaluation of spinal tumors is magnetic resonance (MR) imaging. Most spinal meningiomas show hyper- or isointense on T2-weighted images (WI) and intermediate to hypointense on T1WI [6,7]. They are often solid, well-circumscribed lesions with broad dural attachment. In general, meningiomas show strong homogeneous enhancement after gadolinium administration [8]. The dural tail and internal calcification can be seen, but less commonly than in intracranial meningiomas [2].

There have been several studies on MR imaging findings of spinal meningiomas [6,8–13]. However, they mostly comprise case reports or studies comparing imaging findings with those of spinal schwannoma. Choi et al. have reported MR imaging findings of spinal meningiomas in 36 patients, which is the largest study so far [6].

We here report our cumulative experience from a retrospective evaluation of patients with spinal meningiomas over a period of 15 years. We analyzed the radiologic MR features of meningiomas and subsequently categorized these tumors into radiological MR subtypes. To our knowledge, this is the largest series of spinal meningiomas evaluated with the aim of establishing an MR imaging spectrum for these tumors.

2. Materials and methods

2.1. Study population

Our institutional review board approved this study. The clinical data of patients who were histopathologically diagnosed to have spinal meningioma between May 1, 2003, and May 1, 2017 were

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https://doi.org/10.1016/j.clinimag.2019.02.007
Received 10 May 2018; Received in revised form 14 November 2018; Accepted 11 February 2019

Fig. 1. Various T2 signal intensities in spinal meningiomas. (A) Slightly hyperintensity. Sagittal T2-weighted image shows a mass with higher signal than that of the spinal cord, but lower signal intensity than that of the fat. (B) Isointensity. The mass is isointense compared to the spinal cord. (C) Hypointensity. The mass shows lower signal intensity than that of the spinal cord. There was no case with hyperintensity on T2-weigthed image with higher signal than that of fat or CSF.

Table 1
Patient characteristics (n = 105).

Characteristics		Cases
Mean age (y)[a]		61.5 ± 13 (20–87)
Sex[b]	Male	13 (12)
	Female	92 (88)
Presenting symptoms[b]		
Cord symptoms	Sensory and motor deficit	86 (82)
	Gait disturbance	31 (30)
	Bladder or bowel change	6 (6)
Not cord symptoms	Radicular pain	56 (53)
	Local pain	33 (31)
	No symptom	4 (4)
Pathologic type[b]		
Grade	Grade 1	102
	Grade 2	3
	Grade 3	0
Type	Psammomatous	44 (42)
	Meningothelial	40 (38)
	Transitional	14 (13)
	Atypical	3 (3)
	Fibrous	2 (2)
	Microcystic	1 (1)
	Metaplastic	1 (1)
Residual mass	Positive	4
	Negative	101
Recurrence	Positive	1
	Negative	104

[a] Data is ± standard deviation and data in parentheses are range.
[b] Data in parentheses are percentages.

Table 2
Characteristics of meningiomas (n = 105).

Characteristics		Cases
Location by anatomic compartment	Intradural extramedullary	100 (95)
	Intradural and extradural	5 (5)
	Entirely extradural or intramedullary	0
Craniocaudal location	Cervical	38 (36)
	Thoracic	64 (61)
	Lumbar	3 (3)
Axial location	Ventral	10 (10)
	Ventrolateral	29 (28)
	Lateral	43 (41)
	Dorsolateral	21 (20)
	Dorsal	2 (2)
Average of craniocaudal extension[a]	Millimeter	19.7 (18.1, 21.3)
	Number of vertebrae[b]	1.1 (1, 1.2)

Unless otherwise indicated, data in parentheses are percentages.
[a] Data in parentheses are 95% confidence intervals.
[b] Number of involved vertebral segments.

retrospectively evaluated. Patients who underwent preoperative spinal MR imaging, and had a histopathologically confirmed diagnosis of spinal meningioma through subsequent operation, were included. Exclusion criteria were lack of preoperative spinal MR images and insufficient quality of MR images for evaluation of the spinal tumor. Patients who were pathologically confirmed or suspected to have multiple meningiomas were excluded.

Symptoms at presentation and pathologic grades and types according to the 2016 World Health Organization (WHO) classification

Table 3
Magnetic resonance imaging findings of meningiomas.

Characteristics		Cases (%)
Signal intensity on T2-weighted imaging[a]	High	0
	Slightly high	67 (64)
	Iso	28 (27)
	Low	9 (9)
Signal intensity on T1-weighted imaging[b]	High	1 (1)
	Iso	99 (96)
	Low	3 (3)
Contour of tumor	Smooth	100 (95)
	Lobular	5 (5)
	Ill-defined	0
Dural base	Positive	96 (91)
	Negative	9 (9)
Dural tail sign[c]	Positive	44 (44)
	Negative	56 (56)
Enhancement degree[c]	Intense	97 (97)
	Mild	3 (3)
	None	0
Enhancement pattern[c]	Homogeneous	82 (82)
	Heterogeneous	13 (13)
	Rim	5 (5)
	Focal or none	0
Intratumoral components[a]		
Tumoral cyst	Positive	1 (1)
	Negative	103 (99)
Flow void	Positive	6 (6)
	Negative	98 (94)
Cord signal change[a]	Positive	56 (54)
	Negative	48 (46)

Data in parentheses are percentages.
[a] n = 104 due to one case had no T2WI.
[b] n = 103 due to two cases had no T1WI.
[c] n = 100 due to five cases had no contrast enhanced image.

were reviewed [5].

2.2. MR imaging

MR imaging was performed using different MR scanners and protocols at different hospitals before referral to our hospital. All patients who underwent imaging at our institution had undergone MRI at 1.5 T (Gyroscan Intera; Philips Healthcare, Best, the Netherlands) or 3 T (Achieva; Philips Healthcare, Best, the Netherlands) scanners. Axial and sagittal T1-weighted spin-echo, axial and sagittal T2-weighted fast spin-echo, and axial and sagittal contrast-enhanced fat-suppressed T1-weighted spin-echo images were acquired. One patient who had no T1WI and other two patients who had no T2WI were included. Contrast enhanced T1-weighted MR images obtained after intravenous injection of contrast were available for all except five patients.

2.3. Image interpretation

MR images were retrospectively and independently reviewed by two radiologists (Y.Y. and E.L., with 4 and 11 years of experience in musculoskeletal radiology). The following tumor characteristics and MR imaging findings of the tumors were evaluated: location by anatomic compartment in the spinal canal, craniocaudal extension, axial and longitudinal location, adjacent spinal cord signal change suggesting cord edema or myelomalacia [14], signal intensities on T1- and T2WI, contour of tumor, presence of broad dural base, dural tail sign, degree and pattern of enhancement, and intratumoral components such as cystic portion and flow voids. The longitudinal locations were divided into cervical, thoracic, and lumbar based on the dominant segment involved. The central portion of the section was used as a reference for describing the axial location. The craniocaudal extension of the tumor was described both in millimeters and in terms of the number of vertebrae involved. Signal intensity of a tumor on T1WI was described as low, intermediate, or high, relative to the signal intensity of the spinal cord. Signal intensity of a tumor on T2WI was graded as (a) high: higher than that of the fat, (b) slightly high: higher than that of the spinal cord but equal to or lower than that of the fat, (c) intermediate: equivalent to that of the spinal cord, and (d) low: lower than that of the spinal cord (Fig. 1). The dural tail sign was considered positive if there was thin dural enhancement near the mass with a broad angle to adjacent dura mater.

2.4. Statistical analysis

Cramer's V nominal correlation was used to assess the relationship between MR classification type and histologic subtype. p value < 0.05 was considered statistically significant. The data were analyzed using SPSS version 20 (IBM Corp., Armonk, NY, USA).

Table 4
Characteristics of meningiomas (n = 105) depending on magnetic resonance imaging classification types.

Characteristics	Type A*			Type B	Type C	Type D
	Dural tail (+)	Dural tail (−)	Total			
Cases[a]	34	47	81 (77)	18 (17)	3 (3)	3 (3)
Mean age (y)	61.9 (57.4, 66.4)	61.4 (58, 64.8)	61.6 (58.9, 64.3)	62.2 (55.7, 68.7)	62.3 (52.7, 71.9)	52.7 (24.9, 80.5)
Sex[a]						
Male	2	9	11 (85)	2 (15)	0	0
Female	32	38	70 (76)	16 (17)	3 (3)	3 (3)
Location by anatomic compartment						
IDEM	34	45	79	18	2	1
Intradural & extradural	0	2	2	0	1	2
Longitudinal location						
Cervical	13	13	26	7	2	3
Thoracic	20	32	52	11	1	0
Lumbar	1	2	3	0	0	0
Average of craniocaudal extension						
Millimeter	17.9 (16.3, 19.5)	18.4 (16.8, 20)	18.2 (17.1, 19.3)	18.4 (16, 20.8)	46.7 (40.6, 52.8)	38.8 (18.5, 59.1)
Number of vertebra	1.1 (0.9, 1.3)	1.0 (0.9, 1.1)	1.1 (1.0, 1.2)	1.1 (0.9, 1.3)	2.5 (1.0, 4.0)	2.0 (2.0, 2.0)
Cord signal change[a]	15 (44)	23 (49)	38 (47)	13 (72)	3 (100)	2 (67)

Unless otherwise indicated, data are 95% confidence intervals.
IDEM = intradural extramedullary.
[a] Data in parentheses are percentages.
* MR classification type and histologic subtype were not significantly correlated (r = 0.25; p = 0.097).

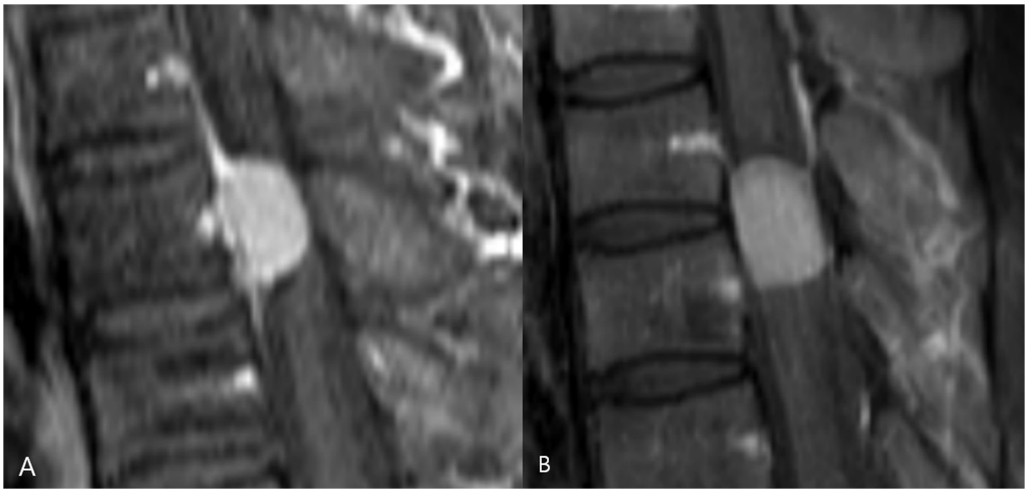

Fig. 2. (A) 69-Year-old woman with spinal meningioma of psammomatous type (WHO grade 1) at T2 level on contrast enhanced T1-weighted image (type A with dural tail sign). (B) 69-Year-old woman with spinal meningioma of psammomatous type (WHO grade 1) at T5/6 level on contrast enhanced T1-weighted image (type A without dural tail sign).

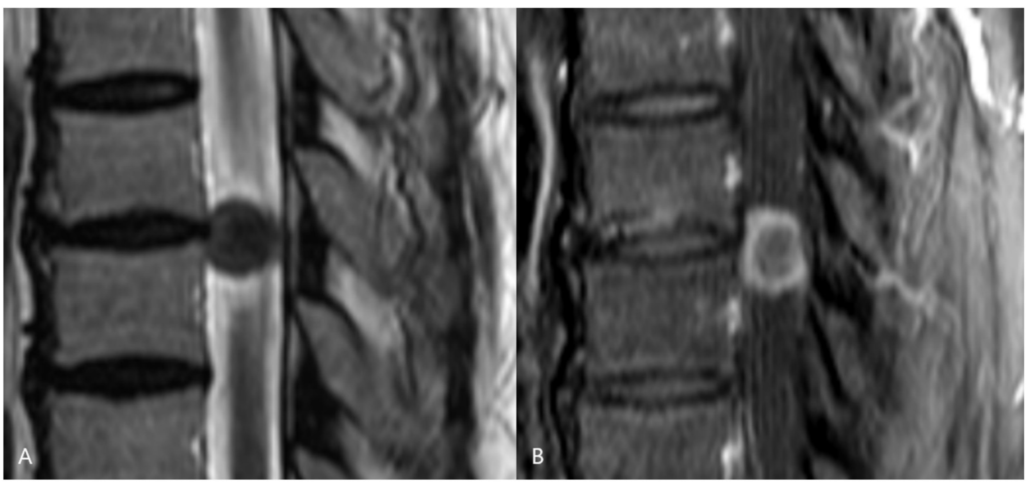

Fig. 3. 55-Year-old woman with spinal meningioma of psammomatous type (WHO grade 1) at T7/8 level (type B). (A) Sagittal T2-weighted MR image shows an intradural and extramedullary mass with an internal markedly hypointense portion. (B) On sagittal contrast enhanced T1-weighted image, the mass shows rim enhancement with internal less enhancing portion. Multiple calcifications were identified histopathologically.

3. Results

3.1. Study population

We identified 111 patients by using the database search. One patient who were pathologically confirmed and five patients who were suspected to have multiple meningiomas were excluded. Finally, 105 patients were included in the analysis (mean age, 61.5 years; age range, 20–87 years) (Table 1). Of these, 92 were female (mean age, 61.5 years; age range, 22–84 years) and 13 were male (mean age, 61.2 years; age range, 20–87 years).

The symptoms frequently presented in the patients were sensory and motor deficits (82%), radicular pain (53%), local pain (31%), and gait disturbances (30%). Four patients had no symptoms, and tumors were found incidentally. Histopathologically, most of the meningiomas were grade 1 (97%), three were grade 2, and there was no grade 3 meningioma: psammomatous in 44 cases (42%), meningothelial in 40 (38%), transitional in 14 (13%), atypical in three (3%), fibrous in two (2%), microcystic in one (1%), and metaplastic in one (1%).

Total follow-up duration was 28 months (range, 3–136 months). One patient with an initial dumbbell-shaped mass in the cervical vertebra extending to the left neural foramen experienced tumor recurrence in 56 months after surgery.

3.2. MR imaging features

The tumor characteristics are summarized in Table 2. The location of mass by anatomic compartment was confirmed by surgical reports. Of the 105 meningiomas, 100 (95%) were entirely intradural extramedullary tumors, while five (5%) also had extradural components. Four cases showed a dumbbell shaped mass, and one case showed a dominant extradural mass with a small intradural component. However, there were no entirely extradural or intramedullary tumors. There were 64 meningiomas (61%) in the thoracic spine and 38 meningiomas (36%) in the cervical spine; of them, 11 tumors were in the upper cervical location of C1-2. Three tumors (3%) were in the lumbar spine, of which one was located at the conus medullaris level, and the other two were below the conus medullaris. Majority of the meningiomas were located laterally (41%), ventrolaterally (28%), or dorsolaterally (20%). Further, 10% were located ventrally to the cord, and only 2% were located dorsally. Mean size of the tumors in craniocaudal direction was 19.7 mm, ranged 8.2–58.6 mm, and extended over 1.1 vertebral segments, ranged 0.5–4.0 vertebral segments. Adjacent spinal cord signal changes were observed in 56 cases (54%), which comprised 19 cases of 38 cervical tumors (50%) and 37 cases of 64 thoracic tumors (58%).

MR imaging characteristics are summarized in Table 3. High, intermediate, and low signal intensities on T2WI were seen in 67 (64%), 28 (27%), and 9 (9%) cases, respectively. All tumors with high signal intensities on T2WI showed lower signal intensity compared to the fat, which was categorized as slightly high signal intensity. None of the cases showed higher signal intensity than that of the fat or cerebrospinal fluid (CSF). Compared to the spinal cord, signal intensities on T1WI were usually intermediate (96%). A broad dural base was seen in

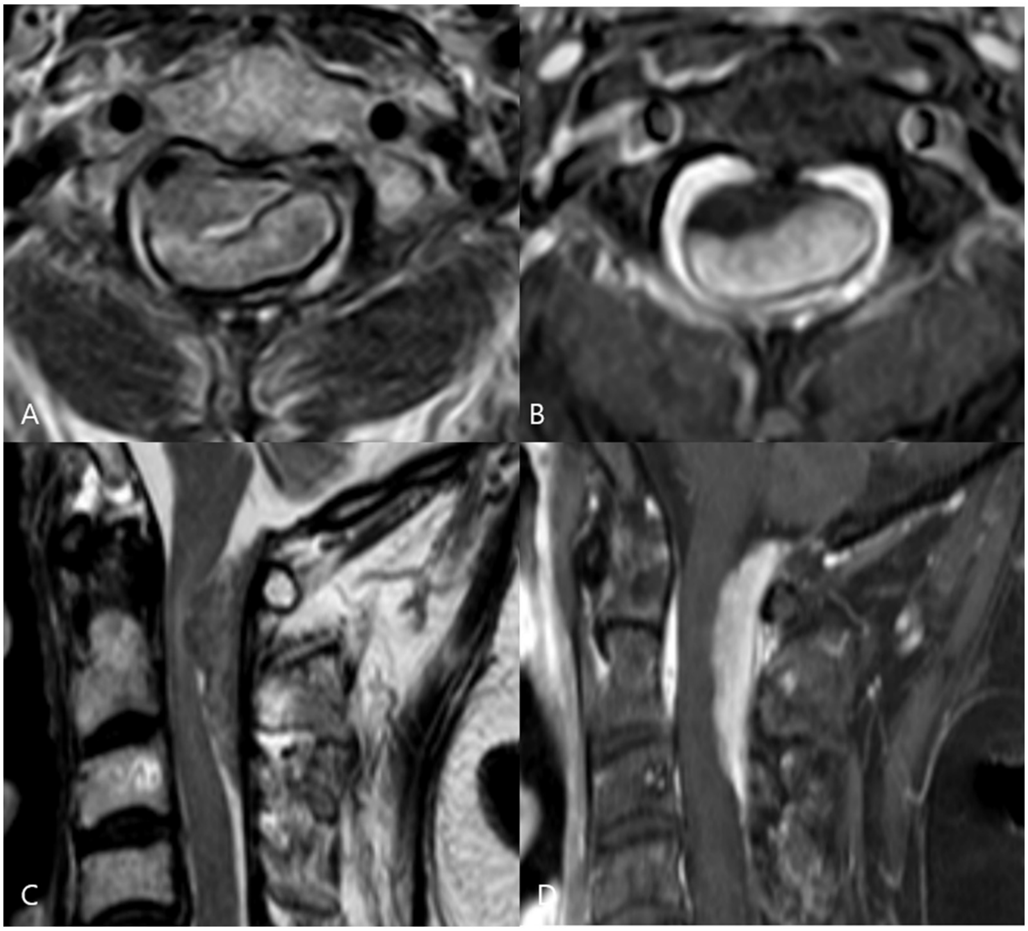

Fig. 4. 62-Year-old woman with spinal meningioma of transitional type (WHO grade 1) at C2/3 (type C). (A, C) Axial and sagittal T2-weighted images show spinal meningioma with en plaque appearance, and adjacent cord signal change due to compression effect on the cord. (B, D) The mass shows homogeneous and intense enhancement on contrast enhanced T1-weighted images.

96 meningiomas (91%), while 44 tumors of them showed a dural tail sign on contrast enhanced T1WI. All except three cases showed intense enhancement. Among the three cases of mild enhancement, two of them showed extensive calcification histopathologically. Most of the cases showed diffuse homogeneous enhancement. However, 13 cases (13%) of heterogeneous enhancement and five cases (5%) of rim enhancement accompanying internal less enhancing portions were also observed. Only one case showed a small intratumoral cyst, and six cases (6%) showed flow voids on T2WI.

Based on the MR characteristics, meningiomas could be categorized into four types (Table 4). Type A included dural-based tumors with a homogeneous signal intensity and intense contrast enhancement (81 cases, Fig. 2); type A was further divided into two subtypes based on the presence of a dural tail sign. Type B included round or oval shaped tumors with an internal hypointense portion on T2WI (18 cases, Fig. 3). Type C included tumors with an en plaque appearance (three cases, Fig. 4), and type D comprised tumors with unusual findings not included in types A-C (three cases, Fig. 5). Types A, B, C, and D accounted for 77%, 17%, 3%, and 3%, respectively. The mean ages of patients with D (52.7 years) were about 10 years lesser than those of types A-C. All patients with type C and D tumors were female. Most male patients (69%) had type A meningiomas without the dural tail sign. While types A and B were common in the thoracic spine, type C was more common in cervical spine, and type D was observed only in the cervical spine. The mean size for types A and B was about 18 mm, presenting 1.1 vertebral segments, while that for types C and D were about 47 mm, presenting 2.5 vertebral segments and 39 mm, presenting 2.0 vertebral segments, respectively. Spinal cord signal change was observed in 47%, 72%, 100%, and 67% of types A, B, C, and D meningiomas, respectively.

Because there were small numbers of pathologic subtypes of fibrous, microcystic, metaplastic meningiomas, statistical analysis for evaluation of the relationship between MR classification type and histologic subtype was done except these subtypes. There was no significant correlation between MR classification type and histologic subtype ($r = 0.25$; $p = 0.097$).

4. Discussion

Meningioma is a common tumor and has relatively established clinical and imaging findings, but so far, there has been no large-scale study on spinal meningiomas. To establish an MR imaging spectrum for these tumors, we analyzed the radiologic MR features of meningiomas and categorized these tumors into radiological subtypes.

Consistent with earlier reports, our findings indicate that meningiomas are common in middle-aged women, occurring predominantly in the thoracic region, and commonly at the lateral or ventrolateral location. Compared to the earlier reports (14–21%), the proportion of cervical meningiomas in our study (36%) was higher [6,15,16]. Sundgren et al. have reported that spinal cord signal change is usually rare in spinal meningiomas [2]. However, we observed 56 cases (54%) with cord signal changes, which is thought to be due to an increase in MR resolution.

In line with earlier reports [2], we found that most tumors showed a slightly high signal intensity on T2WI. However, there is no precise definition of slightly high signal intensity; in our study, it is considered as a higher signal intensity than that of the spinal cord but lower signal intensity than that the fat. None of the cases showed a bright signal intensity compared to the fat or CSF, and only one case showed a small cystic portion inside the tumor [6]. Recently, Takashima et al. have

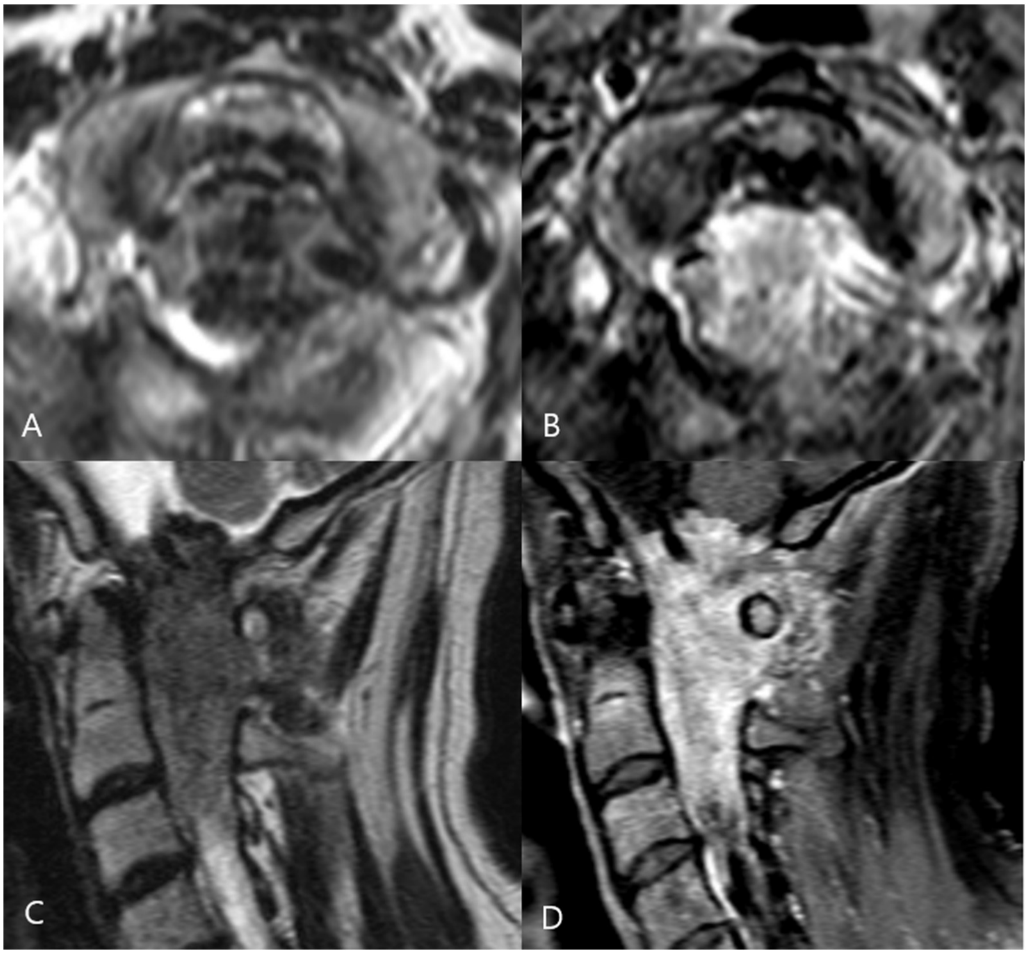

Fig. 5. 37-Year-old woman with spinal meningioma of psammomatous type (WHO grade 1) extending from the foramen magnum to C3 level (type D). (A, C) Axial and sagittal T2-weighted images show an intradural mass with left neural foraminal extension. Spinal cord is laterally deviated due to mass. (B, D) On axial and sagittal contrast enhanced T1-weighted images, the mass shows a heterogeneous but intense enhancement. Encasement of the left vertebral artery is noted.

reported qualitative methods for differentiating intradural and extramedullary schwannoma from meningioma using ROI and ROI ratio of spinal tumor and fat on T2WI, revealing the ROI ratios of schwannomas were significantly higher than those of meningiomas [17].

All the cases in our study showed enhancement, and most of them showed intense enhancement except for three cases that showed marked hypointense on T2WI. These findings are consistent with prior reports that suggest all meningiomas have moderate to intense enhancement [6,8]. Most cases with a heterogeneous enhancement had internal dark signal intensity on T2WI, which may be indicative of calcification, blood product or necrosis. Compared to earlier reports of 1.3–4% calcification in meningiomas [18], our numbers are 54% histopathologically. Among cases with CT scan of 39 meningiomas, 20 tumors (51%) showed internal calcification. This is an important finding considering several reports have suggested that extensive calcification or acellular concretions are associated with poor surgical outcome [4,16].

We classified spinal meningiomas into four types based on the imaging findings. There were some clinical differences among the different types. Type A and B meningiomas accounted for most of the cases, with a similar appearance on MR images. Type C, or en plaque meningioma, refers to meningiomas that grow in a diffuse collar-like manner along the spinal cord [19]. These meningiomas are known to have a different prognosis from that of encapsulated meningiomas, showing a higher frequency of recurrence and postoperative arachnoiditis [20,21], although no type C meningiomas in our study had recurrence. These meningiomas had the largest size and one out of three case showed residual tumor after surgery. This type of meningioma can be found late due to their diffuse growth patterns, leading to a large tumor size at diagnosis. Further, they led to spinal cord signal change in all cases, which can affect prognosis after surgery. The type D meningiomas had a heterogeneous appearance. All of this case of meningiomas were located in cervical spine, and because of its heterogeneity and hypervascularity, these tumors are often mistaken for a schwannoma or hemangiopericytoma. The only case that showed recurrence was type D.

This study has several limitations. First, there were only a small number of cases with type C and D tumors because of their rare prevalence, made it difficult to identify the exact clinical features of them. Second, the number of some pathologic subtypes was small and it is difficult to identify the correlation between pathologic type and MR classification of spinal meningioma. Third, the patients with confirmed or suspected multiple meningiomas were excluded. This is to reduce the effect of genetic predisposition, but there is still possibilities that sporadic multiple cases were excluded or single meningioma cases with genetic predisposition were included [22,23]. Fourth, since our hospital is a referral center, patients who were referred for surgeries had been imaged preoperatively at various other hospitals using different MR scanners and protocols. Fifth, not all patients had follow-up images, making it difficult to determine the exact prognosis of the spinal meningiomas.

In conclusion, spinal meningiomas showed slightly high signal intensity rather than high signal intensity on T2WI. It has been known that meningioma usually has benign disease course, but cord signal changes occurred in more than half of the cases in this study. Spinal meningiomas can be classified by MR imaging appearance, and there were clinical differences among the different types.

References

[1] Cohen-Gadol AA, Zikel OM, Koch CA, Scheithauer BW, Krauss WE. Spinal meningiomas in patients younger than 50 years of age: a 21-year experience. J Neurosurg Spine 2003;98(3):258–63.
[2] Abul-Kasim K, Thurnher MM, McKeever P, Sundgren PC. Intradural spinal tumors: current classification and MRI features. Neuroradiology 2008;50(4):301–14.
[3] Åkeson P, Holtås S. Radiological investigation of neurofibromatosis type 2. Neuroradiology 1994;36(2):107–10.
[4] Schaller B. Spinal meningioma: relationship between histological subtypes and surgical outcome? J Neurooncol 2005;75(2):157–61.
[5] Louis DN, Perry A, Reifenberger G, von Deimling A, Figarella-Branger D, Cavenee WK, et al. The 2016 World Health Organization classification of tumors of the central nervous system: a summary. Acta Neuropathol 2016;131(6):803–20.
[6] Liu WC, Choi G, Lee S-H, Han H, Lee JY, Jeon YH, et al. Radiological findings of spinal schwannomas and meningiomas: focus on discrimination of two disease entities. Eur Radiol 2009;19(11):2707–15.
[7] Hoover JM, Morris JM, Meyer FB. Use of preoperative magnetic resonance imaging T1 and T2 sequences to determine intraoperative meningioma consistency. Surg Neurol Int 2011;2.
[8] De Verdelhan O, Haegelen C, Carsin-Nicol B, Riffaud L, Amlashi S, Brassier G, et al. MR imaging features of spinal schwannomas and meningiomas. J Neuroradiol 2005;32(1):42–9.
[9] Pear BL, Boyd HR. Roentgenographically visible calcifications in spinal meningioma. Am J Roentgenol 1974;120(1):32–45.
[10] Matsumoto S, Hasuo K, Uchino A, Mizushima A, Furukawa T, Matsuura Y, et al. MRI of intradural-extramedullary spinal neurinomas and meningiomas. Clin Imaging 1993;17(1):46–52.
[11] Yamaguchi S, Takeda M, Takahashi T, Yamahata H, Mitsuhara T, Niiro T, et al. Ginkgo leaf sign: a highly predictive imaging feature of spinal meningioma. J Neurosurg Spine 2015;23(5):642–6.
[12] Sato N, Sze G. Extradural spinal meningioma: MRI. Neuroradiology 1997;39(6):450–2.
[13] El Khamary SM, Alorainy IA. Case 100: spinal epidural meningioma. Radiology 2006;241(2):614–7.
[14] Uchida K, Nakajima H, Takeura N, Yayama T, Guerrero AR, Yoshida A, et al. Prognostic value of changes in spinal cord signal intensity on magnetic resonance imaging in patients with cervical compressive myelopathy. Spine J 2014;14(8):1601–10.
[15] Nakamura M, Tsuji O, Fujiyoshi K, Hosogane N, Watanabe K, Tsuji T, et al. Long-term surgical outcomes of spinal meningiomas. Spine 2012;37(10):E617–23.
[16] Sandalcioglu IE, Hunold A, Müller O, Bassiouni H, Stolke D, Asgari S. Spinal meningiomas: critical review of 131 surgically treated patients. Eur Spine J 2008;17(8):1035–41.
[17] Takashima H, Takebayashi T, Yoshimoto M, Onodera M, Terashima Y, Iesato N, et al. Differentiating spinal intradural-extramedullary schwannoma from meningioma using MRI T 2 weighted images. 2018;91:20180262.
[18] Doita M, Harada T, Nishida K, Marui T, Kurosaka M, Yoshiya S. Recurrent calcified spinal meningioma detected by plain radiograph. Spine 2001;26(11):e249–52.
[19] Achari G, Behari S, Mishra A, Pandey R, Jain VK. Extradural meningioma en-plaque of the cervical cord. Neurol Res 2000;22(4):351–3.
[20] Klekamp J, Samii M. Surgical results for spinal meningiomas. Surg Neurol 1999;52(6):552–62.
[21] Caroli E, Acqui M, Roperto R, Ferrante L, D'Andrea G. Spinal en plaque meningiomas: a contemporary experience. Neurosurgery 2004;55(6):1275–9.
[22] Evans D, Watson C, King A, Wallace A, Baser M. Multiple meningiomas: differential involvement of the NF2 gene in children and adults. J Med Genet 2005;42(1):45–8.
[23] Goutagny S, Kalamarides M. Meningiomas and neurofibromatosis. J Neurooncol 2010;99(3):341–7.