Radiographic Features of Spinal Meningioma and Schwannoma: A Novel Specific Feature—Ginkgo Leaf Sign

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Abstract:

Introduction: Meningiomas and schwannomas are common intradural-extramedullary spinal tumors. Because of their different origins, they necessitate different surgical procedures, which makes preoperative diagnosis important.

Methods: In this study, clinical and imaging data for 62 patients diagnosed with either meningioma or schwannoma across multiple institutions were analyzed.

Results: The average age of patients was older (67.6 vs. 58.9 years), and the frequency of females was higher (72% vs. 46%) for meningioma than for schwannoma. Meningiomas were mostly found in the thoracic region (84%), whereas schwannomas were commonly located in the lumbar region (54%). For each tumor type, specific radiological findings were identified. For meningiomas, findings included the ginkgo leaf sign (GLS) (sensitivity 58%, specificity 100%), oval shape (sensitivity 84%, specificity 63%), dural tail sign (DTS) (sensitivity 75%, specificity 100%), and intertumoral calcification (sensitivity 39%, specificity 100%). Combining GLS and DTS greatly improved sensitivity to 89% (specificity 100%). For schwannomas, specific findings included a lobule shape (sensitivity 25%, specificity 95%), dumbbell shape (sensitivity 54%, specificity 100%), and cystic changes (sensitivity 54%, specificity 97%).

Conclusions: GLS may be a specific radiological feature for meningiomas and can aid in diagnosis when combined with DTS. Understanding these distinct radiological characteristics is valuable for preoperative differential diagnosis of intradural-extramedullary spinal tumors.

Keywords:

Meningioma, schwannoma, intradural-extramedullary spinal tumor

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Introduction

Meningiomas and schwannomas represent the predominant histological subtypes among intradural-extramedullary spinal neoplasms, which account for approximately 90% of such lesions in Japan[1-3]. Each spinal tumor has a specific histopathological feature (Fig. 1). Surgical intervention remains indispensable for managing both meningiomas and schwannomas[4]. Nevertheless, these tumors entail different surgical techniques because of the difference in tumor origin[5,6]. Meningiomas require resection that involves the contiguous dural tissue and/or ablation because the local recurrence rate is high[7]. By contrast, for schwannomas the involved nerve root must be removed[5,6]. Preoperative imaging

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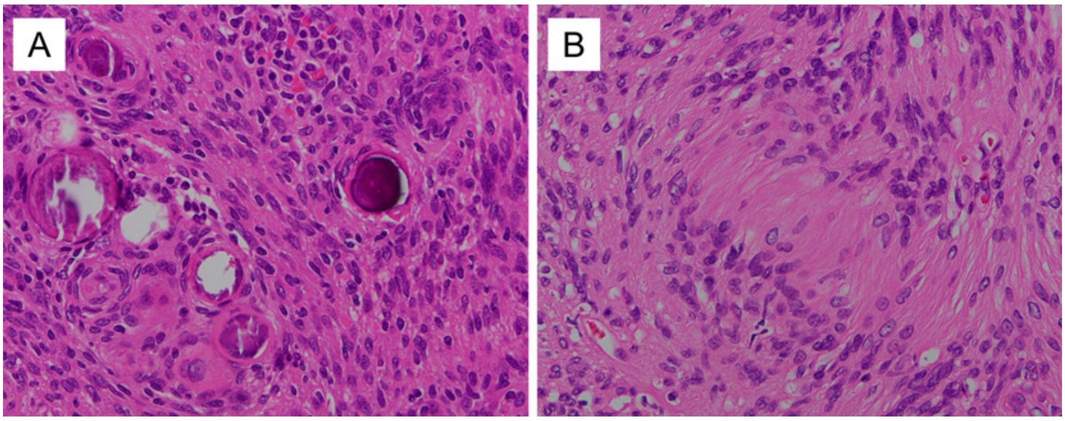

Figure 1. Typical histopathological findings. (A) Meningioma: a proliferation of oval to short spindle-shaped cells that have hyperchromatic nuclei, arranged in a whole-like pattern with Psammomatous bodies. (B) Schwannoma: a proliferation of short spindle-shaped cells that have a fascicular pattern with hyalinization.

diagnosis using computed tomography (CT) and/or magnetic resonance imaging (MRI) is important when choosing the best surgical technique. In previous literature, imaging findings that individually exhibit a characteristic profile for schwannomas and meningiomas have been elucidated. Dural tail sign (DTS) (Fig. 2A) and intertumoral calcification (Fig. 2B) radiologically characterize meningioma. Conversely, cystic changes (Fig. 2C) and scalloping of vertebral bodies (Fig. 2D) characterize schwannoma. Nevertheless, a debate regarding the predictive accuracy of preoperative imaging investigations in the context of these neoplasms has been ongoing. Yamaguchi et al. proposed a distinct imaging feature from a case series of intradural-extramedullary tumors located in a lateral or ventrolateral orientation relative to the spinal cord[8]. This unique feature is called the ginkgo leaf sign (GLS), which is reported to be highly specific to spinal meningiomas (Fig. 3)[8]. Concerning the underlying mechanism, neoplastic growth originates on the ventral aspect of the dentate ligament. The fibers that constitute the dentate ligament have an extensive longitudinal origin along the lateral surface of the spinal cord, which converges at the juncture of attachment to the dura mater, thereby generating a void between the ligament and the dura mater. Moreover, they postulated that the ventrally situated tumor extends dorsally through this interstitial cavity. An enlarged tumor mass causes a deformity on the spinal cord, similar to a fan-like configuration, because of the elongated dentate ligament's tethering effect on the lateral facet of the spinal cord[8]. Thus far, there have been no previous investigations that comprehensively assessed the practical utility of these distinctive imaging features. Hence, the present study aimed to validate the usefulness of the GLS in discriminating intramedullary extradural spinal tumors. Additionally, to facilitate the differentiation between meningiomas and schwannomas, in this study, the diagnostic accuracy of the reported imaging findings was investigated.

Material and Methods

Study design

This was a retrospective, multi-center observational study.

Patients

The records of 62 patients diagnosed with either a spinal meningioma or schwannoma who underwent surgical treatment between 2007 and 2020 at five teaching hospitals were retrieved. Through pathological examination, the diagnoses of all cases were confirmed. Information on clinicopathological characteristics, including sex, age at surgery, and location, was obtained from the medical records. The patients who met the following inclusion criteria were (a) those with pathologically proved meningiomas or schwannomas; (b) those who had MRI imaging, including T1-weighted imaging (WI), T2WI, and enhanced T1WI; and (c) those who had surgical resection. Those who met the exclusion criteria were patients with (a) an intradural-extramedullary tumor that had previously undergone external spinal surgery, (b) neurofibromatosis, (c) inadequate imaging quality, or (d) the majority of the lesion located in the paravertebral region.

Radiological analysis

MRI scans included sagittal T1WI, sagittal and axial T2 WI, sagittal and axial T2WI with fat suppression, and enhanced T1WI.

Imaging features, such as tumor size (major axis), tumor form (oval, lobular, or dumbbell), enhancement pattern (diffuse or peripheral), cystic change, GLS[8] (Fig. 2A), DTS[9,10] (Fig. 2B), scalloping of vertebral bodies (Fig. 2C), and intertumoral calcification (Fig. 2D) were investigated. Expert spinal surgeons assessed all radiological findings at each institute.

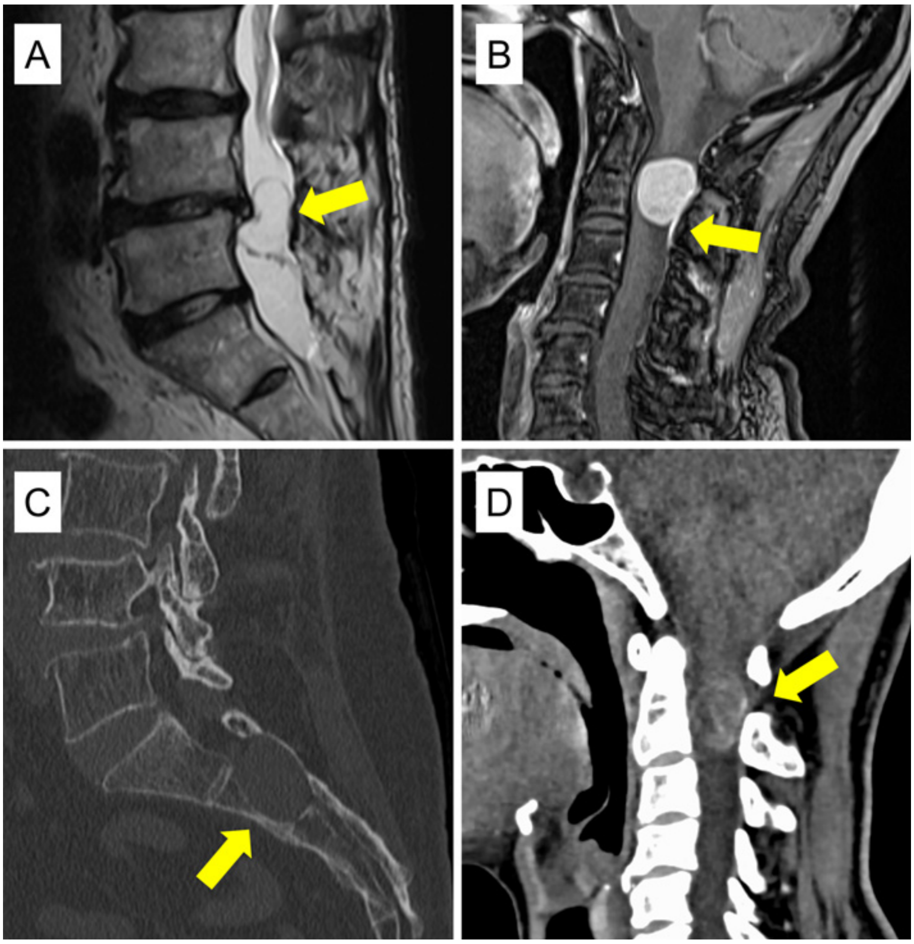

Figure 2. (A) A 75-year-old man who was suffering from light buttock to thigh pain with spinal schwannoma with cystic change (arrow), showing iso-intense signal to cerebrospinal fluid on sagittal T2WI. (B) A 57-year-old woman who was suffering from neck pain and right-hand numbness with spinal meningioma with diffuse enhancement and dural tail sign (arrow) on sagittal Gd-enhanced T1WI. (C) A 76-year-old who was suffering from dysuria with sacral bone showed scalloping (arrow) with a dorsal cortical defect on the CT sagittal view. (D) A 57-year-old woman who was suffering from neck pain and right-hand numbness with spinal meningioma with immature soft tissue calcification on the CT sagittal view.

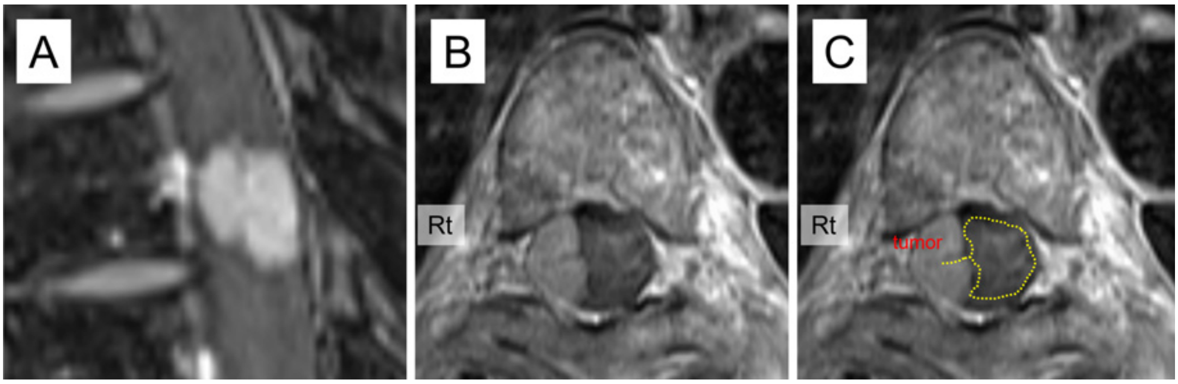

Figure 3. (A) Spinal magnetic resonance imaging on sagittal T1WI with Gd-enhanced T1WI showed an extramedullary tumor squashing the spinal cord. (B) The right half of the spinal canal was occupied by the mass, as shown by axial T1WI with Gd-enhanced T1WI. (C) Diagram that illustrates Fig. 3B. Spinal cord was deformed fan-shaped. (Inset) A photograph of a ginkgo leaf. The leaf of the ginkgo corresponds to the spinal cord, and the petiole corresponds to the dentate ligament.

Table 1. Patient Demographics.

		Meningioma (N=38)	Schwannoma (N=24)	P
Age at surgery (mean±SD, years)		67.6±2.4	58.9±3.1	0.031
Sex	Male/Female	11/29	13/11	0.028
Location	Cervical	5	5	<0.001
	Cervical to thoracic	1	0	
	Thoracic	26	5	
	Thoracic to lumbar	5	0	
	Lumbar	1	13	
	Sacrum	0	1	
Tumor size (mean±SD, mm)		18.6±1.4	21.6±1.7	0.17

SD: standard deviation

Table 2. Specific Radiological Features of Meningioma and Schwannoma.

Radiological features	Meningioma (N=38)	Schwannoma (N=24)	P		Sensitivity (%)	Specificity (%)	LR+	LR−
MRI								
Oval-shaped	32 (84%)	9 (38%)	<0.0001	Meningioma	84	63	2.3	0.25
Lobule-shaped	2 (5%)	6 (25%)	0.047	Schwannoma	25	95	5	0.05
Dumbbell-shaped	0 (0%)	13 (54%)	<0.0001	Schwannoma	54	100	∞	0.46
Cystic change	1 (3%)	13 (54%)	<0.0001	Schwannoma	54	97	18	0.47
Enhancing rim	2/30 (7%)	4/14 (29%)	0.071					
Diffused enhancement	28/30 (93%)	10/14 (71%)	0.071					
Ginkgo leaf sign (GLS)	22 (58%)	0 (0%)	<0.0001	Meningioma	58	100	∞	0.42
Dural tail sign (DTS)	27/36 (75%)	0/24 (0%)	<0.0001	Meningioma	75	100	∞	0.25
GLS and/or DTS	32/36 (89%)	0/24 (0%)	<0.0001	Meningioma	89	100	∞	0.11
CT								
Scalloping	4/38 (11%)	0/21 (0%)	0.29					
Intratumoral calcification	14/36 (39%)	0 (0%)	<0.0001	Meningioma	39	100	∞	0.61

LR: likelihood ratio

Statistical analysis

To compare and assess categorical data, the chi-squared test and the Wilcoxon test for quantitative variables were employed. A statistical significance threshold of P<0.05 was applied. The sensitivity, specificity, positive likelihood ratios (LR+), and negative likelihood ratios (LR−) for items with significant differences were calculated. To assess inter-rater and intra-rater reliability, 30 cases were selected and Cohen's kappa(κ) statistic was employed. For all statistical analyses, IBM SPSS version 19.0 was utilized (IBM SPSS, Armonk, NY, USA).

Results

Patient characteristics

Table 1 summarizes the patient characteristics. In this study, 38 patients with meningioma and 24 patients with schwannoma participated. The mean age at surgery of patients with meningioma was higher than that of schwannoma (67.6±2.4 years vs. 58.9±3.1 years, respectively, P=0.031). The percentage of female patients with meningioma was significantly higher than that of schwannoma (72% vs. 46%, P =0.028). Meningiomas were mainly located in the thoracic lesion (84%), and approximately half of the cases of schwannomas originated in the lumbar lesion (54%). The mean tumor size of meningiomas was 18.6±1.4 mm, and that of schwannomas was 21.6±1.7 mm. Between schwannomas and meningiomas, no significant difference in the tumor size was found (P=0.17).

Radiological features

Table 2 provides the statistical results for differentiating between meningiomas and schwannomas. Statistically significant findings regarding meningiomas were GLS (sensitivity 58%, specificity 100%, LR+ ∞, LR− 0.42, P<0.0001), the oval form (sensitivity 84%, specificity 63%, LR+ 2.3, LR− 0.25, P<0.001), DTS (sensitivity 75%, specificity 100%, LR+ ∞, LR− 0.25, P<0.0001), and intertumoral calcification (sensitivity 39%, specificity 100%, LR+ ∞, LR− 0.61, P<0.0001). GLS and DTS with high specificity among the assessed imaging features were combined. When both GLS and DTS were positive (17 patients), the test showed a sensitivity of 47% and a perfect specificity of 100%, which resulted in an infinite LR+ and an LR− of 0.53. Nonetheless, when either GLS or DTS was positive (32 patients), the sensitivity improved to 89%, with a perfect specificity of 100%. This yielded an infinite LR+ and a remarkably low LR− of 0.11. However, for schwannomas, lobule shape (sensitivity 25%, specificity 95%, LR+ 5.00, LR− 0.05, P= 0.047), dumbbell shape (sensitivity 54%, specificity 100%, LR+ ∞, LR− 0.46, P<0.0001), and cystic change (sensitivity 54%, specificity 97%, LR+ 18.00, LR− 0.47, P<0.0001) were significant specific radiological findings (Table 2). Tumor enhancement patterns and scalloping to the vertebral body did not differ significantly between the two tumors.

The following equation was applied for a multiple logistic regression analysis.

y=0.288 (if female)−20.096 (if dumbbell shape present)−18.756 (if cystic change present)+19.555 (if GLS present+36.349 (if DTS present))−17.051

By inserting y in the following formula, the probability (P) of meningioma for each case can be calculated, which provides a probability value between 0 and 1: $P=e^y/1+e^y$

The case depicted in Fig. 3 was of a female patient, and her tumor showed GLS but no DTS, dumbbell-shaped appearance, or cystic change. Therefore, it was calculated as follows, y=19.843 and P=0.999.

The interobserver and intraobserver reliability revealed a good agreement rate, with κ scores of 0.65 (95% confidence interval [CI]: 0.24-1.00) and 0.65 (95% CI: 0.24-1.00), respectively.

Discussion

Both spinal meningioma and schwannoma predominantly manifest as intradural-extramedullary lesions. The imperative nature of preoperative differentiation between meningioma and schwannoma arises from the requisite divergence in surgical approaches and subsequent oncological outcomes. Previously, radiologic imaging had low resolution, which often makes cases of intradural-extramedullary tumors difficult to distinguish. Considering substantial technological advancements in diagnostic imaging equipment, concerted efforts have been directed toward scrutinizing the diagnostic utility of imaging characteristics for distinguishing meningiomas from schwannomas. MRI, owing to its efficacy in differentiating these two spinal tumors, has garnered recognition. The radiographic features, such as oval or round shape[9,10], DTS[9,11], GLS[9], and homogeneous gadolinium enhancement, have been identified as specific radiological hallmarks of meningiomas.

Moreover, calcification on CT scans establishes a distinctive indicator for meningiomas[12]. Alternatively, cystic change[10,11], higher fluid signals[1,5,9,11], and dumbbell-shaped form[9,10,13] have been documented as particular radiological manifestations that are associated with schwannomas. Nonetheless, atypical presentations have been reported, which include dumbbell-shaped meningiomas[14], cystic meningioma, and another epidural tumor with calcification mimicking meningioma[15]. A contentious discourse has ensued regarding delineating specific radiological attributes distinguishing schwannomas from meningiomas, primarily due to the rarity of these neoplastic entities.

As described by Yamaguchi et al, GLS has been delineated as an innovative and distinct radiographic discovery in the context of spinal meningiomas[8]. They revealed that the GLS shows a sensitivity of 58% and a specificity of 100% in the diagnostic context of spinal meningiomas. Our findings are similar to these previous results. Its consistent specificity of 100% shows that GLS may be a distinctive imaging characteristic unique to meningiomas. Zhai et al. reported meningiomas accompanied by the presence of GLS in the lateral or ventrolateral lesion within a relatively substantial cohort[9]. In this study, GLS was found in only 4% of meningiomas, versus 58% in our study, which suggests variability among studies. A recent report by Krishnan showed a case of spinal meningioma featuring the GLS, which highlights the unique radiological findings[16]. They discussed the underlying mechanism that governs the nonoccurrence of the GLS in schwannomas. They postulated that the discrepancy in GLS manifestation between meningiomas and schwannomas can be attributed to these neoplasms' divergent origins and growth patterns. In instances where the lesion attains significant dimensions, schwannomas may extend longitudinally along the axis of the spinal cord, engendering a mass that spans multiple vertebral levels[9]. By contrast, an enlarging meningioma results in a spinal cord deformity with a fan-like configuration, as the lateral aspect of the spinal cord becomes constricted by the elongated dentate ligament, ultimately tethering tumorto the dura mater[8,9].

The sensitivity was limited in both our work and a prior study (58%). Spinal meningiomas that display the GLS manifest within lateral or ventrolateral locales[8,9]. Within the context of meningiomas, the spatial localization of the tumor is related to the occurrence of the GLS phenomenon. Consequently, we posit that the sensitivity of GLS as a diagnostic marker for meningiomas is insufficient. Nevertheless, in conjunction with classical imaging manifestations, GLS may serve as a key tool in the preoperative differentiation between meningiomas and schwannomas.

DTS has also been reported as a specific imaging finding in meningiomas (sensitivity 58%-64% and specificity 95%-97%)[11,12]. In our study, DTS was also identified as an independent factor to differentiate between meningiomas and schwannomas. Although the specificity for schwannoma was equal (both 100%), the sensitivity of DTS was slightly higher than that of GLS. However, the difference between the two was slight, and neither was diagnostically complete as a radiologic feature of meningioma. By combining DTS and GLS, the diagnostic sensitivity increased to 89%. Consequently, we determined a formula by combining the radiological characteristics specific to a schwannoma.

Our study had several limitations. First, there was a selection bias considering that surgery was performed because of tumor growth or the onset of symptoms. Second, multiple observers were involved in the interpretation of findings because of the multicenter nature of our study. Therefore, interobserver reliability is not completely accurate because interobserver reliability comparisons between facilities have not been conducted. Third, our study focused exclusively on cases of meningioma and schwannoma, precluding an analysis of GLS in other tumor types. Nonetheless, meningiomas and schwannomas exhibit the predominant histological subtypes among intradural-extramedullary spinal tumors. The preoperative differentiation between these entities holds paramount clinical significance. Moreover, because of the retrospective multi-institutional nature of the study, comparing intraoperative findings with radiological findings was difficult. To prospectively compare intraoperative and imaging findings, future studies are necessary. Finally, our study was retrospective and encompassed a relatively limited case-cohort. Therefore, a prospective investigation that involves a more substantial case-cohort is warranted.

To conclude, the radiological findings of intradural-extramedullary spinal tumors (meningioma and schwannoma) were assessed. The radiological characteristics of GLS may be specific for meningiomas and useful for preoperative differential diagnosis. Furthermore, when combined with DTS, GLS can be a useful diagnostic radiological feature.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Ethical Approval: The study design was approved by the institutional review board of Saga University Hospital (2022-10-R-03).

Informed Consent: Informed consent for publication was obtained by all participants in this study by opt-out.

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