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MRIcharacteristics of spinal ependymomainWHO gradeII:a review of 59 cases

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Abstract

Study Design: Retrospective multicenter study.

Objective: The goal of this study is to determine the characteristic imaging features of spinal ependymoma in a review of MRI data for a large series of surgically proven cases.

Summary of Background Data: Common spinal intramedullary neoplasms are mostly ependymomas andcomprise50-60% of spinal neuroepithelial tumors in adults. Preoperative prediction of the pathological diagnosis could enhance surgical planning and explanation of the procedure to patients. However, these types of tumors exhibit a variety of MRI findings.

Methods: Records were examined for 59 patients who underwent surgery for spinal cord ependymomaand had a pathological diagnosis of cellular ependymoma of WHO classification grade II.

Results: The ependymomas included 28 in the cervical spine, 34 in the thoracic spine, and 3 conus lesions. All cases were isointense or hypointense on T1-weighted MRI, and 55 (93%) were hyperintense on T2-weighted MRI. Tumors were located centrally in all cases; 50 (85%) showed surrounding cord edema;and 52 (88%) had associated cysts, including 36 (61%) rostral or caudal cysts, 10 (17%) intratumoral cysts, and 6 (10%) with syringomyelia. Of the 59 tumors,17 (29%) showed the “cap sign”, a rim of extreme hypointensity seen around the tumor onT2-weighted images, due to hemosiderin. Ingadolinium-enhanced MRI, allcases were enhanced, and 27 (46%), 16 (27%),11 (19%), and 5 (8%) cases showed homogeneous, heterogeneous, rim and nodular enhancement, respectively.

Conclusion: Hypointense changes on T2-weighted MRI and hemosiderin deposition reflect easy bleeding. Tumors are associated with various types of cysts, andgadolinium-enhancement patterns reflect a variety of intratumor cellular components. In cases in which the whole tumor

showsgadoliniumenhancement on MRI, rostral or caudal cyst and a cap sign with hemorrhage are characteristics of grade II classical ependymoma.

Key Words:spinal ependymoma, MRI, diagnosis, enhancement, cyst

Level of Evidence:3

Introduction

Spinal cord tumors account for 5% to 10% of all primary central nervous system (CNS) tumors[1,22-24]. The most common intramedullary neoplasms are ependymomas, which comprise 50-60% of spinal neuroepithelial tumors in adults[2]. These tumors may develop at any age, but present most frequently in the middle adult years[3-5]. Most ependymomas have benign pathological behavior, are slow growing, and, although primarily unencapsulated, tend to compress, rather than infiltrate, adjacent cord parenchyma[5-7]

Prediction ofthe pathological diagnosis preoperatively could enhance surgical planning and the ability of the surgeon to describe the procedure to patients.However, this is challenging becausespinal ependymomas exhibit a variety of MRI findings[8,9]. Thus, the purpose of this study is to determine the characteristic imaging features of spinal ependymoma through a review of MRI data from a large series of surgically proven cases.

Materials and Methods

The subjects were 59 patients (35 males, 24 females) who underwent surgery for spinal cord ependymoma in 5 institutions (3 tertiary referral centers and 2 academic hospitals) associated with the Nagoya Spine Group between June 2000 and December 2015. Surgery was performed by five board-certified spine surgeons.Reliable and detailed information were obtained froma comprehensive prospective registry. The average age was 51 (range 19-77) years (Figure1). Approval for the study was obtained from Institutional Review Boards.Data were retrospectively obtained from medical records.The pathological diagnosis in all 59 cases was confirmedby two pathologists ateach institutionas cellular ependymoma by surgical biopsy.Based on histology of microsections stained with hematoxylin and eosin, all tumors were grade IIin the WHO classification for tumors derived fromependymal cells, excluded grade I[10].

MRIwas performed at eachinstitution with a field strength of 1.5T.All patients underwent serial MRI using T1-weighted (TR, 400-700 ms; TE, 9-25 ms), fast spin-echo T2-weighted (TR, 3000-5000ms; TE, 96-150ms), and gadolinium-enhanced contrast (0.1 mmol/kg Gd-DTPA) T1-weighted sequences.All MRI data were evaluated by twoboard-certified neurosurgeons and tworadiologists, who reviewed all images and not just reports. The neurosurgeons worked mainly as spine surgeons and interpreted MRIs daily in clinical and research practice. The reviewers (K.I. and M.T.) identified and characterized abnormalities by consensus.Criteria used to evaluate MRIscans includedtumor localization, type of cord enlargement (symmetric or asymmetric), presence and type of cystic components (intratumoral or rostral or caudal cysts) or reactive dilatation of the central canal(syringomyelia), evidence of hemorrhage, length of involvement, signal characteristics, gadolinium-enhancement pattern, surrounding cord edema, and hemorrhage “cap sign”.Tumor localization in contrast images was examined to understand the relationship between the tumor and spinal cord, and to determine if the tumor was central.

Results

Of the 59ependymomas, 28were in the cervical spine, 34 in the thoracic spine, including 3were conus lesions (Figure 2). Details are shown in Table 1. The extent of involvement rangedfrom 1 to 6 vertebral segments, with a mean of 2.5. All cases showed isointense or hypointense lesions on T1-weighted MRI, and 55 (93%) were hyperintense on T2-weighted MRI. Tumors were located centrally in all cases; 50 (85%) showed surrounding cord edema (Figure3A,B);44 (75%)had a clear boundary ongadolinium-enhanced T1-weighted MRI (Figure 3C,D);52 (88%) had associated cysts, including 36 (61%)rostral or caudal cysts, 10(17%) intratumoral cysts, and 6 (10%) with syringomyelia (Figure4A-H); 17 (29%) had a “cap sign”, a rim of extreme hypointensity due to hemosiderin, at the poles of the tumor on T2-weighted images (Figure3E); and 4 (7%) had formed a niveau inside the cyst (Figure 3F,G). On gadolinium-enhanced T1-weighted images,all cases were enhanced, and 27 (46%),16 (27%),

11 (19%),and 5 (8%) tumors had homogeneous, heterogeneous, rim, and nodular enhancement, respectively (Figure5A-D).In casesin which the whole tumor showedgadoliniumenhancement on MRI, a rostral or caudal cyst and a cap sign with hemorrhage were found at significantly higher rates (Figure 6AB).

As an illustrative case, we report findings ina 19-year-old male with slight numbness of the upper extremities without neck pain or motor deficit. At onset, MRI showedspinal cord swelling and gadolinium-enhanced T1-weighted images showeda homogeneous tumor from T4-T6 (Figure7A,B). Two years later, the tumor size had increased and cystic components were present on the rostral and caudal sides. Gadolinium-enhanced T1-weighted MRI showeda heterogeneous signal (Figure7C,D). Numbness of the hands had worsened, and surgery was performed.The pathological finding was cellular ependymoma of WHO grade II.

Discussion

Intramedullary spinal cord tumors account for 2-4% of all CNS tumors[11-14]and are most frequently diagnosedas ependymoma; other diagnoses include astrocytoma, hemangioblastoma, and myxopapillary ependymoma[8].Such tumors should be surgically treated as soon as neurological symptoms appear[5]. In World Health Organization (WHO) guidelines, ependymomas are classified into grades I, II, and III[2]: subependymoma WHO grade I, myxopapillary ependymoma WHO grade I, ependymoma WHO grade II, and anaplastic ependymoma WHO grade III.The most common intramedullary spinal cord tumors are grade IIependymomas, comprising about 60% of all such tumors[15,25-27].

Ependymomas are usually well circumscribed and relatively amenable to complete removal; therefore, gross total resection is attempted for most benign pathologies[8,12,13].In contrast, for astrocytoma, tumor resection insurgery followed by radiation therapy and chemotherapyare desirable,

and radiation therapy and chemotherapy should be prioritized over tumor resection in cases of high grade malignancy. For surgical planning, it is desirable to know the pathological diagnosis, but this requires a biopsy that involves preparation equivalent to that for resection.Moreover, in spinal ependymoma, spinal syringomyelia and cysts merge at a high rate, andthese maybe seen as another intramedullary tumor or a Chiari malformation and adhesion arachnoiditis. The surgical plan largely depends on the presence or absence of the tumor in imaging findings, especially on gadolinium-enhanced MRI.Thus, it would be useful if this diagnosis could be predicted preoperatively based on MRI findings.

Axial images show that ependymomas tend to be centrally located[8,9,15], andthis was confirmed in our series. Epstein et al. hypothesized that ependymomas originate around the central canal and then expand symmetrically and circumferentially, compressing or interrupting the spinothalamic tract[16]. Grossly, ependymomas are cylindrical, elongated masses causing fusiform expansion of the spinal cord. Previous reports suggest that 50% of spinal ependymomas have an associated cyst[9,17], andwe found a higher incidence of cysts of 88% (52/59). Three distinct types of cysts have been identified: intratumoral cysts, rostral or caudal cysts, and reactive dilation of the central canal (syringomyelia)[17]. Our cases includedthese three types of cysts at rates of 17%, 61% and 10%, respectively.

An intratumoral cyst (within the tumor itself)is thought to arise from degeneration, necrosis, and liquefaction within the neoplasm, and contains a mixture of elements such as protein, old hemorrhage, and necrotic tumor tissue[9]. This inhomogeneous composition leads to variable signal characteristics on MRI, and not always the expected low intensity and hyperintensity on T1- and T2-weighted images, respectively.Rostral and caudal cysts do not show contrast enhancement around their borders, as seen for intratumoral cysts, and have been shown to contain hemorrhagic or xanthochromic fluid, but not tumor cells[5,9]. Secondary reactive dilation of the central canal, referred to as syringomyelia, is most likely related to partial obstruction of the central canal by the tumor. This dilation can be recognized

because of its central location in the spinal cord, cerebrospinal fluid-equivalent signal, location beyond the tumor margins, lack of enhancement with contrast agent, and hypoechoic signal on intraoperative ultrasound. There is resolution of dilation of the central canal after removal of the tumor. Extensive regions of cord enlargement seen on MRI may be caused primarily by long rostral or caudal cysts or by secondary reactive dilation of the central canal, whereas the tumor itself may be quite small.

Spinal ependymomas have a well-known tendency to bleed, but the pathogenesis of this effect is poorly understood. The tendency for hemorrhage has been suggested to be due to the highly vascular connective tissue stroma[18,19].Furthermore,because ependymomas are well circumscribed and lack intervening neural tissue, they are more likely to have a vulnerable interface between the tumor and normal cord substance[20]. In our series, 29% (17/59) cases had a “cap sign,” a rim of extreme hypointensity due to hemosiderin seen at the poles of the tumor on T2-weighted images. This finding is thought to be secondary to hemorrhage.

For signal characteristics, we focused on spinal cord swelling, signal intensity, contrast effect and tumor location as criteria for MRI-based diagnosis. Almost all intramedullary spinal cord tumors show at least some contrast effect following intravenous administration of a gadolinium-based contrast agent[8,9]. Our series reflected the generally accepted view that ependymomas are isointense to hypointense on T1-weighted MRI and hyperintense on T2-weighted MRI[15,17]. Areas of hypercellularity appear as hypointense within the bulk of a relatively hyperintense lesion on T2-weighted images. On contrast-enhanced MRI, these tumors show strong but heterogeneous enhancement and often have well-defined margins[5,8,15]. Ependymomas havealso been widely reported to show intense, homogeneous, sharply demarcated focal enhancement[16,17].In our series,various contrast enhancement effects were seen, and in an illustrative case, sequential changesin gadolinium-enhanced MRI were found, indicating changes in intratumor cellular components.

There are several limitations in this study. The first is the small number of cases. Second,we focused only ongrade II classical ependymoma derived from ependymal cells.Third, MRI at each institution usedvarious pulse sequences and other parameters.However, grade IItumors are most frequently diagnosed as ependymoma,and spinal ependymomas exhibit a variety of MRI findings; therefore,a summary of MRI variation maybe helpful for better diagnosis andsurgical planning based on improved preoperative information.And recognition of the imaging features andenhancement of these tumors on MRI should prove useful for preoperative diagnosis and surgical planning for spinal tumors in this study.

Conclusion

Most tumors have clear boundaries and arelocated in the center of the spinal cord. Hypointense changes on T2-weighted imagesand hemosiderin deposition reflect easy bleeding. These tumors areassociated with various types of cystand havevariable gadolinium-enhancement patterns that reflect a variety of intratumor cellular components. In a case in which the whole tumor showsgadoliniumenhancement on MRI, a rostral or caudal cyst and a cap sign with hemorrhage arecharacteristics of grade II classical ependymoma.

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Figure Legends

Figure1. Age distribution of all cases.

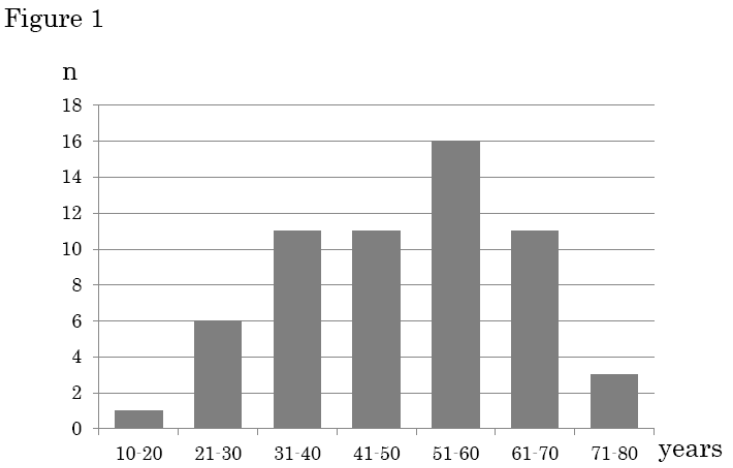


Figure2: Localization of 59 spinal ependymal tumors in WHO grade .

Figure2

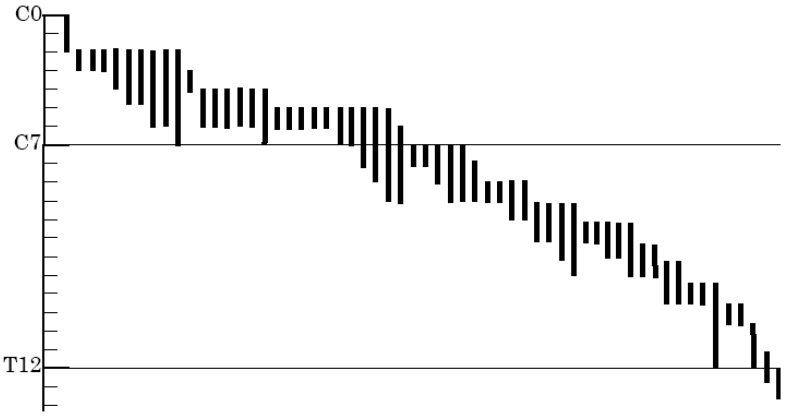


Figure3.T2-weighted MRI showing (A) a case with edema surrounding the spinal cord (arrow) and (B) a case without edema. Gadolinium-enhanced T1-weighted MRI showing (C) a tumor with a clear boundary and (D) a tumor with an unclear boundary. Sagittal T2-weighted MRI showing the presence of a hemorrhage “cap sign” (E), an area of low signal intensity reflecting hemosiderin deposition from prior hemorrhage with hemosiderin capping the margins of the lesion (arrows). T2-weighted sagittal (F) and axial (G) MRI showingniveau formation inside a cyst (arrows).

Figure3

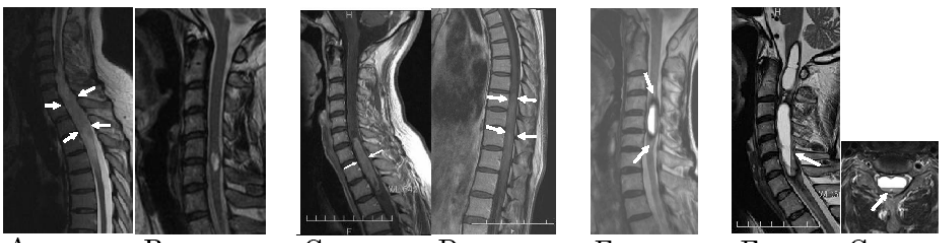
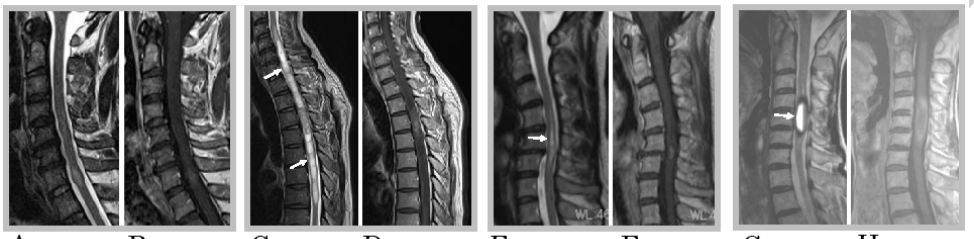


Figure4.T2-weighted (A,C,E,G) and gadolinium-enhanced T1-weighted (B,D,F,H) MRI of cystic components (arrows).(A,B) No cystic component. (C,D) Rostral and caudal cyst around tumor. (E,F) Reactive dilation of the central canal. (G,H) Intratumoral cyst.

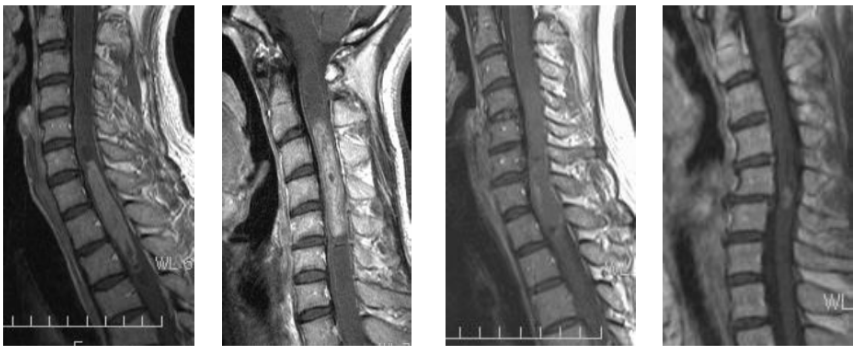
Figure4



A B C D E F G H

Figure5.Gadolinium-enhanced T1-weighted MRI for tumors showing (A) homogeneous, (B) heterogeneous, (C) rim, and (D) nodular enhancement.

Figure5



A B C D

Figure6. Gadolinium-enhancement patterns of whole tumors on MRI. These tumors had significantly higher rates of (A) rostral or caudalcystic componentsand (B) a cap sign.*p<0.01, **p<0.05.

Figure 6

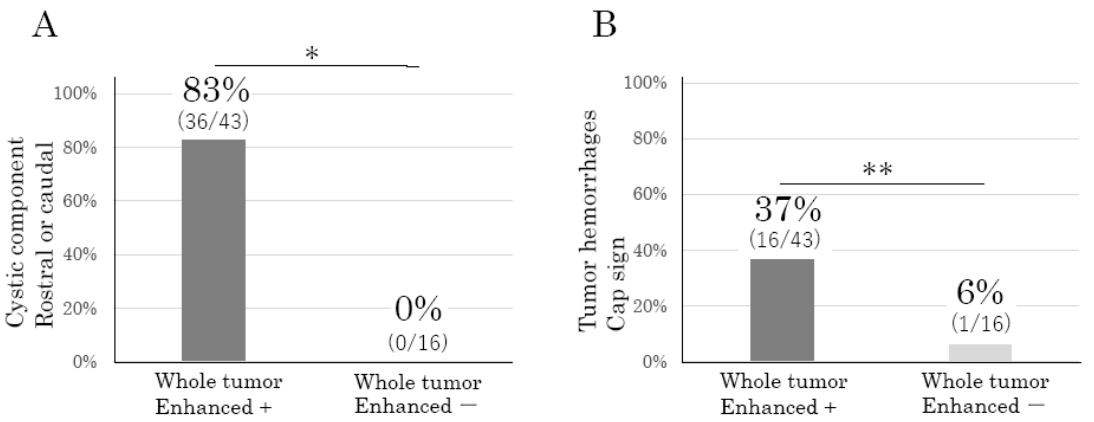
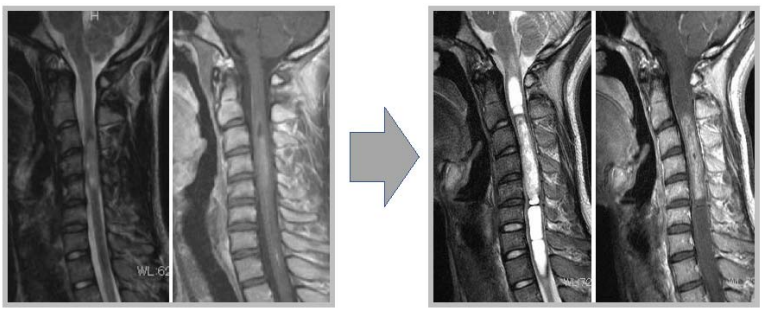


Figure7.Sequential changes in T2-weighted (A,C) and gadolinium-enhanced T1-weighted (B,D) MRI in the case of a 19-year-old male with slight numbness of the upper extremities without neck pain and motor deficit. At onset, images showed spinal cord swelling (A) and a homogeneous tumor from T4-T6 (B). Two years later, cystic componentson the rostral and caudal sides were enlarged (C) andthe tumor size had increased and was heterogeneous (D).

Figure7



A B C D

Table 1. MRI characteristics of spinal ependymoma (n=59)

Item	Percentage (cases)
Location	
Cervical	47% * (28)
Thoracic	58%* (34)
Conus	5%* (3)
Edema surrounding spinal cord	
Edema (+)	85% (50)
Tumor location	
Central	100% (59)
Tumor hemorrhages	
Cap sign (+)	29% (17)
Cystic component	
Rostral or caudal	61% (36)
Intratumoral	17% (10)
Syringomyelia	10% (6)
None	12% (7)
Gadolinium-enhancement pattern	
Enhanced (+)	100% (59)
Whole tumor enhanced: Homogeneous	46% (27)
Whole tumor enhanced: Heterogeneous	27% (16)
Rim	19% (11)
Nodular	8% (5)

*Data overlap in some cases.