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ABSTRACT

SUMMARY: Myxopapillary ependymomas (MPEs), classified as grade 2 tumors by the World Health Organization, are rare spinal neoplasms. Despite their slow growth and generally benign nature, MPEs have a high recurrence rate and potential for CSF dissemination. This study aims to identify the MRI characteristics and pathologic patterns of MPE and investigate potential correlations between the MRI characteristics and specific histopathologic patterns. We assessed 13 patients (7 men; mean age, 45.1 years) with pathologically proved MPE. MR images were reviewed for tumor location, size, T1 and T2 signal characteristics, contrast enhancement, hemosiderin cap presence, vertebral scalloping, drop metastasis, and prominent intradural flow voids. Four histopathologic patterns (microcystic, solid, hemorrhagic, and high hyalin content) were defined and segmented, with surface areas measured and percentages calculated relative to the total tissue surface. Most tumors were in the lumbar region (84.61%), with MRI revealing typical features such as T2 hyperintensity (100%) and contrast enhancement (92.3%). A rare nonenhancing MPE was noted. Large tumors exhibited a microcystic pathology pattern, with 2 cases with this pattern showing drop metastasis on MRI. Smaller tumors typically presented a solid pathology pattern with homogeneous MRI signals. This study underscores the diverse MRI presentations of MPE and suggests a potential link between microcystic patterns in pathology and large MPE with drop metastasis.

ABBREVIATIONS: MPE = myxopapillary ependymoma; SD = standard deviation; WHO = World Health Organization

Myxopapillary ependymomas (MPEs) are rare tumors, classified as grade 2 tumors by the World Health Organization (WHO) 2021 classification. The incidence is 0.6 to 1.00 per million person-years in the American population, and they represent 1%–5% of all spinal neoplasms.[1,2]

While MPEs typically exhibits a slow growth pattern and are generally regarded as benign, they have a high probability of recurrence or CSF dissemination,[3-6] and rare cases may present with extraneural metastasis.[2] The current knowledge of this possible aggressive clinical behavior with dissemination and recurrence has led to the reclassification of MPEs, which have been considered grade 1 tumors before the 2021 WHO classification[5,7] and are currently classified as grade 2 tumors.

The symptoms are nonspecific; patients can present with low back pain aggravated by lounging position, leg pain, paresthesia, lower extremity weakness, and urinary sphincteric disturbances.[8,9] Because of the nonspecific nature of symptoms, MRI and pathology are crucial for accurate diagnosis.

Classically, MPE is an intradural extramedullary mass most commonly found in the conus-cauda-filum terminale region at lumbar, or low thoracic level.[7] MRI is the best technique to image spinal tumors. On MRI, it is a well-defined, heterogeneous intradural tumor, hyperintense on T2WI and isointense on T1WI.[7,10,11] Some tumors may be spontaneously hyperintense on T1WI; this is thought to be because of a recent hemorrhage.[11,12] MPE is a highly vascular tumor that virtually always enhances after contrast administration.[10] It may present superficial siderosis because of its high vascularity and propensity to bleed.[13]

In histopathology, MPE typically exhibits papillary structures composed of cuboidal or elongated cells arranged around fibrovascular cores. These structures are often associated with myxoid material surrounding blood vessels or found in microcysts.[7,14] The diagnosis of MPE can be supported by its distinctive DNA methylation profile and immunohistochemistry pattern. Notably, MPE can manifest as hybrid tumors that bear a resemblance to classic ependymomas.[15]

While MPE is considered a well-known entity in clinical radiology, the literature lacks a recent series focusing on its MRI characteristics, with the largest series to date, involving 20 patients, published in 1995.[10] We think that because of the improvements

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in MRI techniques, MPE is diagnosed today in its more incipient forms. The rest of publications on MRI characteristics of MPE are mostly limited to case reports[16-18] and reviews.[11,19] Additionally, a recent series of 24 patients,[20] which focused on the differential diagnosis between MPE and schwannomas, used certain MRI parameters for their analysis. To the best of our knowledge, no study has been published on the radiologic-pathologic correlation of MPE.

The primary purpose of this study is to describe the diverse MRI characteristics of MPE. Our secondary purpose is to identify pathologic patterns linked to atypical cases to explain their MRI characteristics.

CASE SERIES

Approval from the local ethics committee on research involving humans was obtained.

We screened the radiology report database by using the keywords: "ependymome myxopapillaire" for consecutive patients who had an MRI study obtained between January 2008 and July 2022 with a pathology diagnosis of an MPE. MRI studies were performed on a 1.5T MRI or 3T MRI. All studies included the sequences: sagittal T1WI, sagittal and axial T2WI, sagittal and axial T1WI after gadolinium contrast injection; we used 3-mm slice thickness for all sequences at 1.5T and 3T MRI. MRI studies were evaluated and reviewed for tumor location, size, T1 and T2 signal characteristics, contrast enhancement, hemosiderin cap presence, vertebral scalloping, drop metastasis, and prominent intradural flow voids. The internal reference used to assess the signal of MPE was the spinal cord. Patients' medical records were retrospectively reviewed for the clinical presentation.

The pathology slides were scanned and anonymized. The total surface of the tissue was measured for each patient. We defined 4 patterns of interest that were segmented: microcystic, solid, hemorrhagic, and high hyalin content. A microcystic pattern was defined as a high content of cysts filled with mucin. A solid pattern was defined as an area with a high content of cellules and a low content of mucin and cysts. Pattern surface areas were measured, and percentages were calculated relative to the total tissue surface.

Thirteen patients were included in the study, 7 men and 6 women, with a mean age of 45.1 years; standard deviation (SD), 11 years. One patient was excluded because of a lack of consent. For patient number 13, we analyzed the MR images acquired after the first surgery, which consisted of a laminectomy with the purpose of a biopsy. The residual tumor was mostly intact and was resected in a second surgery. We decided to include this case without the initial presurgical MRI, as we were able to study the MRI aspect of the residual tumor and the histopathology from the sample obtained in the second surgical excision.

The clinical presentation was variable, with most patients presenting with leg pain (12/13, 92.31%) or back pain (10/13, 76.92%). Other symptoms at presentation included: urinary sphincter disturbance (3/13, 23.08%), lower extremity weakness (2/13, 15.38%), back pain worsening during in lounging position (2/13, 15.38%), and sensory loss (1/13, 7.69%).

Most MPEs were located in the lumbar region (11/13, 84.61%). In 1 patient, the tumor was at the level of the first sacral vertebra; he presented with sciatic pain and had no lumbar pain. One patient had a low thoracic lesion (T11–T12) and presented with right leg weakness, amyotrophy, and no lumbar pain.

Three lesions were considered incidental findings, as they were associated with disc hernias, thus explaining the symptoms. These lesions were the smallest lesions of the series (0.6, 0.7, and 1.1 cm).

Imaging

The MRI analysis of each case is presented in Supplemental Data. The tumor size ranged from 0.6 cm to 12 cm, with a mean size of 3.98 cm; SD, 3.16 cm. Most tumors exhibited isointensity on T1WI (8/13, 61.53%), hyperintensity on T2WI (13/13, 100%), and enhancement following gadolinium injection on T1WI (12/13, 92.3%). Two lesions in the series displayed high signal intensity on T1WI. Notably, 1 tumor did not enhance after gadolinium contrast administration. Posterior vertebral scalloping was identified in the 4 largest lesions (6.3, 6.8, 7.2, and 12 cm). A "heart-shaped" pattern of scalloping was observed (4/13, 30.76%), characterized by scalloping of the lateral aspects of the posterior vertebral wall while respecting the median part (Fig 1). This was observed in lesions extending on 2 or more vertebral levels. Three cases presented drop metastasis as enhancing lesions located at the end of the dural sac (23.07%). A hypointense peripheral rim on T2-weighted images, consistent with a hemosiderin cap sign, was present in 5 patients (38.46%).

Pathology

The results of the pathology analysis are presented in Supplemental Data. The microcystic pattern was identified in 3 patients, with varying quantities observed across the tissue surface (4%, 16%, 9%). Notably, these cases corresponded to the largest tumors in the series, measuring 6.8 cm, 12 cm, and 7.2 cm, respectively. The 2 lesions with the highest microcystic content (16% and 9%) were found to be associated with drop metastasis (Fig 2 and Supplemental Data).

A mostly solid pattern was predominantly observed in 4 cases (90%, 100%, 100%, and 71%). On MRI, these cases were small-sized tumors with homogeneous high T2 signal and homogeneous enhancement (Fig 3 and Supplemental Data).

The notable case that did not exhibit enhancement on MRI featured a 100% solid pattern on histopathology slides (Fig 4 and Supplemental Data). Pathologic analysis of this case revealed a classic ependymoma histopathology, with a methylome test consistent with an MPE.

Hemorrhagic components were a common feature in most cases. However, our analysis did not reveal any notable associations between cases with high hemorrhagic content and the presence of a hemosiderin cap sign or hyperintensity on T1-weighted images.

The presence of a high hyalin content did not show any specific associations with distinct MRI characteristics.

DISCUSSION

In this study we analyze the spectrum of MRI presentations of MPE. The most common presentation of MPE in our series was of a well-defined mass situated in the filum terminale area, demonstrating characteristic MRI features. These included hyperintensity

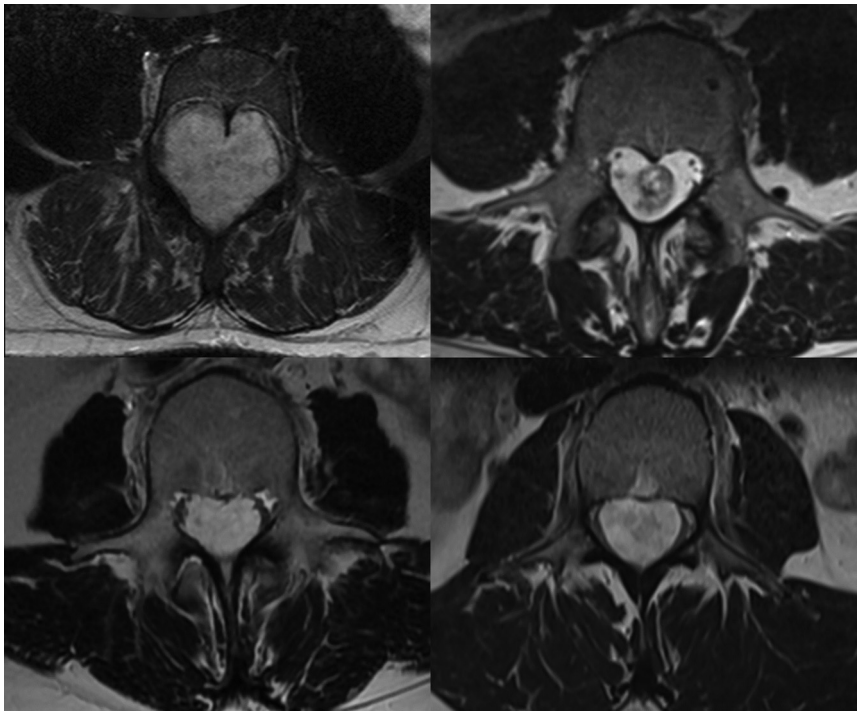

FIG 1. Axial T2WI of the 4 cases with the largest tumors showing intradural masses, T2 hyperintense, with a "heart-shaped" scalloping of the posterior vertebral wall.

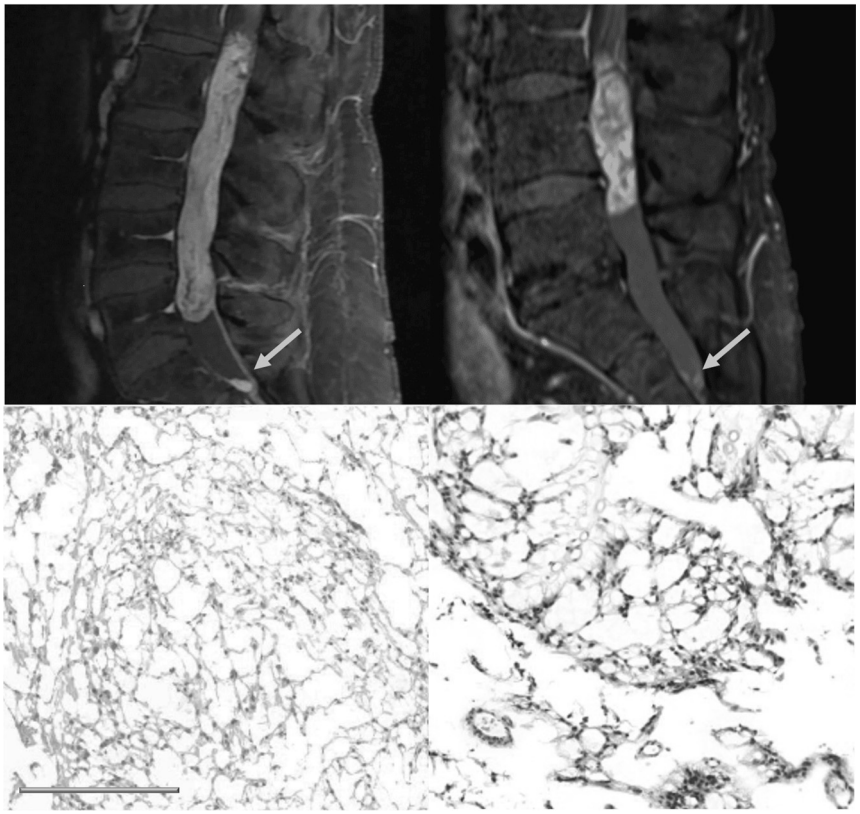

FIG 2. *Upper sections*, Sagittal post gadolinium contrast T1WI with fat saturation showing 2 cases of large intradural masses with heterogeneous enhancement with drop metastasis as enhancing lesions in the dural cul-de-sac (*white arrows*). *Lower sections:* Corresponding pathology images of hematoxylin-eosin staining showing myxopapillary ependymomas with microcystic pattern (line for scale of 0.2 mm).

on T2WI, isointensity on T1WI, contrast enhancement, and heterogeneity on T2WI and postcontrast T1WI. These findings are consistent with previous reports,[7,10,11] further supporting the diagnostic value of these MRI characteristics in identifying MPE. A minority of MPEs showed a high T1 signal. Small lesions tended to have a homogeneous T2 signal, while larger lesions were heterogeneous.

Another observation in our study was the presence of posterior vertebral scalloping in large tumors. This scalloping pattern exhibited a heart-shaped appearance on axial images. Posterior vertebral scalloping can serve as an indirect CT scan sign of a filum terminale tumor.

Extraordinarily, 1 case did not show any enhancement on postcontrast T1WI. MPE is a highly vascular tumor that is considered to virtually always enhance after contrast administration.[10] Histology analysis of this case was of a classic ependymoma; however, the methylome test results were consistent with MPE. Consequently, the final diagnosis was of MPE. Nonenhancing spinal ependymomas are rare, with only a few cases reported in the literature, mostly classic ependymomas or spinal subependymomas.[21-25] To the best of our knowledge, Kahan et al[12] published the only other case of a nonenhancing MPE in a case series of 26 patients with spinal ependymomas, where 1 case did not show enhancement on T1WI postcontrast, with a pathology result of MPE. Additionally, a case report described a nonenhancing intradural extramedullary tumor in the filum terminale region.[23] The pathology results indicated a classic ependymoma, but the authors did not specify whether a methylome test was conducted. Consequently, the possibility that it was a case of MPE, like our case, cannot be excluded. The pathology presentation of a classic MPE with an MPE-positive methylome test could suggest a hybrid MPE with a predominant component of classic ependymoma. The prognostic significance of MPE hybrid tumors remains undetermined.[15] Furthermore, it is also known that MPE can manifest with minimal myxoid features.[7]

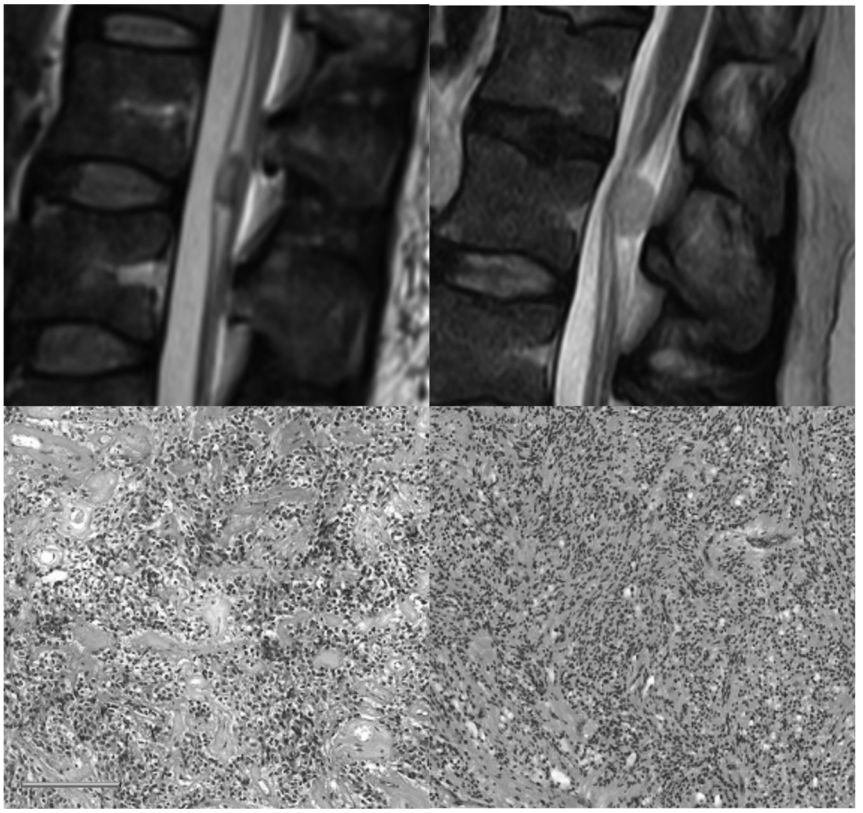

FIG 3. *Upper sections:* MR sagittal T2WI showing 2 cases of small-sized filum terminale masses that are homogeneously T2-hyperintense. *Lower sections:* Corresponding pathology images of hematoxylin-eosin staining showing 2 cases of myxopapillary ependymoma with a solid pattern (line for scale of 0.2 mm).

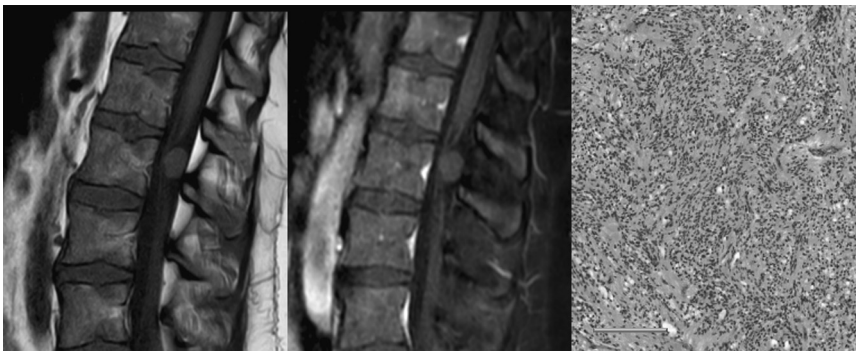

FIG 4. MR sagittal T1WI without contrast enhancement (*left*) and T1WI fat saturation with contrast enhancement (*middle*) showing a filum terminale mass, T1 isointense to the conus medullaris, and no enhancement observed after gadolinium contrast injection. Pathology image (*right*) of hematoxylin-eosin staining showing a myxopapillary ependymoma with a solid pattern (line for scale of 0.2 mm).

One insight from our pathologic analysis was the identification of a microcystic pattern in the 3 largest tumors of the series. Notably, the 2 cases with the highest microcystic pattern content were linked to drop metastasis. This discovery suggests the possibility that the microcystic pattern may contribute to a less stable tumor structure, increasing susceptibility to the formation of drop metastases. Drop metastases were present on the preoperative MRI in 3 patients of the series. Drop metastasis was classically considered a rare occurrence described initially in case reports.[26] In a larger study from 2015, Weber et al[2] found only 4 of 182 patients (2.2%) with drop metastasis at the initial presentation. Two more recent studies[27,28] showed 21.1% and 29.2% of patients with drop metastasis at the initial presentation; our study reveals a similar occurrence with 3 out of 13 patients (23.07%). As previously discussed, 2 patients presenting with drop metastases exhibited a significant microcystic pattern on pathology slides. Further studies are needed for confirmation of a potential correlation and to examine the diagnostic and prognostic implications of this pattern. One study demonstrated that preoperative drop metastases were significantly associated with a risk of recurrence.[28] If there is a correlation between the microcystic structure of the MPE and the risk of drop metastasis, this could aid in better selecting the patients who may benefit from radiation therapy, as adjuvant radiation therapy was shown to be particularly useful in patients with drop metastasis.[28]

The 4 smallest tumors of the series were associated with a solid pattern on histopathology. On MRI these tumors were homogeneous on T2 and T1 before and after contrast administration. This homogeneity may be attributed to a more compact tumor structure with a lower content of microcystic spaces, in opposition to large heterogeneous tumors.

It was previously hypothesized that some MPEs may be T1 hyperintense because of recent hemorrhage,[11,12] and that they may present superficial siderosis because of their high propensity to bleed.[13] Contrary to these hypotheses, our analysis did not reveal any significant associations between T1 hyperintensity or the presence of a hemosiderin cap on MRI and larger hemorrhagic components on pathology slides. Hemorrhage was present in most cases of our series, primarily in the peripheral regions of the tissue. Assessing hemorrhage on pathology slides may not fully capture the real intratumoral hemorrhage, given the potential contamination of intraoperative bleeding of the slides.

The main differential diagnoses of MPE are: cauda equina neuroendocrine tumor; neurogenic tumors, such as schwannoma; and neurofibroma and meningioma. Large MPEs usually

show a characteristic appearance with heterogeneous high T2 signal with low T2 components and heterogeneous enhancement, but these findings are not specific. Posterior vertebral scalloping shows a characteristic heart-shaped pattern in large MPE, which may help differentiate it from other entities. The enhancement pattern may help in the differential diagnosis[11]: cauda equina neuroendocrine tumor may have a salt and pepper pattern due to vascular flow voids, neurogenic tumors may present with a target enhancement, and meningiomas with a dural tail enhancement. Also, meningiomas are rare in the lumbar region. We found that large MPE enhanced heterogeneously, without target enhancement or salt and pepper patterns. Leptomeningeal spread makes it more probable that the diagnosis is an MPE, as the other tumors rarely present leptomeningeal spread.[7] However, smaller lesions are more difficult to differentiate from other entities as they all may present with homogeneous high T2 signal, isointensity on T1, and homogeneous enhancement and do not present with vertebral scalloping.

This study has limitations owing to its retrospective design and a small sample size. There were variations in MRI protocols among patients; some had T1WI with fat saturation postcontrast, while others had T1WI without fat saturation. One patient had a first surgery consisting of a laminectomy for a biopsy and was included without an initial presurgical MRI, although we analyzed the MRI signal and pathology from the mostly intact residual tumor. Clinical data were extracted from medical reports, the duration of symptoms was not consistently documented, and there was variability in symptom documentation. Because of the study's small size, we cannot draw statistically significant conclusions regarding the correlation between MRI and pathologic characteristics.

CONCLUSIONS

The imaging spectrum of myxopapillary ependymomas is large, and this study suggests a possible association between cases with drop metastases and cases of large tumors and a microcystic pattern on pathology. Conversely, small homogeneous tumors may be associated with a compact solid pattern in pathology.

Our series adds to the literature a rare case of myxopapillary ependymoma showing no enhancement, which, to our knowledge is the second one reported.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

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