Angiomatous meningioma with cystic degeneration: A case report

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Abstract. Angiomatous meningioma (AM) is an uncommon type of meningioma, with cystic degeneration being even rarer. Typically, the imaging features of AM include solid masses with severe peritumoral edema, and the presence of 'root like' vascular flow void shadows within them during magnetic resonance imaging (MRI) enhancement. The present study reports the case of a 58-year-old male who came to seek medical attention mainly due to a bilateral frontal distending headache that had persisted for 18 days and was gradually worsening. Unlike in other patients with typical AM, the imaging examination of this patient showed that the solid component of the tumor accounted for a smaller proportion of the total lesion volume; the lesion was predominantly composed of cystic components, with no obvious severe edema around the tumor. An enhanced MRI scan did not show any characteristic vascular flow voids. During the surgery, the surgeon separated the solid part of the tumor from the dura mater, cut off the tumor's blood supply artery, extracted a portion of the cystic fluid for decompression and completely removed the tumor. The postoperative pathology confirmed that the tumor was an AM. The present case report describes the rare imaging manifestation of cystic AM, and analyzes it in conjunction with other related studies on AM. New diagnostic references are provided for patients with similar imaging manifestations, and practical diagnostic and treatment experience are also provided for the treatment of AM with concurrent cystic degeneration in the future.

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Introduction

Meningiomas are the most common primary intracranial tumors in adults, accounting for 40% of all intracranial tumors. It is estimated that the incidence rate is 951/100,000 individuals, most of whom are women, and the ratio of men to women is ~1:2.3 (1,2). Angiomatous meningioma (AM) is a relatively rare type of meningioma, accounting for ~2.1% of the 15 subtypes of meningioma. Meningiomas are further stratified into three grades based on their biological behavior: i) WHO Grade I (benign), consisting of meningothelial (syncytial) meningioma, fibrous (fibroblastic) meningioma, transitional (mixed) meningioma, psammomatous meningioma, angiomatous meningioma, microcystic meningioma, secretory meningioma, lymphoplasmacyte-rich meningioma and metaplastic meningioma; ii) WHO Grade II (atypical), consisting of clear cell meningioma, chordoid meningioma and atypical meningioma; and iii) WHO Grade III (anaplastic), consisting of papillary meningioma, rhabdoid meningioma and anaplastic meningioma. AM is notably vascular, soft in texture and tends to develop numerous small perforating arteries that integrate with adjacent brain tissues, increasing their susceptibility to bleeding. The most prevalent sites for AMs include the cerebral convexity, as indicated by Hasselblatt *et al* (3) (42%), Ben Nsir *et al* (4) (58.6%) and Liu *et al* (5) (66.7%). AM with cystic degeneration is even less common (6,7). Most reports are confined to individual case studies. A total of 8 cases have been reported in the published literature to date. Several potential mechanisms account for cystic alterations in AM (8). Intratumoral apoplexy may cause necrosis and further form cystic cavities inside the tumor. Glial cells surrounding the tumor proliferate and secrete fluid persistently, mostly generating cysts in peritumoral brain tissues. Peritumoral brain tissue with edema or demyelination can develop cystic lesions, and isolated fluid spaces in edematous areas may combine into large peritumoral cysts. Trapped subarachnoid spaces between tumor and brain tissue hinder fluid outflow, contributing to progressive peritumoral cyst formation. These cysts lie in the interval between the tumor and adjacent brain tissue (8). In the present study, a case of AM was treated at The Affiliated Hospital of Hebei University (Baoding, China)

in August 2023. This case offers new diagnostic references for similar imaging presentations and practical experience for managing cystic-degenerated AM.

Case report

A 58-year-old man was admitted to The Affiliated Hospital of Hebei University in August 2023 with a bilateral frontal distending headache that had appeared 18 days before without obvious triggering factors and was gradually worsening. There were no other accompanying symptoms such as nausea, vomiting, visual disturbance, limb weakness or seizures. At 15 days after the onset of the headache, the patient visited a local hospital (Xushui District Hospital of Traditional Chinese Medicine, Baoding, China), where a computed tomography (CT) scan of the head revealed a space occupying lesion in the left parietal lobe. After 3 days, the patient was admitted to The Affiliated Hospital of Hebei University for further diagnosis and treatment. During the outpatient visit to the hospital, a physical examination revealed no obvious positive signs of nervous system involvement. A head CT scan showed a mass lesion in the left parietal region (Fig. 1A), and a magnetic resonance imaging (MRI) plain scan with enhancement was recommended. This scan showed a cystic mass at the left parietal region, which was considered a teratoid tumor (Fig. 1B-F). Three-dimensional arterial spin labeling (3D-ASL) showed local high perfusion in the left parietal mass lesion (Fig. 2D). The preoperative diagnosis was of a potential left parietal lobe teratoma. During surgery, a horseshoe-shaped incision was made in the parietal region on the left side, and after the milling cutter freed the bone flap, extensive bleeding was observed in the dura mater. Following hemostasis, the dura mater was suspended. The dura mater was cut in an arc with the sagittal sinus as the base. In the center of the surgical area, there was severe adhesion between the dura mater and tumor tissue. The surgeon used electrocoagulation to cut off adhesions. After removing the dura mater, the solid part of the tumor appeared to be purple-red in color, with a soft texture and abundant blood supply. The cyst wall of the cystic part of the tumor was grayish-white, tough and had an arachnoid space with surrounding brain tissue (Fig. 2A). Blunt separation was performed along the gap between the tumor and brain tissue. During the separation process, the junctional area of the tumor was separated, and some dark red bloody fluid leaked out. Next, a puncture needle was inserted along the fistula, with its tip kept centered in the cyst (to avoid puncturing solid-component blood vessels), and 7 ml of dark red bloody fluid was slowly aspirated (to prevent a sudden drop in intracranial pressure), leading to a notable decrease in tumor tension. After electrocoagulation was used to seal the fistula, the separation continued, and the tumor and capsule were completely removed (Simpson type 1 resection; a standard classification for meningioma resection degree, where grade I indicates complete resection of the tumor, the attached dura and abnormal bone, with the lowest recurrence risk) (9). After the tumor was detached, its gross appearance was spherical, with tortuous blood vessels on the surface. Upon incision, the cyst wall was not thick and there were partitions inside, containing a large number of blood clots (Fig. 2B and C). The preoperative bilateral limb muscle strength was recorded as grade 5. Postoperatively, bilateral limb muscle strength was preserved at Medical Research Council (MRC) grade 5, as evaluated using the MRC muscle strength grading system (10), the gold standard 6-point ordinal scale for quantitative neurological assessment of skeletal muscle function. A CT scan showed a complete resection of the tumor. The postoperative pathological report revealed a large amount of coagulation and necrotic tissue, with meningeal tissue. For pathological processing, the surgical specimen was fixed in 10% neutral buffered formalin at room temperature for 24 h, then embedded in paraffin and sectioned into 4-μm thick slices. Histochemical staining with hematoxylin and eosin was performed at room temperature for 10 min, and the sections were observed under a light microscope, with a magnification of x200 for the vascular structure observation. Histochemical staining showed AM (Fig. 2E and F). Immunohistochemistry also indicated positive results for epithelial membrane antigen, CD31 and CD34, and a lack of staining for desmin, glial fibrillary acidic protein, progesterone receptor (PR), S-100 and neuron-specific enolase. The positive rate of Ki-67 was 2% (Fig. 3A-I). Endogenous peroxidase blocking reagent (cat. no. PV-9000; Beijing Zhongshan Golden Bridge Biotechnology Co., Ltd.) was incubated with the tissues at 37˚C for 10 min. The following ready-to-use primary antibodies (all Beijing Zhongshan Jinqiao Biotechnology Co., Ltd.) were applied and incubated overnight at 4˚C: Epithelial membrane antigen (cat. no. ZM-0095UM), CD31 (cat. no. ZA-0568UM), CD34 (cat. no. ZM-0046UM), desmin (cat. no. ZA-0610UM), glial fibrillary acidic protein (cat. no. ZA-0529UM), PR (cat. no. ZA-0255UM), S-100 protein (cat. no. ZA-0225UM), neuron-specific enolase (cat. no. ZM-0203UM) and Ki-67 (cat. no. ZM-0167UM). Secondary antibody incubation was performed with horseradish peroxidase-conjugated enhanced enzyme-labeled goat anti-mouse/rabbit IgG polymer (cat. no. PV-9000; ready-to-use; Beijing Zhongshan Jinqiao Biotechnology Co., Ltd.) and incubated at 37˚C for 30 min. This system was a biotin-free polymer detection system. The sections were observed and images were captured under a light microscope at a magnification of x200. These results were consistent with the histopathological characteristics of AM. The patient received no further treatment. At the 6-month follow-up after surgery, no tumor recurrence was observed.

Discussion

AM has the histological and clinical characteristics of a benign meningioma, and according to the 2021 WHO Central Nervous System Tumor Classification, it belongs to the WHO Grade I tumor group (6). The difference between AM and other subtypes of meningioma is that AM is a highly vascular tumor tissue, rich in abnormal vascular components in the tumor body, with an extremely rich blood supply (11,12). The study by Hasselblatt *et al* (3) suggested that meningiomas with vascular components covering >50% of the tumor area can be diagnosed as AM. AM is most common on the convex surface of the brain and generally progresses slowly. Most patients have no symptoms at the beginning, while some patients may exhibit symptoms of chronic intracranial hypertension, such as seizures, focal neurological disorders, sudden headaches or cranial nerve paralysis (12). The patient in the current case

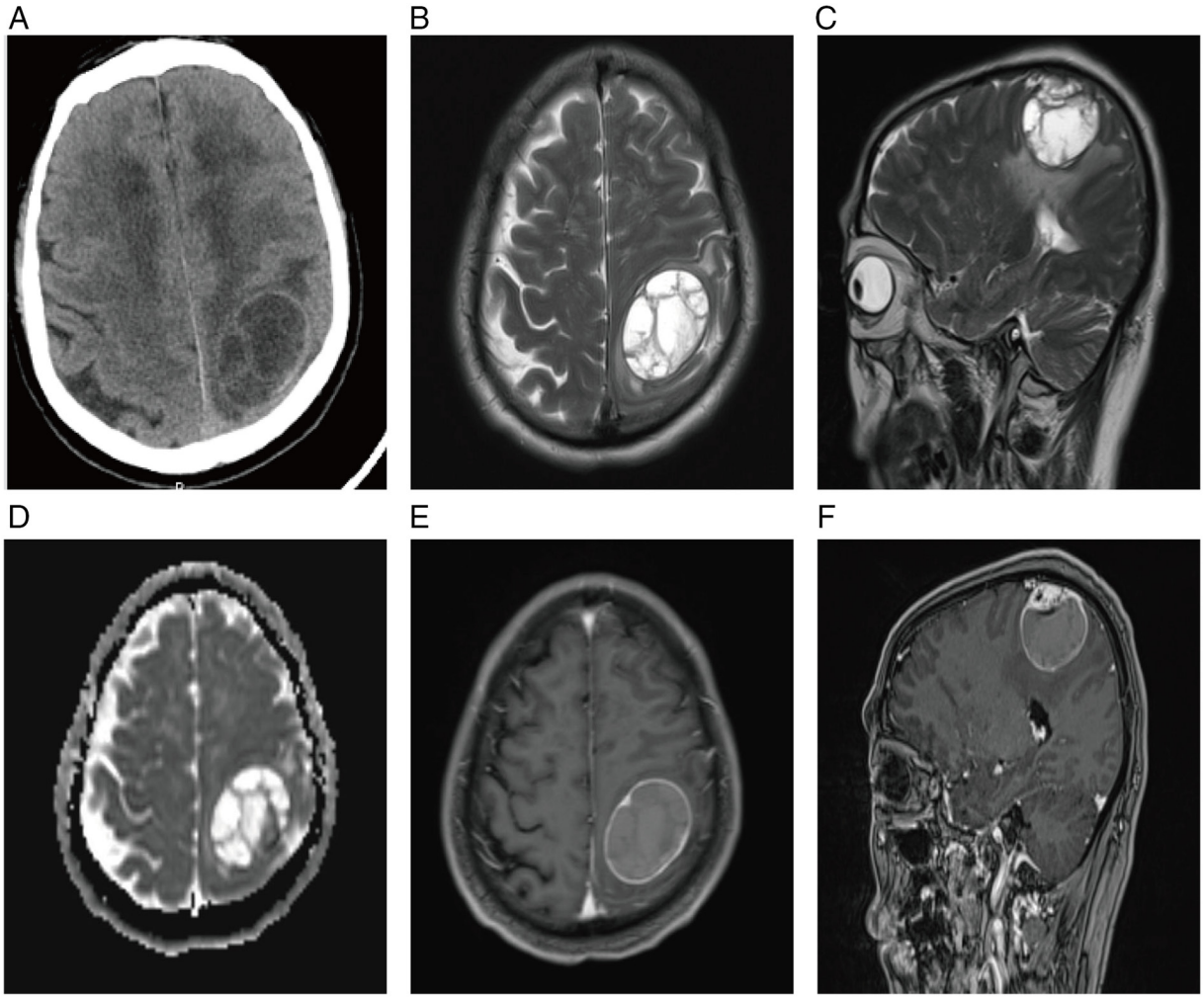

Figure 1. Patient imaging data. (A) Computed tomography plain scan shows a mixed low-density circular mass in the left parietal region. (B) MRI T2WI axial image shows a mass at the left parietal region, presenting a mixed signal of cystic and solid masses. (C) MRI T2WI sagittal image shows that the solid part of the tumor is connected to the meninges. There is an arachnoid space between the tumor and the brain tissue, and there is slight edema in the peritumoral brain tissue. (D) High signal on apparent diffusion coefficient. (E) Enhanced MRI axial image shows that the cystic part of the tumor is not notably enhanced. (F) Enhanced MRI sagittal image shows that the solid part of the tumor is markedly enhanced. MRI, magnetic resonance imaging; WI, weighted imaging.

presented with a persistent headache, which may be related to the continuous increase in tumor volume leading to dysfunction of intracranial pressure compensation and the appearance of intracranial hypertension.

In clinical practice, meningiomas are generally diagnosed through CT combined with imaging examinations such as MRI, with the characteristic features of MRI being especially important. Meningiomas are isointense on T1-weighted imaging (T1WI) and hyperintense on T2WI and fluid-attenuated inversion recovery, with uniform and consistent enhancement and an obvious meningeal tail sign on contrast-enhanced scans (13,14). The imaging manifestations of AM are notably different from those of classical meningiomas. Usually, AM are mainly characterized by low signal intensity on T1WI and high signal intensity on T2WI. The incidence of peritumoral brain edema (PTBE) is high, with moderate or severe PTBE being the main manifestation in AM. Enhanced MRI shows uniform enhancement (15). Severe PTBE has always been regarded as the imaging diagnostic basis for AM (16), and studies have shown that this may be related to abnormal activation of the vascular endothelial growth factor A pathway and changes in tumor capillary length in AM (17). However, in the present case, only mild PTBE was observed on MRI T2WI, and the meningeal tail sign and vascular flow void shadows on MRI enhanced scan were also atypical, which may be related to cystic degeneration of the tumor. Based on the postoperative pathological findings of hemorrhagic necrotic tissue and meningeal tissue in this case, its cystic degeneration may be associated with the rupture and hemorrhage of abnormal intratumoral blood vessels, as well as the necrosis and liquefaction of local tissues, a mechanism also mentioned in previous cases of cystic angioblastoma-type meningioma (AM) (7,8). Regarding the mild peritumoral edema in the present case, unlike the severe peritumoral edema caused by overactivation of the VEGF-A pathway in typical AM, although VEGF was not detected by immunohistochemistry in this case, the 'buffering effect' of the cystic structure may have alleviated the mechanical compression of the tumor on the surrounding brain tissue (17). Meanwhile, the reduced stimulation of necrotic tissue on vascular endothelium further diminished the edema severity. The absence of typical vascular flow voids is attributed to the high proportion of

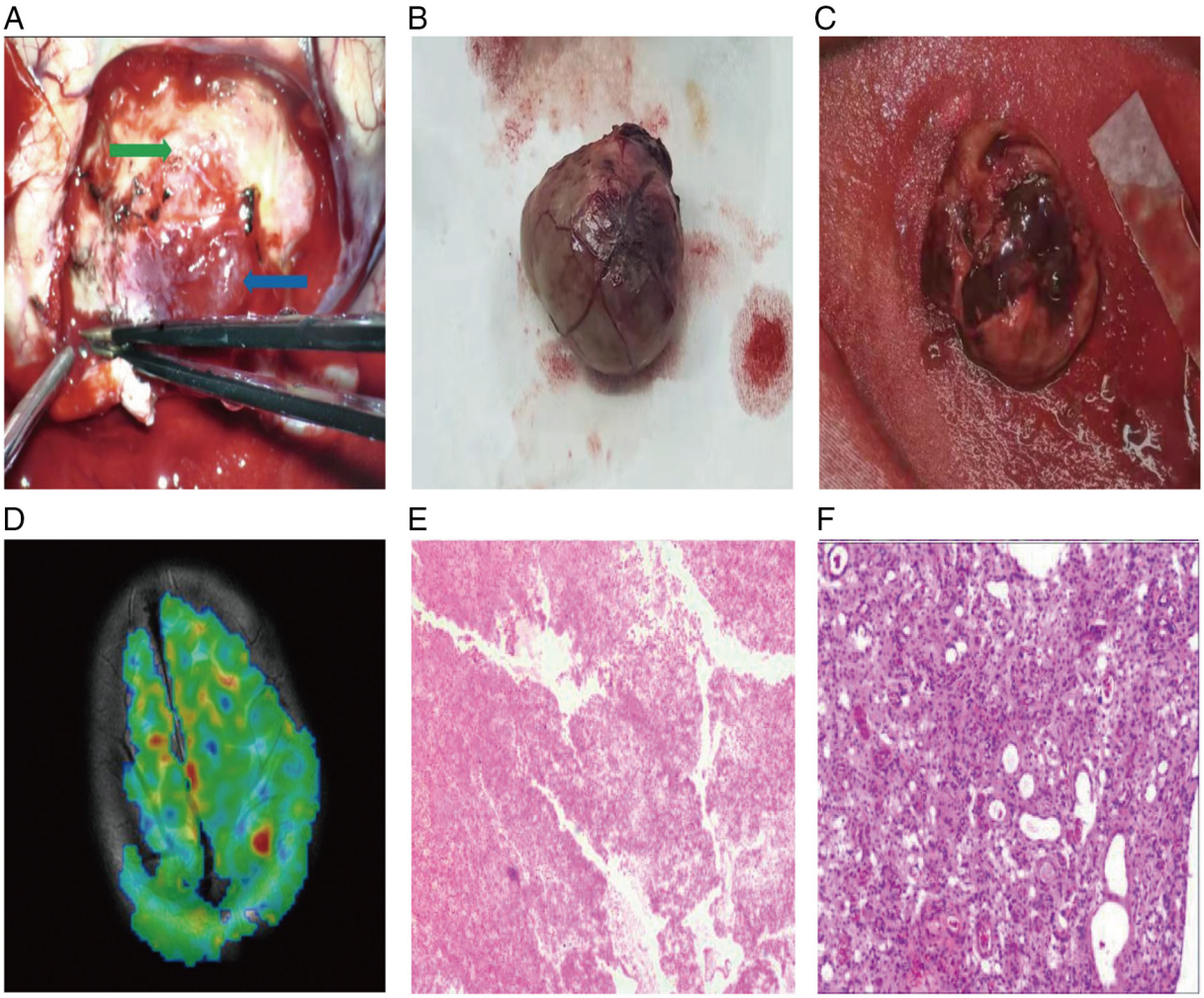

Figure 2. Surgical and pathological data. (A) During the surgery, the solid part of the tumor (blue arrow) was purple-red in color, with a soft texture and abundant blood supply. The cystic part (green arrow) had a grayish-white cystic wall, tough texture and an arachnoid space with surrounding brain tissue. (B) Completely detached tumor with visible tortuous blood vessels on the surface. (C) Upon opening the tumor, the cyst wall was not thick and there were partitions inside, containing a large amount of blood clots. (D) 3D-arterial spin labeling showing solid partial hyperperfusion of the tumor. (E) Postoperative pathological report showing coagulation necrosis tissue (blood clot) (hematoxylin and eosin staining; magnification, x40). (F) Histochemistry report showing an AM and its vascular structure (hematoxylin and eosin staining; magnification, x200).

cystic components in the tumor, coupled with the low vascular density and small caliber of the intratumoral blood vessels in the solid component (as evidenced by the slender vascular structures in pathological examination), which failed to reach the threshold for MRI detection of flow voids (18). The appearance of vascular flow void shadows in AM on enhanced MRI is generally 'root like', and some studies have described it as a 'sunrise sign' and used it as a basis for differentiation from other blood-rich tumors (19,20), but it is not applicable to this patient. In addition, AM often presents a high signal on the apparent diffusion coefficient (ADC), which is related to the tumor tissue containing a large number of blood vessels and having low resistance to water diffusion. This is consistent with the findings of the patient in the present case.

In summary, the imaging findings of this patient are not consistent with the typical presentation of AM: The solid component of the tumor accounted for a smaller proportion of the total lesion volume, while the cystic part was large, the PTBE was not severe, the meningeal tail sign was not obvious on enhanced scanning, there were few vascular flow void shadows and the morphology was atypical. Overall, the imaging findings of this case differ from those of typical AM. Compared with prior reported cystic AM, it has a higher cystic proportion (far exceeding 50%) and an absence of mild vascular flow voids, which are the main cause of the preoperative misdiagnosis as teratoma (7). For a differential diagnosis, using core evidence of a high ADC signal (excluding highly proliferative tumors) + focal hyperperfusion in the solid part on 3D-ASL (supporting hypervascular tumors), it is readily distinguishable from cystic gliomas (low ADC signal) and intracranial metastases (often with multiple nodules) (21). This approach offers a reference for cases with atypical imaging. The key features are a low solid proportion, high cystic proportion, mild peritumoral edema, indistinct dural tail sign on enhancement, few vascular flow voids and atypical morphology. The study by Galldiks *et al* (14) also demonstrated that due to the limitations of CT and MRI, introducing positron emission tomography (PET) into preoperative examinations of meningiomas can help in forming more accurate imaging diagnoses for cases with atypical

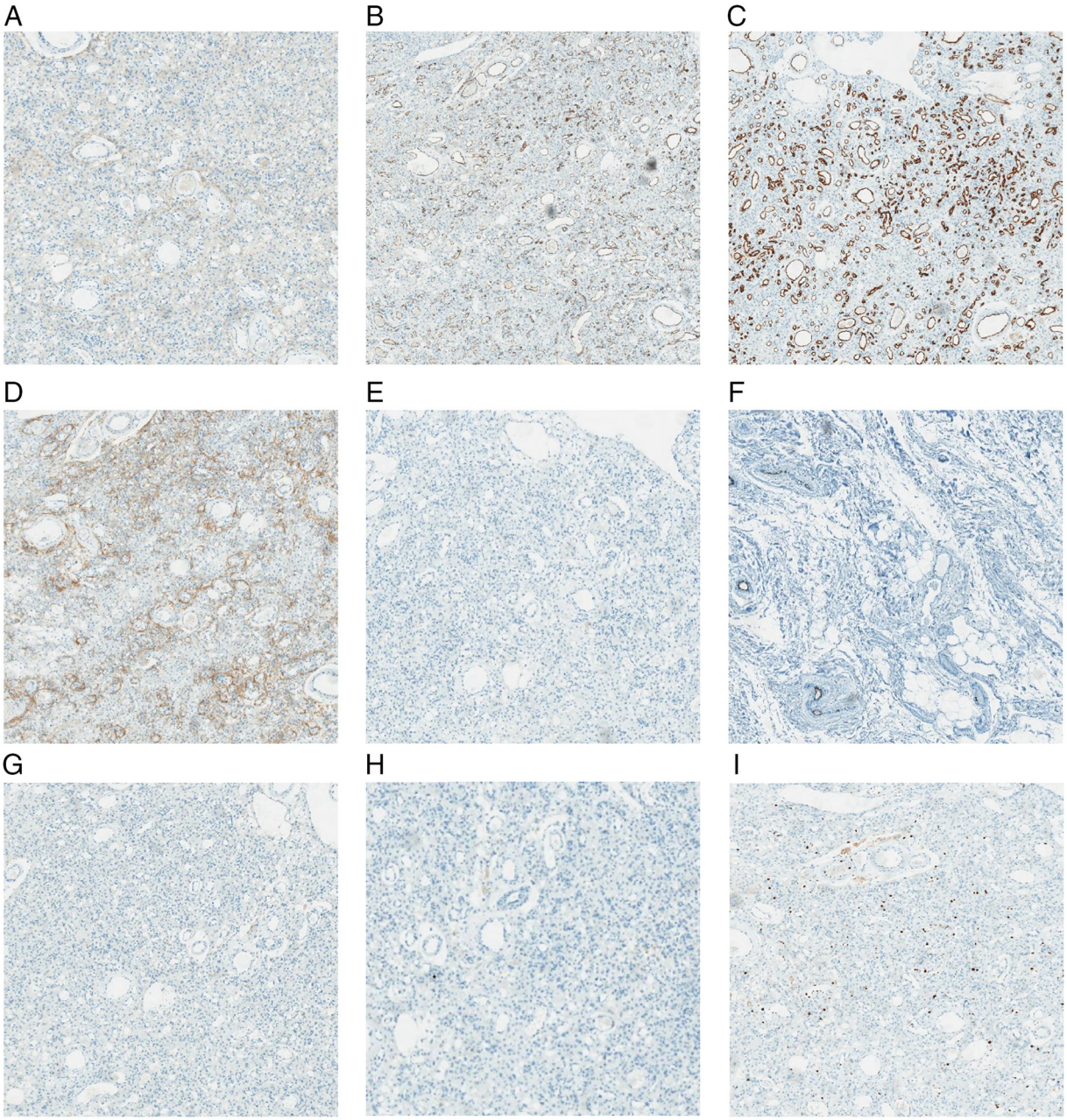

Figure 3. Immunohistochemical staining results of the tumor. (A) Epithelial membrane antigen-positive. (B) CD31-positive. (C) CD34-positive. (D) Desmin-negative. (E) Glial fibrillary acidic protein-negative. (F) progesterone receptor-negative. (G) S-100-negative. (H) Neuron-specific enolase-negative. (I) Ki-67 labeling index, ~2%.

routine imaging examinations. In addition, the development of radiomics, texture analysis based radiomics methods, ADC whole tumor histogram analysis, pseudo-continuous arterial spin labeling perfusion imaging and other methods have also provided new ideas for the preoperative diagnosis of AM (21-23). In addition, although the application of digital subtraction angiography (DSA) in the diagnosis of meningiomas is constantly declining, DSA can still provide important assistance for preoperative diagnosis and surgical planning when important blood vessels such as the sagittal sinus are infiltrated by tumors (13). This also suggests that PET or DSA examination may provide ideas for the preoperative diagnosis in cases of blood-rich tumors with atypical imaging findings.

At present, the main treatment method for AM is still surgery, and the degree of resection is an important factor reflecting the prognosis. The Simpson classification method is commonly used to distinguish the degree of resection (9). However, AM is highly vascular and may even be confused with vascular malformations on histological analysis. AM is one of the most blood-rich intracranial tumors. In a previous study, the mean estimated amount of intraoperative bleeding of the AM was 1,350 ml, and 13.8% of patients required a blood transfusion to safely conclude the surgery (4). In the present case, during the surgical procedure, the surgeon first disconnected the solid part of the tumor from the dura mater, severed the blood supply artery of the tumor and was able to extract a portion of the cystic fluid for decompression during

the resection process, thereby removing all of the tumor and its attached dura mater, achieving a Simpson type 1 resection. However, this surgical approach is only applicable to AM with minimal solid, predominant cystic components and 3D-ASL showing focal hyperperfusion confined to the solid component (not global tumor hyperperfusion). The approach is contraindicated in hypervascular AM with a solid proportion of >50% and a vascularity score of ≥4 (4); blind application to these cases may cause a sudden intraoperative blood loss surge from tumor vessel rupture during puncture decompression, far exceeding the reported mean of 1,350 ml, and even induce cerebral herniation. In the present study, the postoperative pathological report revealed coagulation and necrotic tissue under the microscope, with meningeal tissue also observed. The patient was followed up for 6 months after surgery. Postoperative 3-month and 6-month head MRI reexaminations showed no tumor recurrence, and the surgical area had no residual bleeding or edema. Neurological function evaluation showed that the patient's bilateral limb muscle strength remained at grade 5, with no symptoms such as headache, dizziness or limb sensory disturbance, and the patient had returned to normal daily life. Study limitations include a relatively short follow-up duration (6 months); thus, the long-term recurrence risk and stability of neurological function in cystic AM require further validation through prolonged follow-up.

In conclusion, the imaging findings of the patient in the present case are not typical, which poses certain difficulties for the preoperative diagnosis. This case report describes the rare imaging manifestations of cystic AM, providing new diagnostic references for patients with similar imaging manifestations. When encountering blood-rich tumors with atypical imaging manifestations, such as AM, and when traditional imaging examinations cannot meet diagnostic requirements, the introduction of new radiomics methods is a wise choice. PET or DSA examination may also provide evidence for the preoperative diagnosis of AM. With the continuous intersection of imaging technology and other disciplines, a pathological analysis based on MRI will also greatly help diagnose different subtypes of meningiomas, and provide assistance in formulating surgical planning and determining clinical prognosis. At the same time, in order to completely remove the tumor, first disconnecting the tumor supply artery and then removing the cystic fluid for decompression is a safe and effective surgical technique in the treatment process of such patients, and blood transfusion should be performed when necessary to safely conclude the surgical process.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

ZTB, YJS and HGL collected the clinical case data and were major contributors to the manuscript. YW collected and analyzed the imaging data of the patient. HPL performed the postoperative follow-up of the patient. HPX participated in the pathological section evaluation and analysis. SAY and JYC guided the surgical management of patients, advised on perioperative treatment plans and reviewed the manuscript. XCW and ZMZ supervised the research, designed the study and critically revised the manuscript for important intellectual content. ZTB and ZMZ confirm the authenticity of all the raw data. All authors have read and approved the final version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

The patient provided written informed consent for publication of the case report and any accompanying images.

Competing interests

The authors declare that they have no competing interests.

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