

Angiomatous Meningioma: CT and MR Imaging Features¹

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Purpose: To describe the computed tomography and magnetic resonance imaging features of angiomatous meningiomas.

Materials and Methods: We reviewed the imaging findings of six patients with pathologically proven angiomatous meningiomas and characterized the location, margin, dura base, CT attenuation, MR signal intensity, intratumoral signal void, contrast enhancement, intratumoral cystic change, and peritumoral edema.

Results: Most tumors showed high signal intensity on T2-weighted images, and low signal intensity on diffusion-weighted images. After intravenous contrast administration, the tumor showed heterogeneous strong enhancement. Most tumors had a lobulated margin with prominent intratumoral signal voids. Four patients showed marked or small intratumoral cystic changes.

Conclusion: Typically, angiomatous meningiomas were dura-based masses characterized by lobulated margins with high signal intensity on T2-weighted imaging (T2WI), low signal intensity on diffusion-weighted imaging (DWI), prominent intratumoral signal voids, intratumoral cystic changes, and marked enhancement after intravenous contrast administration.

Index words : Meningioma
Angiomatous
Tomography, X-Ray Computed
Magnetic Resonance Imaging

Certain characteristic findings of ordinary meningiomas on computed tomography (CT) and magnetic resonance imaging (MRI) are easily identified and hence, easy to diagnose (1). However, certain meningioma subtypes have unusual imaging findings, making it difficult to diagnose them as well as determining the

appropriate treatment protocol. This is particularly true for rare meningioma subtypes, which include the angiomatous meningioma, which shows unusual imaging features compared to ordinary meningiomas.

To our knowledge, there are few studies regarding angiomatous meningiomas that describe both pathological and clinical features (2, 3). Moreover, their imaging features have not been reported thus far.

In this paper, we aimed to characterize the CT and MR imaging features of angiomatous meningiomas.

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Materials and Methods

We retrospectively reviewed six cases of angiomatous meningiomas treated between October 18, 2005 and November 1, 2008 at our university hospital. These included two men and four women aged 40–64 years old (mean, 52 years old). All the patients underwent surgical treatment to completely remove the tumor, and a pathological diagnosis was made. Conventional MRI (*n* = 6), diffusion-weighted imaging (DWI) (*n* = 2), CT (*n* = 3), and perfusion MRI (*n* = 1) findings were retrospectively analyzed; MRI studies were performed using a 1.5-T unit in all patients. T2-weighted (T2WI) axial and/or coronal/sagittal images were obtained for all patients. In addition, contrast-enhanced T1-weighted (T1WI) were obtained after intravenous contrast administration. The CT and MRI findings were assessed by a specialized

neuroradiologist and a general radiologist for the following: (1) tumor location, (2) tumor margin, (3) dura base, (4) attenuation on pre-contrast enhanced CT, (5) signal intensity on DWI and T2WI, (6) intratumoral signal void, (7) degree of contrast enhancement, (8) intratumoral cystic changes, and (9) peritumoral edema. The attenuation and signal intensity were compared using gray matter as a reference. The degree of tumor margin lobulation, intratumoral signal void, contrast enhancement, intratumoral cystic change, and peritumoral edema were graded as absent (-) and one positive finding (+) to three positive findings (+++) from the above list. The pathological findings were retrospectively reviewed for confirmation of the diagnosis.

Results

The clinical and imaging features are summarized in

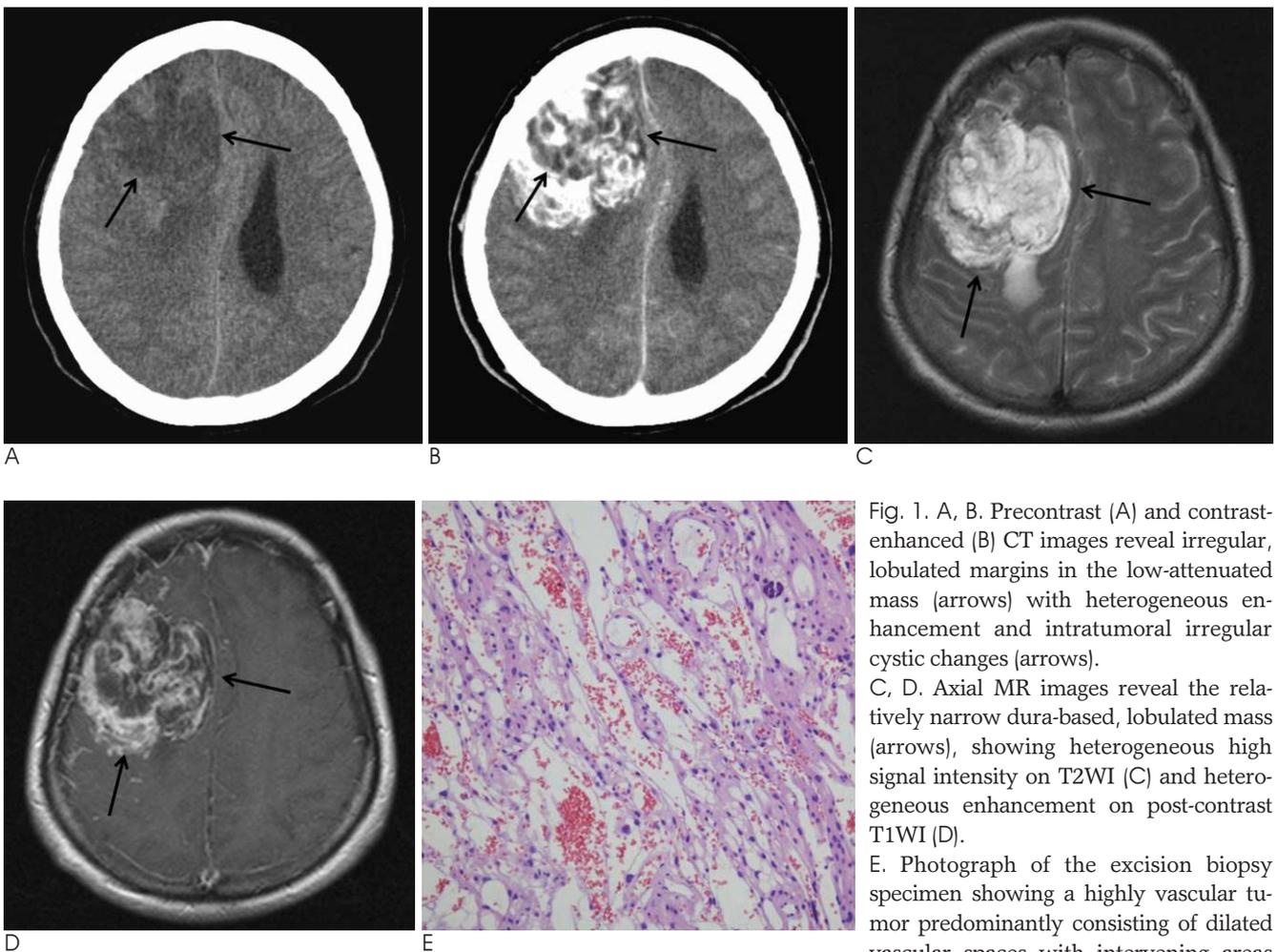


Fig. 1. A, B. Precontrast (A) and contrast-enhanced (B) CT images reveal irregular, lobulated margins in the low-attenuated mass (arrows) with heterogeneous enhancement and intratumoral irregular cystic changes (arrows). C, D. Axial MR images reveal the relatively narrow dura-based, lobulated mass (arrows), showing heterogeneous high signal intensity on T2WI (C) and heterogeneous enhancement on post-contrast T1WI (D). E. Photograph of the excision biopsy specimen showing a highly vascular tumor predominantly consisting of dilated vascular spaces with intervening areas with spindle and oval cells as well as abundant cytoplasm and oval vesicular nuclei (H & E, × 400).

Table 1. The Clinical and Imaging Features of Angiomatous Meningiomas

	Age (yrs)/ Sex	Location	Dura Base	Attenuation on pre-CT	SI on T2WI	SI on DWI	Intra-tumoral Signal Voids	Lobulating Margin	Enhancement	Cystic Change	Peri-tumoral Edema
1	54/F	Rt. F	N	Hypo	High	-	+++	+++	Hetero ++	+++	+
2	40/F	Rt. F-T	B	Hypo	High	Slightly low	+++	++	Hetero +++	++	+
3	46/F	Rt. P	N	-	High	Slightly low	+++	+	+++	-	+
4	50/M	Lt. S	N	Iso	Intermediate to high	-	++	+	+++	+	+++
5	64/M	Lt. F	N	-	High	-	+++	+	+++	+	++
6	59/F	Rt. F	B	-	Intermediate to high	-	++	+	+++	-	+

Table 1. In five patients, the preoperative diagnosis was benign meningioma, while for case 1, the preoperative diagnosis was a malignant or atypical meningioma or hemangiopericytoma (Fig. 1).

All patients underwent surgery and each tumor was completely resected. On T2WI, most tumors showed high signal intensity (n = 4), whereas the two smaller sized tumors showed intermediate to high signal intensity (n = 2). CT was performed for three patients, and the precontrast CT findings revealed low attenuation in two patients, which were contrary to typical meningioma findings, as well as isoattenuation in one patient. After intravenous contrast administration, most tumors showed strong enhancement, while two tumors showed heterogeneous enhancement. On DWI, two tumors showed slightly low signal intensity. The dura base was relatively narrow in four patients, contrary to the other two patients who had a broad dura base. All the tumors had lobulated margins and prominent intratumoral signal voids, which corresponded to hypervascular feeding arteries observed in each tumor. Marked intratumoral cystic changes were observed in one tumor (case 1) (Fig. 1) while three tumors showed small intratumoral cystic changes, and the remaining two patients showed no cystic changes. All patients had variable degrees of peritumoral edema. Perfusion MRI was performed for one patient (case 2) (Fig. 2), and revealed markedly increased regional cerebral blood volume (rCBV) in the tumor consistent with a hypervascular tumor (Fig. 2).

Discussion

In this study, we have described the CT and MR imaging features of six patients diagnosed with an angiomatous meningioma. To the best of our knowledge, this is

the first study of a case series describing angiomatous meningiomas.

Although meningiomas account for 13-26% of all intracranial neoplasms (4), considerable controversy persists regarding the nature and predictability of the signal changes observed with their MR images (1).

The relationship between the MR signal intensity and meningioma subtype was first described by Elster et al. in 1989 (5).

In the Elster study, each meningioma was classified according to a signal intensity score. Subsequent histopathological correlation revealed that the meningothelial and angioblastic variants have a much higher T2-signal intensity than do fibroblastic or transitional tumors. Consideration of the secondary features (peritumoral edema, presence of calcium aggregates, and central necrosis/ cyst formation) led to a more specific histologic prediction (5). Kaplan et al. reported on the MR characteristics of the meningioma subtypes using a 1.5-T unit in 1992 (6). In their study, the reliance on signal changes alone resulted in accurate pattern subtyping in 80% of the evaluated cases. In four of 24 patients, secondary imaging features were necessary for subtype differentiation. The utilization of adjunctive imaging features (i.e., mass effect, peritumoral edema, and intratumoral cyst formation), in conjunction with signal changes, permitted the identification of the correct histological pattern in 96% of patients (6). However, their study did not involve cases of angiomatous meningiomas. Overall, the CT and MRI features of angiomatous meningiomas have not been well described thus far.

Angiomatous meningiomas are a subgroup of meningiomas, in which numerous vessels prevail on the background of a typical meningioma. This entity is diag-

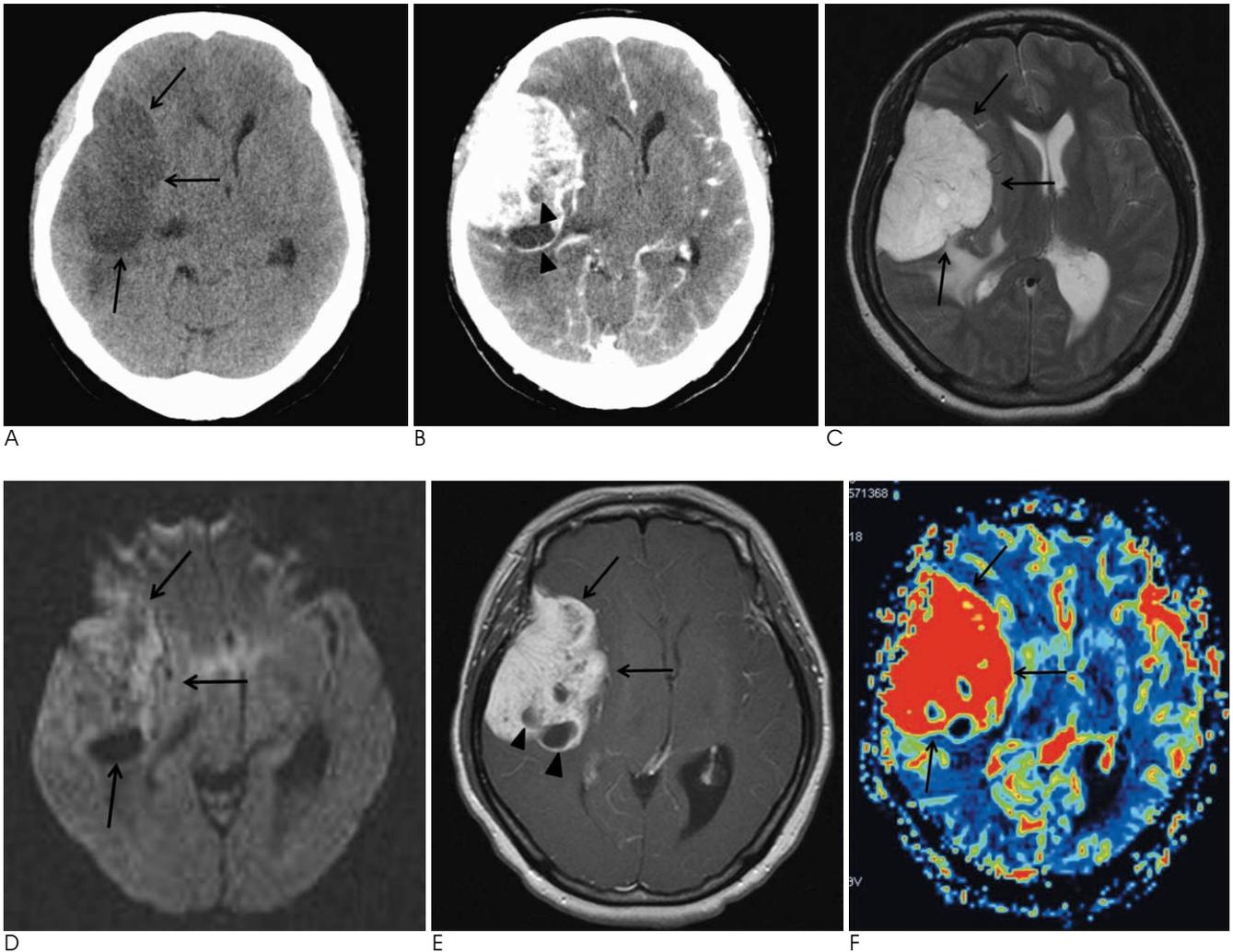


Fig. 2. A, B. Precontrast (A) and post-contrast (B) CT images reveal the lobulated low-attenuated mass (arrows) with marked enhancement and multiple cystic changes (arrowheads).

C-E. MR images reveal the lobulated mass (arrows) with multiple cystic changes (arrowheads) showing high signal intensity on T2WI (C), slightly low signal intensity on DWI (D), and marked enhancement with prominent intratumoral vascularities on post-contrast T1WI (E).

F. Perfusion MRI shows markedly increased rCBV in the tumor (arrows).

nosed on the basis of a vascular component, which exceeded 50% of the total tumor area (2, 3). Such extremely vascularized meningiomas are rarely encountered (2).

In some older studies, the term "angioblastic" meningioma has been used for a broad group of highly vascularized tumors arising from the meninges, which include angiomatous meningiomas as well as hemangiopericytomas (2, 7, 8). Hemangiopericytomas are often radiologically confused with angiomatous meningiomas, because their imaging features are similar (dura-based, lobulated masses with heterogeneous contrast enhancement) (9). Hemangiopericytomas have an unremitting tendency to recur and may metastasize extracranially as a WHO grade II tumor; therefore, radical surgery complemented by postoperative radiotherapy is

the treatment of choice for hemangiopericytomas (10). However, angiomatous meningiomas are grouped under WHO grade I tumors and recurrences are not observed in patients who undergo gross tumor resection (2, 3). Therefore, postoperative radiotherapy is not required for angiomatous meningiomas. Consequently, this differentiation has important prognostic and therapeutic implications (2, 3).

Although meningiomas typically appear isointense or hypointense on T2WI (11–15), the tumors in all our patients showed high signal intensity on T2WI. The signal intensity of meningiomas on T2WI is correlated with and can serve as a crude predictor of the histological type (5). Angiomatous meningiomas, with their numerous dilated blood vessels and vacuoles, might be expect-

ed to have a long T2 value (5).

In our case series, four cases were identified to have homogeneous contrast enhancement, which was consistent with the contrast enhancement pattern typically found in meningiomas (11-15). However, two cases showed heterogeneous enhancement because of intratumoral cystic changes. Further, the size of these tumors was relatively larger than that of the other tumors with homogeneous enhancement. Intratumoral cysts are known to be more common in angiomatous and meningothelial types than other histological meningioma types (11, 16, 17).

The pathophysiological mechanisms involved in the formation of intratumoral cysts within meningiomas have been discussed by various authors (8, 15, 18-20). According to Fortuna et al. (11, 21), intratumoral cysts are the outcome of cystic degeneration, ischemic necrosis, or hemorrhage within the tumor. The cyst may produce a mass as large as the meningioma itself (11, 20). In several instances, the expansion of the cyst, rather than the tumor, is responsible for the increased mass effect and clinical deterioration (8, 11, 22).

DWI has been used to study various diseases along with studies of the normal brain. Correspondingly, DWI and ADC maps may provide additional useful information in the diagnosis of patients with brain tumors, such as identifying the cellularity and tumor grade (4, 11, 23, 24). The cellularity of a tumor is defined as the number of cells in a given area, and it is an important factor in determining microscopic water diffusion (4). Kono et al. (24), described increased tumor cellularity to be correlated with a lower ADC value. In our cases, DWI was performed for two patients, who showed slightly low signal intensity. Angiomatous meningiomas have a lower cellularity than do typical meningiomas because they have numerous vessels and intratumoral cystic changes.

In all the patients in our case series, peritumoral edema was noted, which reflects a combination of vasogenic brain edema and cerebral gliosis due to prolonged brain compression and other factors (25). The causes of edema associated with meningiomas have been widely studied, but there is no apparent consensus regarding the primary underlying factor or mechanism. Venous obstruction, tumor vascularity, pial-meningeal anastomoses, capillary permeability, the presence of vascular endothelial growth factor, and tumor secretion are all factors known to contribute to peritumoral edema (25-28).

All the tumors evaluated here showed lobulated mar-

gins; the bigger the size of the tumor, the greater was the degree of tumor lobulation.

Perfusion MRI was performed for one patient, and showed a marked increase in the tumor's cerebral blood volume (CBV). The mean rCBV of the parenchyma of the angiomatous meningioma was the highest amongst the other tumor subtypes, including meningothelial and anaplastic meningiomas, which corresponded well with the histological features observed, and accurately indicated an extremely high degree of vascularity (29-31).

In summary, imaging studies revealed that angiomatous meningiomas were dura-based masses with lobulated margins that were characterized by relatively high signal intensity on T2WI and slightly low signal intensity on DWI. Prominent intratumoral signal voids and intratumoral cystic changes were frequently observed. Further, the mass showed marked enhancement after intravenous contrast administration, and the enhancement pattern was heterogeneous when intratumoral cystic changes were present. We consider that our findings will enable the accurate diagnosis of angiomatous meningiomas with appropriate differentiation from more aggressive tumors.

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혈관중성뇌수막종의 CT와 MRI의 영상 소견¹

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목적: 혈관중성뇌수막종의 전산화단층촬영과 뇌 자기공명영상 소견을 알아보고자 한다.

대상과 방법: 병리학적으로 확진된 혈관중성뇌수막종을 가진 6명의 환자를 대상으로 이들이 촬영한 CT와 MRI에서 종양의 위치, 경계, 종양 기저부와 경막의 관계, CT 감쇄도, MR 신호강도, 종양 내 혈관에 의한 신호 소실, 조영 증강 정도, 종양 내 낭종성 변화와 종양 주위 뇌부종에 대해 분석하였다.

결과: 대부분의 종양은 T2 강조영상에서 높은 신호강도, 확산강조영상에서 낮은 신호 강도를 보였다. 조영제 주입 후에는 비균질성의 강한 조영증강을 보였다. 대부분의 종양은 엽상의 경계가 있었고, 현저한 종양 내 혈관에 의한 신호 소실을 동반하고 있었다. 4명의 환자에서는 종양 내 낭종성 변화가 보였다.

결론: 혈관중성뇌수막종의 영상 소견은 엽상의 경계를 갖고 경막에 기저부를 두고 있으면서 T2 강조 영상에서는 높은 신호강도를, 확산강조영상에서는 낮은 신호 강도를 보이고, 조영제 주입 후에는 강한 조영 증강을 보이고, 현저한 종양 내 혈관에 의한 신호 소실을 동반하는 것으로 정리할 수 있다.