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Cystic Meningiomas: MR Characteristics and Surgical Correlations

John J. Wasenko, Leo Hochhauser, Edward G. Stopa, and Jeffrey A. Winfield

PURPOSE: To describe the MR appearance of cystic meningiomas, and to correlate the MR appearance with the surgical and neuropathologic findings. **METHODS:** Eight patients with cysts associated with meningiomas were studied on a 1.5-T MR system. Unenhanced sagittal T1- and axial T2-weighted images were obtained in all patients. Axial and coronal gadopentetate dimeglumine-enhanced T1-weighted spin-echo images were obtained in seven patients. Additional sagittal T1-weighted spin-echo contrast-enhanced images were obtained in four patients. **RESULTS:** The cystic components were intratumoral and eccentric in two cases, intraparenchymal in one case, and extraparenchymal (trapped cerebrospinal fluid) in five cases. Cyst wall enhancement was present in two of seven cases performed with intravenous gadopentetate dimeglumine. There was no correlation between cyst signal intensity and cyst content. A preoperative diagnosis of cystic meningioma was possible in all eight cases. **CONCLUSIONS:** MR demonstrates the extradural location of the tumor and its cystic component, correlates well with the surgical presentation and the neuropathologic results, and allows the preoperative diagnosis of cystic meningioma based on the MR findings. Division into three types of cysts aids the neurosurgeon, who must decide whether total resection is feasible. To obtain total resection and reduce the risk of recurrence with an intratumoral cyst, the surgeon must ensure that the plane of resection is in fact between the thin enhancing membrane of the tumor cyst and the adjacent arachnoid. In cases in which the cyst is trapped cerebrospinal fluid or intraparenchymal in location, the cyst wall adjacent to or within the brain parenchyma is not included in the resection.

Index terms: Meninges, cysts; Meninges, magnetic resonance; Meninges, neoplasms

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Meningiomas are usually solid tumors. Cystic meningiomas are uncommon variants, which have been well documented with computed tomography (CT) (1–8). There have been a few reports on the magnetic resonance (MR) appearance of these tumors (9, 10). We present the MR appearance of eight meningiomas associated with cysts and correlate the images with the findings at surgery and the neuropathologic results. Cystic meningiomas can be correctly diagnosed preoperatively using MR with a higher degree of accuracy than by other neuro-

radiologic imaging techniques because of multiplanar imaging capability and the lack of beam-hardening artifact. Determining the exact location of the cystic component enables preoperative planning. It ensures the exact relationship between tumor and cyst, allowing for complete microsurgical tumor resection. It is our purpose to correlate the MR findings with those observed at surgery and neuropathologic examination.

Material and Methods

Eight patients with cystic meningiomas were studied: six women and two men ranging in age from 58 to 85 years. Unenhanced and contrast-enhanced CT was performed in four and MR on a 1.5-T system in eight patients. Axial or sagittal T1-weighted (450–650/10–17/2 [repetition time/echo time/excitations]), axial proton-density (2350–3000/15–30/1), and T2-weighted (2350–3000/80–90/1) spin-echo images were obtained in five patients. Coronal proton-density (2500/30/1) and T2-weighted (2500/90/1) spin-echo images were obtained in one pa-

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tient. Axial fast spin-echo proton-density (2500/18/1) images with echo trains of 4 and T2-weighted (2500–3500/90–108/1) images with echo trains of 8 were obtained in two patients. In one patient, axial fast variable-echo proton-density (3500/18/1) images and T2-weighted (3500/90/1) images, both with echo trains of 8, were obtained. Gadopentetate dimeglumine-enhanced T1-weighted (500–600/10–17/2) images were obtained in the axial and coronal planes in seven patients. Sagittal contrast-enhanced T1-weighted (500–600/10–17/2) images were obtained in four patients. In one case, no contrast material was administered. A selective right external carotid artery embolization was performed in case 4. The MR images were evaluated by two neuroradiologists to determine the relationship of the cystic components with respect to the tumors, subarachnoid spaces, and brain parenchyma.

Tumor resection was performed in all eight patients. From a neurosurgical perspective, it is practical to group the cystic components as intratumoral, trapped cerebrospinal fluid (CSF), or intraparenchymal in location. Although there are three types of intratumoral cysts, the surgical approach and extent of resection are similar; that is, the tumor, cystic component, and cyst wall are excised. When the cyst is trapped CSF adjacent to the tumor, it is essential to identify the interface between the tumor edge and the extratumoral arachnoid component. In such a case, the tumor is resected, whereas the cyst merely requires drainage. When the cyst is intraparenchymal in location, the guiding surgical principle is that the cyst should not be resected. All surgical specimens were histologically confirmed.

Results

The signal intensity of meningiomas was compared with that of gray matter. Signal intensity was isointense in five and hyperintense in three cases on T1-weighted images. On T2-weighted images, one lesion was hypointense, five hyperintense, one isointense and hypointense, and one hypointense and hyperintense. Cystic components appeared isointense in six and hyperintense in two instances relative to CSF on T2-weighted images. The tumor locations were over the temporal convexities in four cases, over the frontoparietal convexities in two cases, parasellar in one case (case 3), and arising from the cribriform plate in one case. The cyst locations were intratumoral and eccentric in two cases (Fig 1), intraparenchymal in one (Fig 2), and extratumoral and extraparenchymal (trapped CSF) in five cases (Fig 3). The locations of the cysts were determined before surgery in six of eight cases. In two cases it could not be determined whether the cystic

component was trapped CSF or within the brain parenchyma. Tumor enhancement was intense and homogeneous in five cases and intense and heterogeneous in two cases. Enhancement of the cyst walls was seen in two cases. Dural tail signs were present in two cases, indicating the extraaxial locations of the tumors. In two of four cases in which CT was performed, the extraaxial locations of the tumors were well identified. In the other two cases the tumors appeared to be intraaxial in location.

After neuropathologic examination, meningiomas were classified according to their predominant histologic patterns. Six meningiomas exhibited a predominantly meningothelial growth pattern, and two were predominantly transitional. Four loculated CSF cysts, one intratumoral cyst, and the one intraparenchymal cyst were isointense with CSF on T2-weighted images. One loculated CSF and one intratumoral cyst were hyperintense relative to CSF on T2-weighted images. In the five cases in which the cystic components were extratumoral and extraparenchymal (trapped CSF), clear CSF was aspirated. In the two cases in which the cysts were intratumoral, xanthochromic fluid containing hemosiderin-laden histiocytes was detected. Liquefactive necrosis without hemosiderin was noted in one case (case 3) in which the cystic component was within the brain parenchyma. In this case, resection of the cyst was necessary to afford greater surgical exposure to the tumor with reduced retraction on the dominant right frontal lobe. After cyst collapse, the tumor was resectable. There was no correlation of cyst signal intensity with cyst content in any of the eight cases. Five of the six meningothelial meningiomas were hyperintense in signal intensity on T2-weighted images. The sixth was isointense and hyperintense on T2-weighted images. One of two transitional meningiomas was hypointense; the other was hyperintense and hypointense on T2-weighted images. The results are summarized in the Table.

Discussion

The MR appearance of meningiomas has been well described (9–18). In general, these tumors are hypointense or isointense to gray matter on T1-weighted images and hyperintense or isointense on T2-weighted images. The histologic type of meningioma may be pre-

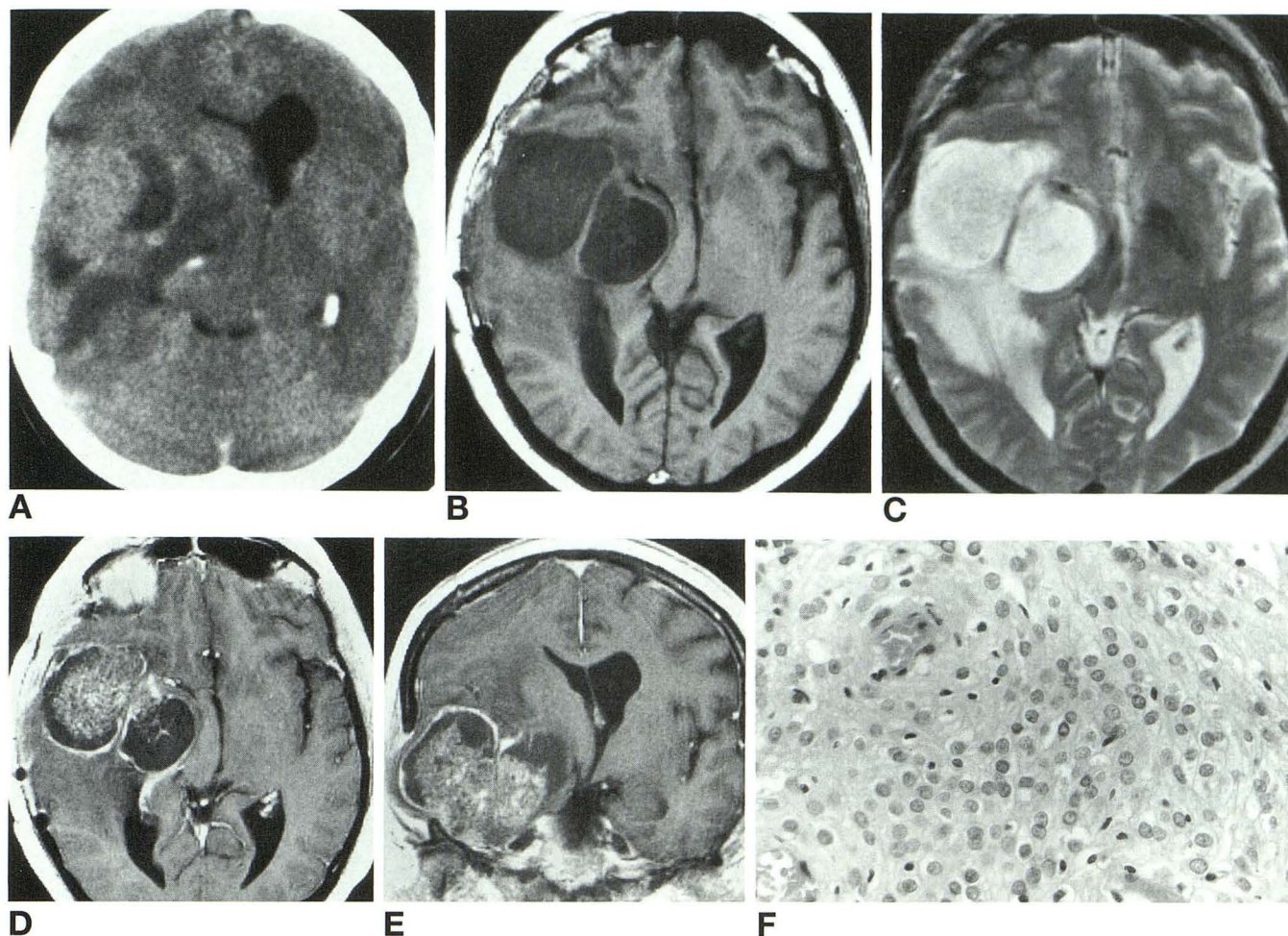


Fig 1. Case 1: recurrent cystic meningioma (type 1, eccentric intratumor cysts).

A, Contrast-enhanced CT reveals a homogeneously enhancing mass overlying the right temporal convexity.

B and C, The mass is isointense in signal intensity on T1-weighted (550/10) and hyperintense on T2-weighted (2390/90) images relative to gray matter. The cystic components are isointense with CSF.

D and E, Contrast-enhanced axial and coronal T1-weighted images (550/10) demonstrate intense enhancement of the solid component and peripheral enhancement around the eccentric cystic components within the tumor.

F, Photomicrograph of an 8- μ m histologic section of the meningothelial meningioma corresponding to the MR image (hematoxylin and eosin stain, magnification $\times 400$). Note the sheetlike growth pattern and absence of cellular whorling. There is no evidence of mitotic activity or nuclear pleomorphism.

dicted by MR in more than 80% of cases (10). These predictions are based on the new World Health Organization classification and include the group of angiomatous meningiomas of which the hemangiopericytoma is a subgroup (19). We are aware, however, that the hemangiopericytoma is felt by some to represent a distinct, mesenchymal neoplasm unrelated to meningiomas (20). On T2-weighted images, fibroblastic and transitional meningiomas are hypointense, but angioblastic and meningothelial (syncytial) meningiomas are hyperintense. Meningiomas show intense homogeneous enhancement with intravenous administration of

gadopentetate dimeglumine (13–15). Enhancing dural tails thought to represent increased vascularity and venous congestion within the adjacent meninges have been observed in 60% to 100% of tumors (16–18). This finding is not specific for meningiomas and may be seen with glioblastomas, as well as parenchymal and dural metastases, and also in benign lesions such as schwannomas (21, 22). Approximately 85% of meningiomas demonstrate typical radiologic features (9). Atypical features, including cyst formation, lipomatous transformation, and ring enhancement, may be exhibited in 15% of meningiomas (5, 9).

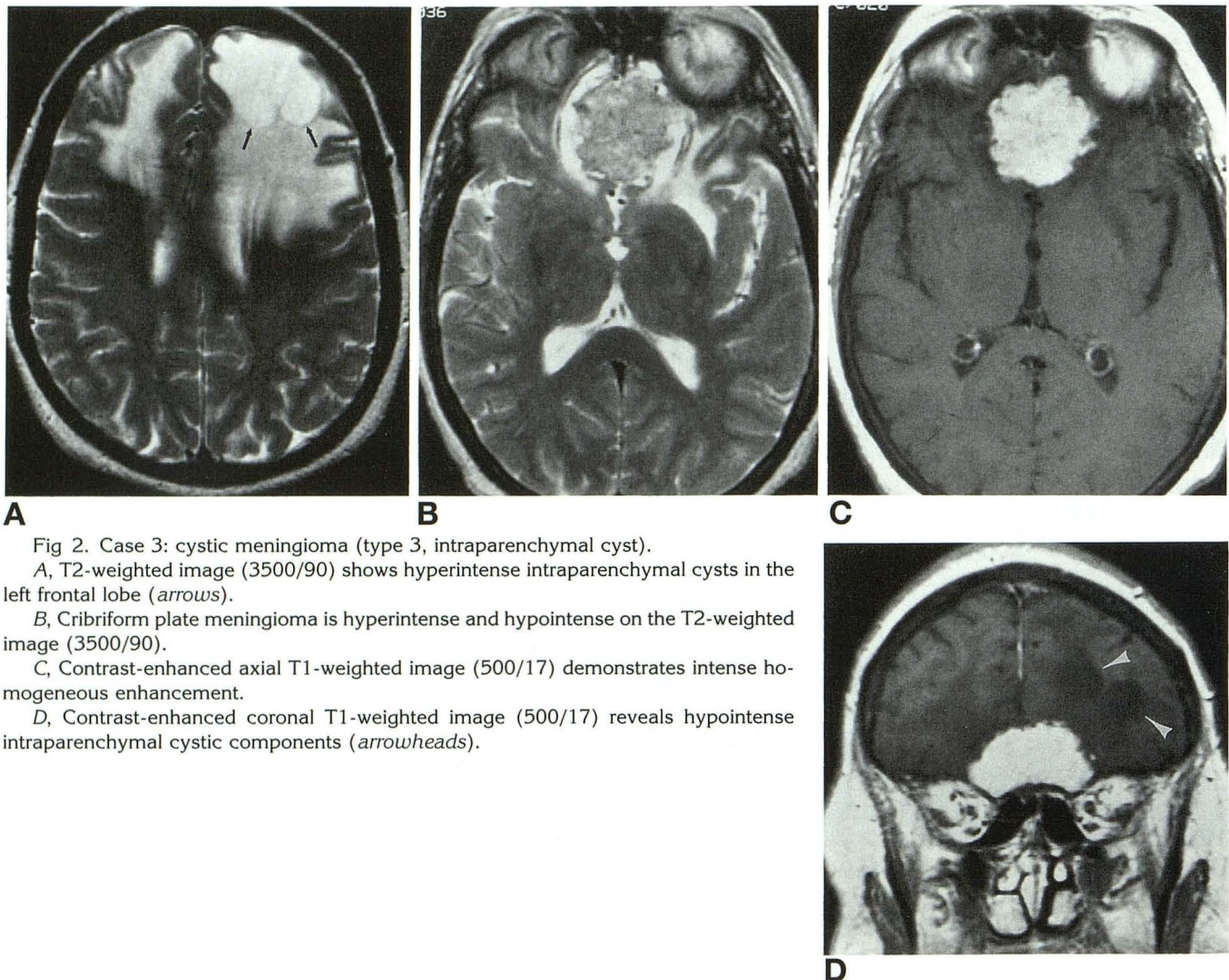


Fig 2. Case 3: cystic meningioma (type 3, intraparenchymal cyst).

A, T2-weighted image (3500/90) shows hyperintense intraparenchymal cysts in the left frontal lobe (arrows).

B, Cribriform plate meningioma is hyperintense and hypointense on the T2-weighted image (3500/90).

C, Contrast-enhanced axial T1-weighted image (500/17) demonstrates intense homogeneous enhancement.

D, Contrast-enhanced coronal T1-weighted image (500/17) reveals hypointense intraparenchymal cystic components (arrowheads).

Cystic meningiomas constitute an uncommon subgroup of intracranial meningiomas and have been well described by CT criteria (1–8). In a series of 131 meningiomas, 7% had cystic components either intratumoral or subarachnoid in location (5). There have been a few reports of the MR appearance of these uncommon tumors (9, 10). In one report, MR showed a left convexity cystic meningioma with curvilinear enhancement along the cyst wall suspicious for neoplastic involvement (9). In another report, 6 of 40 meningiomas demonstrated cyst formation or necrosis (10).

Meningiomas associated with cysts were described by Cushing and Eisenhardt, who noted the cysts to be peritumoral in location (23, 24). Rengachary et al further classified this entity into two types: intratumoral and extratumoral (2). Subsequently, the lesions were clas-

sified into four types by Nauta et al (3). Finally, a fifth type was added by Worthington et al (8). Currently, cystic meningiomas are classified into five types based on cyst characteristics or location with respect to the tumors (3, 8). The cyst may be (a) central or (b) eccentric in location; (c) its wall may contain nests of tumor cells; (d) it may be located adjacent to the tumor within the brain parenchyma; or (e) it may consist of a CSF loculation trapped between tumor and brain. The fourth type is the most frequently encountered of the five types (3, 8).

There are several proposed mechanisms of cyst formation. One is cystic degeneration within the tumor; others are secretion of fluid by tumor cells, gliotic proliferation in adjacent brain with formation of fluid by glial cells, and loculation of CSF (8). Cyst formation within

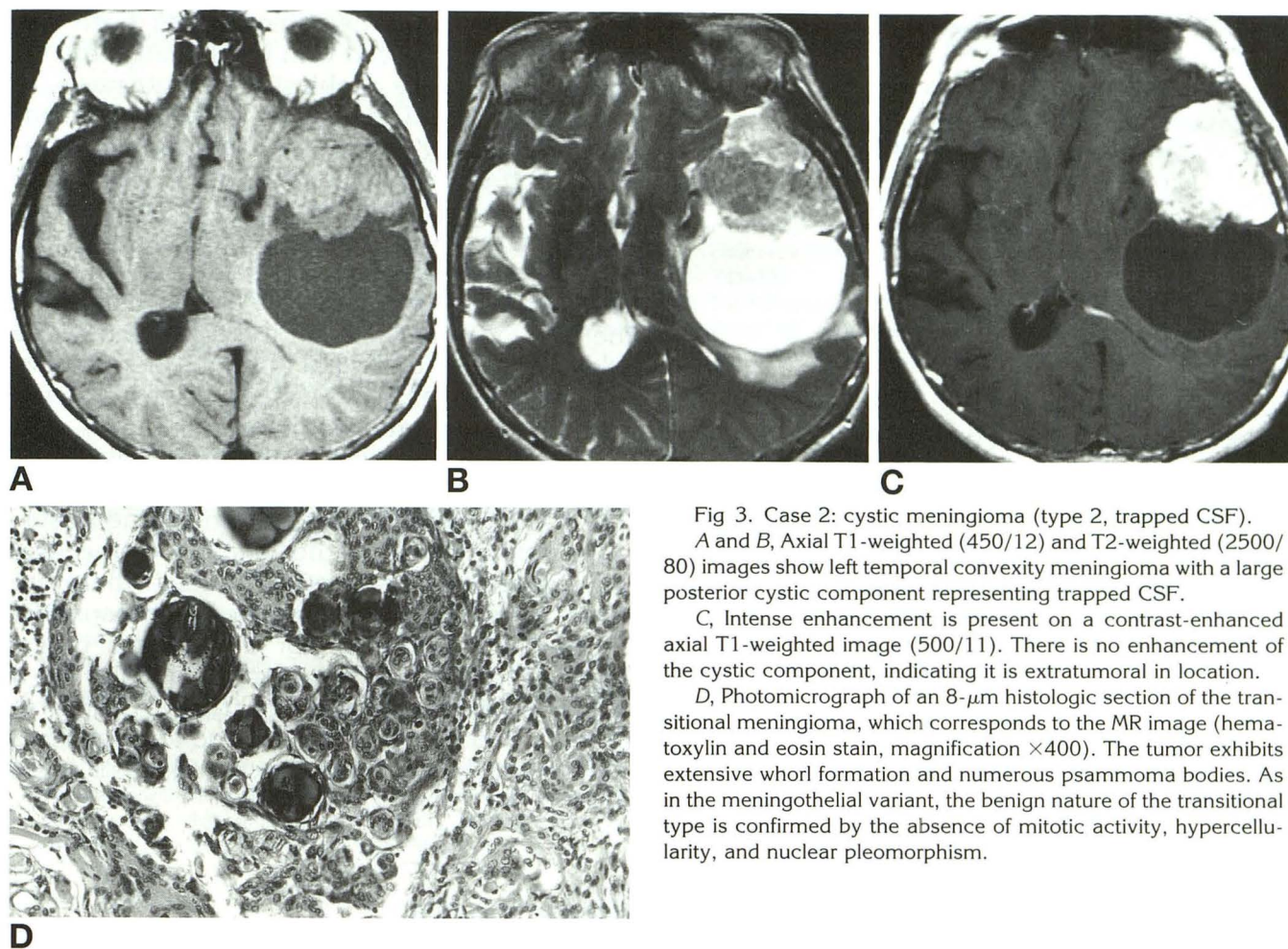


Fig 3. Case 2: cystic meningioma (type 2, trapped CSF).

A and B, Axial T1-weighted (450/12) and T2-weighted (2500/80) images show left temporal convexity meningioma with a large posterior cystic component representing trapped CSF.

C, Intense enhancement is present on a contrast-enhanced axial T1-weighted image (500/11). There is no enhancement of the cystic component, indicating it is extratumoral in location.

D, Photomicrograph of an 8- μ m histologic section of the transitional meningioma, which corresponds to the MR image (hematoxylin and eosin stain, magnification $\times 400$). The tumor exhibits extensive whorl formation and numerous psammoma bodies. As in the meningothelial variant, the benign nature of the transitional type is confirmed by the absence of mitotic activity, hypercellularity, and nuclear pleomorphism.

Characteristics of cysts associated with meningiomas

Case	Cyst Wall Enhancement?	Cyst Location	Cyst Signal Relative to CSF on T2-weighted Images	Histologic Pattern	Cyst Content
1	Yes	Intratumoral Eccentric	Isointense	Meningothelial	Xanthochromic fluid
2	No	Trapped CSF	Isointense	Transitional	CSF
3	No	Intraparenchymal	Isointense	Transitional	Liquefactive necrosis
4	No contrast	Trapped CSF	Hyperintense	Meningothelial	CSF
5	Yes	Intratumoral Eccentric	Hyperintense	Meningothelial	Xanthochromic fluid
6	No	Undetermined ^a	Isointense	Meningothelial	CSF
7	No	Undetermined ^a	Isointense	Meningothelial	CSF
8	No	Trapped CSF	Isointense	Meningothelial	CSF

^a Trapped CSF versus intraparenchymal cyst. Actual location was trapped CSF.

the tumor also may be seen as a result of tissue necrosis in the malignant variants of meningioma.

The mechanism of extratumoral cyst formation (trapped CSF) is not fully understood. The cyst may form as the result of a ball valve mechanism with the gradual accumulation of

CSF in several sulci between the enlarging tumor and brain parenchyma. A cystic cavity is thus formed in the subarachnoid space (Fig 4).

A cystic component or necrosis is more commonly seen in angioblastic and meningothelial meningiomas (3, 25), possibly as a result of their greater propensity for malignant transfor-

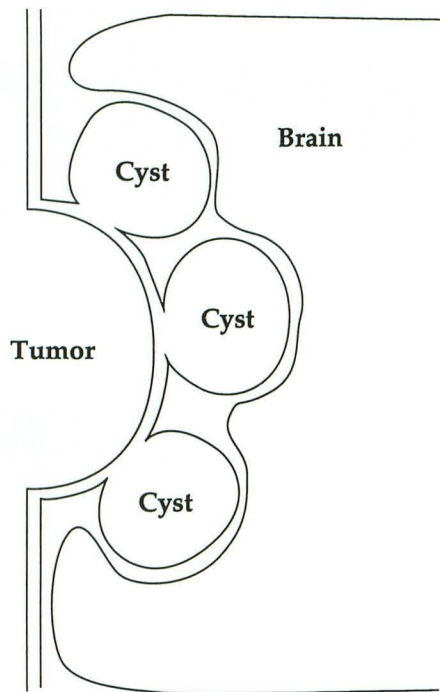


Fig 4. Formation of a trapped CSF cyst. A trapped CSF collection forms in the subarachnoid space between the enlarging tumor and underlying brain, possibly as the result of a ball valve mechanism.

mation and secretion, respectively. We also have made this observation: six of eight meningiomas in this study were meningothelial in origin. Correlation of signal intensity with the histopathologic subtypes of meningioma was similar to that reported by Elster et al (10). The meningothelial subtype was hyperintense and the transitional subtype hypointense on T2-weighted images.

There was no correlation between cyst content and cyst signal intensity. The intratumoral cysts consisted of xanthochromic fluid that contained hemosiderin laden histiocytes. One intratumoral cyst was isointense, and one was hyperintense relative to CSF on conventional spin-echo T2-weighted images. The most likely explanation for the observed signal intensity is that the intratumoral cysts did not contain sufficient hemosiderin to result in preferential T2 proton relaxation with resultant decreased signal intensity.

Neuropathologic studies may be complicated by the difficulties frequently encountered in differentiating cystic meningiomas, particularly the meningothelial subtype from glioblastoma multiforme (26). This subtype may simulate a glioblastoma at both the gross and microscopic

levels. The cystic meningioma has been frequently misdiagnosed with CT, because the tumor may simulate glioblastoma, metastasis, or sarcoma (2–8). The location of the tumor cannot be precisely determined because of beam-hardening artifact inherent with CT. MR clearly showed the extradural locations of the tumors, enabling the preoperative diagnosis of cystic meningioma with great confidence in all eight cases. Furthermore, we were able to determine the cyst locations in six of the eight cases. The additional finding of dural tail signs on contrast-enhanced studies in two cases further supported the diagnosis of meningioma.

Division of the cystic component into three groups is of practical value to the neurosurgeon. The most important factor from the neurosurgeon's perspective is the location of the cyst with respect to the tumor. Although there are three types of intratumoral cysts, the surgical approach is the same for these three types. These therefore may be grouped clinically into a single intratumoral category (type 1). The remaining two may then be referred to as trapped CSF (type 2) and intraparenchymal cysts (type 3).

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