Lateral Intraventricular Anaplastic Meningioma: A Series of 5 Patients at a Single Institution and Literature Review

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■ OBJECTIVE: **Lateral intraventricular anaplastic meningiomas (LIAMs) are rare lesions. The aim of this study is to clarify clinical and radiologic characteristics and the optimal treatment strategies of LIAMs with long-term follow-up.**

■ METHODS: **From September 2008 to September 2017, 5 patients with LIAM were enrolled in our study. The clinical profiles, radiologic features, treatment strategies, and outcomes were retrospectively analyzed.**

■ RESULTS: **Five patients (all female; mean age, 48.8 years; range, 33–61 years) were included in this study. The most frequent symptoms were those related to increased intracranial pressure. Mean duration of symptoms was 6.7 months (range, 2 weeks–2 years). The average tumor size was 4.98 cm at the maximal diameter (range, 3.0–6.2 cm). All were confirmed with a diagnosis of anaplastic meningioma. Gross total resection was achieved in all 5 patients. All patients experienced improvement of symptoms. Recurrence and progression were identified in only 2 patients. At the last follow-up, the mean recurrence-free survival was 13 months (range, 7–21 months) and the mean overall survival was 16.25 months (range, 8–21 months). One patient was lost to follow-up.**

■ CONCLUSIONS: **Female and right trigone area predominance were found in our case series. Shorter duration of symptoms, irregular tumor shape, peritumoral edema, and heterogeneous enhancement may indicate an aggressive feature. Maximal safe resection followed by radiation therapy may be the best strategy for patients with LIAM. Long-term clinical follow-up and serial imaging are recommended.**

INTRODUCTION

Meningiomas are the second most common primary intracranial tumors, comprising approximately 20% of the all brain neoplasms.[1] Most meningiomas are usually benign, and malignant meningiomas are relatively rare compared with benign ones, accounting for only 1%–3% of all meningiomas.[2] They commonly occur in the parasagittal cerebral convexity, sphenoid wing, and cerebellopontine angle region but may also be found elsewhere, including the ventricular system. Meningiomas rarely involve intraventricular space, comprising only 0.5%–5% of all intracranial meningiomas.[3] The most common lesion site of intraventricular meningiomas (77.8%) is the lateral ventricle, and most occur in the trigone area.[4,5] Thus, lateral intraventricular anaplastic meningiomas (LIAMs) are extremely rare.

The origin of intraventricular meningioma is believed to be the stroma of the choroid plexus or the tela choroidea.[3] Intraventricular meningiomas often reach large volumes before becoming symptomatic as a result of slowly growing mass and the fluid ventricular cavity. The localization of lateral ventricle is deep inside the cerebral hemisphere and closely adjacent to vital neurovascular structures, such as the motor and sensory centers

Key words
- Anaplastic meningioma
- Clinical and radiologic features
- Lateral ventricle
- Prognosis
- Treatment

Abbreviations and Acronyms
AM: Anaplastic meningioma
CT: Computed tomography
GTR: Gross total resection
LIAM: Lateral intraventricular anaplastic meningioma
MRI: Magnetic resonance imaging
OS: Overall survival
RFS: Recurrence-free survival
RT: Radiotherapy
SR: Surgical resection
WHO: World Health Organization

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and the optic and language cortex.[6] Consequently, to achieve gross total resection (GTR) without complications is difficult for neurosurgeons and still presents a neurosurgical challenge.

To the best of our knowledge, only 20 cases of anaplastic/malignant meningiomas of the lateral ventricle have been reported.[7-22] Because of their low incidence, their clinical and radiologic features and treatment strategies are unclear and controversial. In this retrospective investigation, we reported our experience of a series of 5 LIAMs operated at our center, to study the clinical and neuroimaging characteristics findings, pathology, and prognosis related to treatment. The relevant literature is reviewed.

METHODS

Patients

Five consecutive craniotomies for LIAMs carried out at West China Hospital of Sichuan University from September 2008 to September 2017 were investigated, including preoperative imaging studies and intraoperative confirmation of a purely lateral ventricle tumor. The histopathologic diagnosis was based on the 2007 World Health Organization classification of tumors of the central nervous system.

Clinical Data

Medical information was reviewed retrospectively through patients' medical and surgical records. Clinical data including age at diagnosis, gender, symptoms, and duration from onset to admission, tumor size and location, presence of hydrocephalus, surgical resection, histologic records, surgical outcome, and clinical follow-up were analyzed.

Tumor size was recorded according to the measurement of the maximum diameter on magnetic resonance imaging (MRI). Data regarding the location of the tumor and characteristics of contrast enhancement were obtained from the preoperative postcontrast imaging. Tumor location was divided into 5 groups: frontal horn, body, trigone, temporal horn, and occipital horn of lateral ventricle. Tumor shape was divided into 2 groups: spherical and irregular. Contrast-enhanced MRI scans were classified into 2 groups: homogeneous and heterogeneous contrast enhancement.

Karnofsky Performance Status was assessed using clinic records of preoperative visits. The extent of resection was assessed based on postoperative computed tomography (CT) scans or MRI and the surgeon's operative notes. The Simpson scale was used during the operation. GTR was equivalent to Simpson grade 1–2 resection, and subtotal resection was equivalent to Simpson grade 3–4 resection. MRI was performed annually for long-term follow-up. Further scans were obtained if new clinical symptoms developed. Tumor recurrence was defined by the presence of new pathologic tissue on repeated MRI (not noticed at an earlier control) and regrowth of residual by further growth of tissue already detected on the previous postoperative MRI. Progression of LIAM was defined according to the neuroimaging studies obtained after surgery.

The postoperative adjuvant radiotherapy (RT), postoperative complications, recurrence-free survival (RFS), and overall survival (OS) were all recorded. The end point of the study was RFS and OS. RFS was defined as the time between surgery and tumor recurrence on neuroimaging studies. OS was defined as the time from resection to death, with patients alive at the time of the last follow-up censored at that date. All the patients mentioned in this article gave their consent for inclusion in this study.

RESULTS

Patient Characteristics

Clinical information for all 5 patients is summarized in **Table 1**. Of the 5 patients, the mean age at diagnosis of anaplastic meningioma (AM) was 48.8 years (range, 33–61 years), and they were all women. All of the patients had a mean preoperative Karnofsky Performance Status of 86 (range, 80–100). The mean interval from onset of symptoms to admission was 6.7 months (range, 2 weeks–2 years). The initial clinical manifestations included headache ($n = 3$), dizziness ($n = 3$), vomiting ($n = 2$), contralateral homonymous hemianopia ($n = 1$), and epilepsy ($n = 1$). The tumor was found incidentally in 1 case.

Three of the 5 tumors were primary AMs (**Figure 1**). However, the remaining 2 patients had a history of low-grade meningioma and were regarded as having malignant transformation, which was defined as a World Health Organization (WHO) grade III meningioma evolving from WHO grade I or II meningiomas. One previous meningioma had been diagnosed 46 months before the malignant diagnosis and was identified as atypical meningioma (case 1). The other previous meningioma was also atypical and had been diagnosed 7 months before the diagnosis of the AM (case 3).

Radiologic Features of AM

The radiologic data are summarized in **Table 2**. All patients underwent CT, MRI, or both preoperatively. CT data were unavailable for all 5 patients. MRI data for 4 patients were available for review. In this study, concerning the location, 3 tumors were located in the right lateral ventricle and 2 were in the left. The maximal diameter of the tumor ranged from 3.0 to 6.2 cm, with a mean of 4.98 cm. Regarding tumor shape, 4 tumors were irregular (**Figure 2**). On MRI, 3 tumors were hypointense and 1 was hypointense with isointense to gray matter on T1-weighted imaging, whereas on T2-weighted images, 3 tumors were hyperintense and 1 was isointense with hyperintense. The tumors presented with heterogeneous enhancement in all 4 patients. Peritumoral brain edema was found in 3 patients, whereas no patients presented with hydrocephalus.

Treatment and Outcomes

Treatment was tailored to the individual patient in all cases. One asymptomatic tumor was resected because of documented growth after careful consideration of the risk and benefit. Of the 5 anaplastic lateral ventricular meningiomas, 4 were completely resected via a parieto-occipital transcortical approach and 1 via a transtemporal approach. Two patients underwent multiple surgical resections: 3 times for case 1 and 2 times for case 3. Three patients underwent adjuvant RT on 1 or more occasions during their treatment course; patient 1 received Gamma Knife radiation therapy (Elekta, Stockholm, Sweden) twice after her first

Table 1. Clinical Information of the 5 Patients with Intraventricular Anaplastic Meningioma

Case Number	Gender/ Age (years)	Presentations	Duration of Symptoms	Approach	Treatment for Lateral Intraventricular Anaplastic Meningioma	Times of Gamma Knife Surgery	Histology	Time to Recurrence (months)	Treatment for Recurrence/ Metastasis Lesion	Recurrence-Free Survival (months)	Follow-Up (months)	Outcome
1	F/47	Headache, dizziness, vomiting, contralateral homonymous hemianopia	3 months	Transcortical parieto-occipital approach	GTR	2	Anaplastic	—	Subtotal resection	7	8	Dead
2	F/61	None	24 months	Transcortical parieto-occipital approach	GTR	1	Anaplastic	No	—	17	17	Alive
3	F/54	Headache	2 weeks	Transtemporal approach	GTR	1	Anaplastic	7	Gamma Knife surgery	7	19	Alive
4	F/49	Dizziness	1 month	Transcortical parieto-occipital approach	GTR	No	Anaplastic	No	—	21	21	Alive
5	F/33	Headache, dizziness, vomiting, and epilepsy	5 months	Transcortical parieto-occipital approach	GTR	No	Anaplastic	No	—	Not available	Lost	Not available

F, female; GTR, gross total resection.

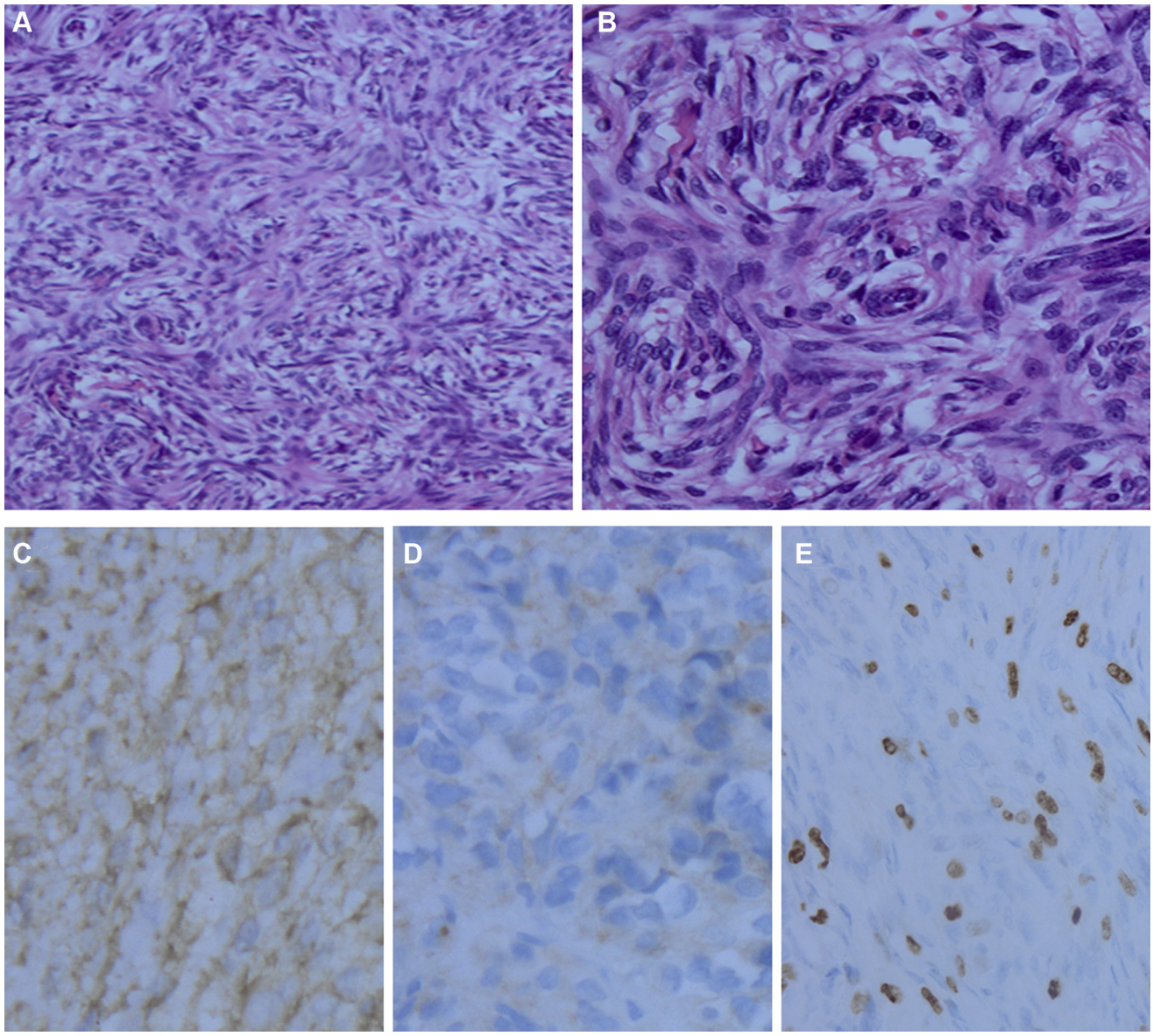

Figure 1. Hematoxylin and eosin–stained brain specimen obtained during the first surgery reveals anaplastic meningioma (**A**, ×100) and (**B**, ×400). Photomicrographs (×400) of the immunohistochemical stains showing anaplastic meningioma cells are positive for Vim (**C**), and partially positive for epithelial membrane antigen (**D**) and the Ki-67 labeling index (**E**).

operation; patient 2 received Gamma Knife radiation therapy once before the surgery; and patient 3 received Gamma Knife radiation therapy once after 1 tumor recurrence.

Patients with symptoms of headache, vomiting, and dizziness all improved after surgery. One patient with postoperative epilepsy resolved after treatment with an antiepileptic drug; this patient had also experienced seizures before surgery. One patient developed left hemiparesis with muscle power of grade 4 after surgery and it spontaneously resolved 1 week after discharge. None of the patients had a new onset of visual deterioration. One patient with preoperative contralateral homonymous hemianopia remained unchanged at discharge. The remaining 3 patients (60%) did not have any medical or surgical complications. Two patients had a relapse of the tumor after 7 months; patient 3 remained stable until the last follow-up, patient 1 received surgery after the second recurrence; the histologic diagnosis was poorly differential squamous-cell carcinoma with brain metastasis, and she died 1 month after the last surgery.

Clinical follow-up after diagnosis was available for 4 patients and 1 patient was lost to follow-up. At the last follow-up, the mean RFS was 13 months (range, 7–21 months) and the mean OS was 16.25 months (range, 8–21 months). Of the 3 patients with

Table 2. Neuroradiologic Features of the 5 Patients with Intraventricular Anaplastic Meningioma

Case Number	Tumor Location	Maximum Diameter (cm)	T1WI	T2-Weighted Imaging	Magnetic Resonance Imaging Enhancement	Peritumoral Edema	Tumor Shape	Cystic Component	Hydrocephalus
1	R/trigone	6.2	NA	NA	NA	NA	NA	NA	NA
2	Left/trigone	3	Hypointense to isointense	Isointense to hyperintense	Heterogeneous	Yes	IR	No	No
3	Left/trigone	5.8	Hypointense	Hyperintense	Heterogeneous	Yes	IR	No	No
4	R/trigone	4.2	Hypointense	Hyperintense	Heterogeneous	No	IR	No	No
5	R/trigone	5.7	Hypointense	Hyperintense	Heterogeneous	Yes	IR	No	No

R, right; NA, not available; IR, irregular.

primary AMs (1 lost to follow-up), none received retreatment during the follow-up period.

DISCUSSION

Incidence and Clinical Characteristics

AM is classified as a rare morphologic variant of WHO grade III meningioma with distinctive histologic features.[23] The occurrence of pure LIAM is exceedingly rare. Only 20 cases from the previous case reports or retrospective case series have been reported because of its low incidence (**Table 3**).[7-22] To the best of our knowledge, the present study is the largest series of LIAMs from a single neurosurgical center. In our study, LIAMs accounted for 0.09% of all intracranial meningiomas ($n = 5355$) treated at our institute during the same period. Our results are in line with the incidence reported in the literature.

Female predominance is reported in most studies; intraventricular meningiomas affect women approximately 4 times more often than men, ranging from 41% to as high as 82%.[6,24] All patients in our series were women, which is consistent with the female predilection in the literature. However, the sex distribution is slightly more frequent among men in the 20 reviewed cases, in which there were 7 males and 6 females, in contrast to the overall tendency of meningiomas. Similarly, Bhatoe et al.[25] found a male predominance of intraventricular meningiomas. Generally, the risk of developing meningioma increases with age. During recent decades, the reported mean age of patients with lateral intraventricular meningiomas ranged from 20 to 50 years. The mean age of patients with LIAM in this study was 48.8 years (range, 33–61 years), which is in accordance with the observed mean age in several large case series.[3,21,26] However, the mean age of the 20 reviewed cases was 50.9 years (range, 8–81 years), which is slightly older than the age reported in the literature.

Similar to common intraventricular neoplasms, because of the increased intracranial pressure as well as direct pressure on the adjacent cerebral parenchyma caused by the tumor, the clinical manifestation of LIAMs are headache, impaired cognition, amnesia, seizures, visual deficits, ataxia, and so on, which appear in the late stages of lesion progression.[27] The available ventricular space and the slow-growing pattern of meningiomas may be caused by the delay in clinical manifestations, and the clinical presentations are related to tumor origin, location, and size.[4] Headache and dizziness are the most common presenting symptoms in our series, followed by vomiting. The mean duration between symptom onset and presentation in this study was 6.7 months (range, 0.5–24 months), shorter than common meningioma, which probably reflects the aggressive feature and fast growth pattern of the tumor.

Pathogenesis

The pathogenesis of LIAMs remains controversial. Most studies of the cause of these tumors suggest that the origin may be the tela choroidea and the choroid plexus stroma.[3,25] Menon et al.[26] described 2 extension modes of intraventricular meningiomas: one is the tumor originating from the choroid plexus and growing within the ventricle, and the other is the tumor originating from the tela choroidea and growing partly within the ventricle and partly into the surrounding brain. Lateral

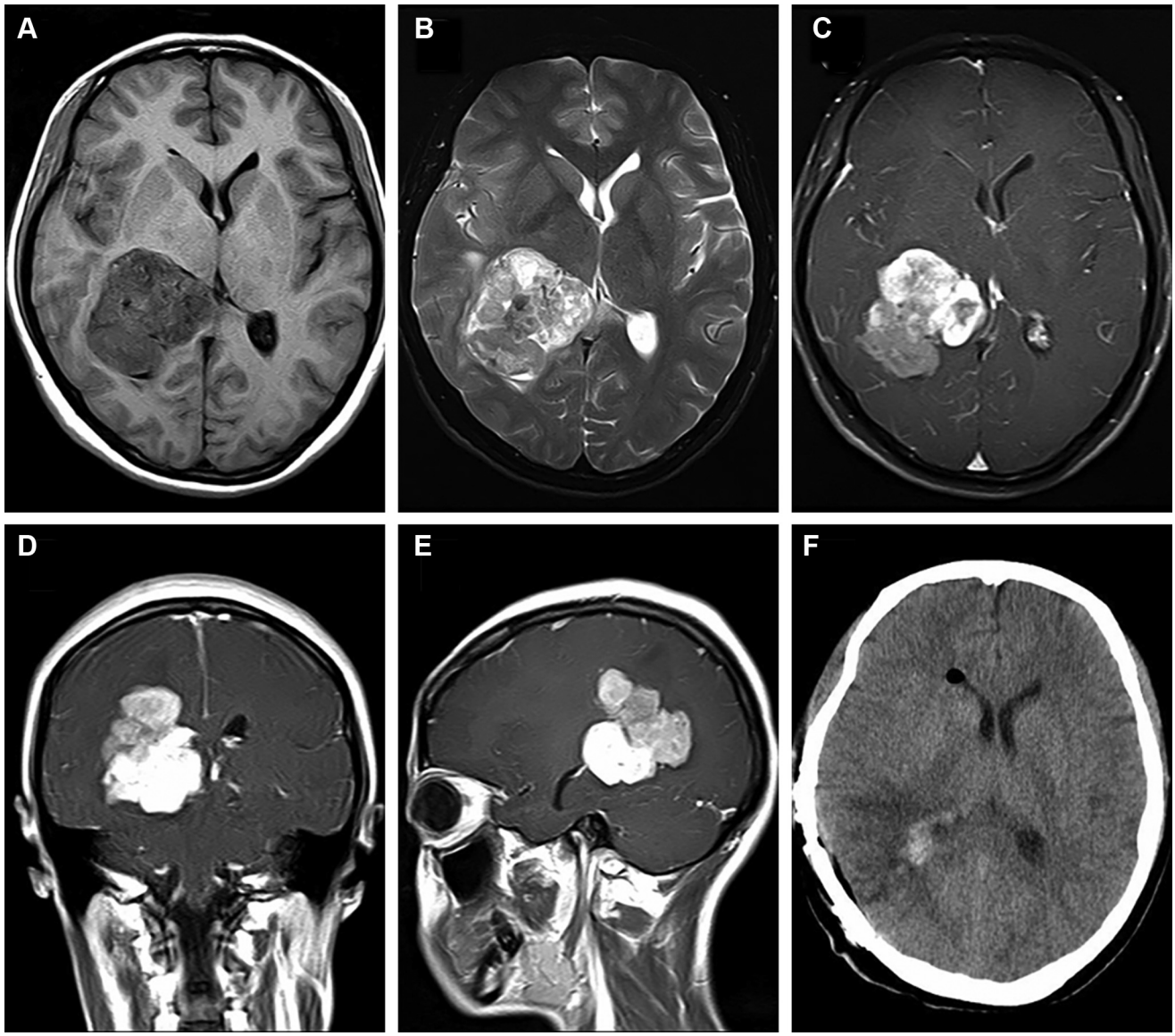

Figure 2. Preoperative T1-weighted image (**A**), T2-weighted image (**B**), sagittal (**C**), axial (**D**), coronal (**E**) T1-weighted contrast-enhanced magnetic resonance images of case 5 show a large enhancing mass in the trigone area of the right lateral ventricle. Postoperative computed tomography scan of the brain shows gross total resection of the tumor (**F**).

intraventricular meningiomas are most commonly present in the trigone area.[5] In our series, all were located in the trigone. According to the literature, 10 cases were located in the trigone area and 1 in the frontal horn, and there is a mild preponderance of the lesions on the right side (8 vs. 3), although the mechanism is still not clear.[25,27] In the current series, the LIAMs were almost equally distributed, 3 being on the right side and 2 on the left.

Diagnosis and Differential Diagnosis

The diagnosis of LIAMs depends on the imaging examination, which provides helpful information for preoperative evaluation. CT and MRI are the modalities of choice for diagnosing these tumors. On CT scans, intraventricular meningiomas are usually slightly hyperdense with contrast enhancement and may contain peritumoral hypodensity attributed to white matter edema. Malignant subtypes may show greater than expected restricted diffusion, although recent studies note that this is useless for predicting histologic grade.[28] On MRI scan, the meningiomas are isointense or hypointense on T1-weighted imaging, and isointense or hyperintense on T2-weighted imaging, with strong contrast enhancement. In some cases, there may also be hypointense and heterogeneous signal areas caused by tissue necrosis, intratumoral hemorrhage, or cystic change in the center of the mass on MRI.

Hydrocephalus caused by LIAMs is usually localized to the ipsilateral trigone and temporal horn.[5] On magnetic resonance spectroscopy, a high ratio of alanine to phosphocreatine with high levels of alanine and low levels of phosphocreatine has been reported as a specific characteristic for meningiomas.[29,30] Contrarily, Vucković et al.[31] suggested that the lack of a reliable alanine peak is not an absolute indicator of the exclusion of meningiomas from the differential diagnosis. Noninvasive CT angiography or magnetic resonance angiography can confirm the predominant blood supply and the draining veins.

Preoperative differential diagnosis for intraventricular tumors is important when planning surgical strategies and determining the extent of the required resection. MRI shows intraventricular meningioma as a homogeneous enhanced mass resembling the usual type of meningioma. A heterogeneous signal frequently presented on both T1-weighted imaging and T2-weighted imaging sequences, which is indicative of an aggressive type of meningioma, as in our case.[18] Thus, the differential diagnosis includes intraventricular lesions, such as choroid plexus papilloma and carcinoma, ependymoma, oligodendroglioma, metastasis, and lymphoma. The irregular tumor shape, peritumoral edema, and heterogeneous enhancement make the preoperative diagnosis difficult to determine without pathologic evidence. However, the presentations are significantly more frequent in aggressive meningiomas.

Surgery Treatment

Because mass effect is the main pathogenic mechanism, surgery is the primary therapy for the treatment of intraventricular meningiomas. Furthermore, surgery should be attempted with a microneurosurgical technique based on protection of the important functional brain areas around the lateral ventricle. Nevertheless, the removal of LIAMs still represents a neurosurgical challenge, and the challenge starts with the choice of approach. Several surgical approaches, such as the transfrontal approach, the anterior transcallosal approach, the posterior transcallosal approach, the transtemporal approach, and the transcortical parieto-occipital approach, have been applied to lateral ventricle meningiomas, and each offers unique pros and cons.[5,10]

As reported, the transcortical parieto-occipital approach is advantageous for tumors in the trigone. Ma et al.[10] suggested that the transcortical parieto-occipital approach in combination with intraoperative ultrasonography is a preferred route for the trigone lesion and can achieve a high level of GTR. Because the optic radiation runs inferolaterally to the atrium, Bhatoe et al.[25] implied that visual damage is not a direct consequence of the parieto-occipital approach itself but of the large size of the tumor. Menon et al.[26] stated that the parieto-occipital approach through a high cortical posterior parietal sulcus is a safe approach for trigone lesions, especially on the left side, and has little risk of speech or motor deficits. Four patients underwent this approach in our study without any complications except 1 patient who was treated via a transtemporal approach and developed a decrease of muscle force, which may be caused by the brain edema. Preexisting nonspecific symptoms (e.g., headache and dizziness) resolved in all. In addition, Grujicic et al.[3] reported that the transtemporal approach allows early exposure of the tumor feeding vessels and provides a direct and short trajectory to the atrium but increases the risk of damaging the optic radiation. Meticulous planning of the operative approach should take the tumor location, size, minimal brain retraction, the feeder of the tumor, and the function of brain into account.

The degree of surgical excision has an impact on OS and RFS in patients with benign meningiomas,[32] but it is controversial for patients with AM and various reports have provided different views. Moliterno et al.[2] showed improved median OS with GTR (3.2 years) compared with subtotal resection (1.3 years) in 37 patients with AM. Nevertheless, Rosenberg et al.[33] stated that they did not confirm the degree of resection as a significant contributor to patient outcome. Moreover, Balasubramanian et al.[34] reported a median OS of 80 months after subtotal resection compared with 56 months after GTR in 3 and 15 patients with AM, respectively. Sughrue et al.[35] showed a median survival of 107 months for patients with AM with near total resection (>90% resection) and 50 months for patients with AM with GTR. In addition, patients with primary AMs had a longer median OS compared with those with progressed tumors (3 vs. 2.4 years), and it was unrelated to the extent of tumor resection.[2] Some investigators have stated that LIAMs showed aggressive behavior and a high recurrence rate because of the difficulty in removing the tumors and the great surgical morbidity. Consequently, maximal safe resection other than aggressive removal may be the best strategy for patients with LIAM.

Radiation Therapy

Although surgical resection remains the primary therapy in most reports, RT as an adjuvant therapy is controversial for AM. Several studies have indicated that RT is effective for malignant meningiomas and has an impact on OS and progression-free survival in patients with primary or recurrent AM.[36,37] Dziuk et al.[38] found that the 2-year disease-free survival of surgery combined with RT was higher than that of surgery alone. Rosenberg et al.[33] presented data concerning 13 patients with malignant meningiomas and reported a median time to recurrence of 9.6 months. These investigators reported that 3 patients treated with surgery followed by RT had a median survival of 5.4 years versus 2.5 years in 10 patients treated with surgery only. Balasubramanian et al.[34] noted improved 3-year progression-free survival with stereotactic radiosurgery (20%) compared with their previous study (9%). Furthermore, several studies found that the superior tumor control rate was positively associated with postoperative high-dose radiation therapy.[39,40] However, AMs, especial recurrent AMs, may be more likely to be insensitive to RT.[41,42] In our study, Gamma Knife was chosen for some of the patients. No significant adverse effects were seen.

Chemotherapy

Recurrent AMs tend to be more aggressive than at initial presentation even after radical microsurgical resection. As with other modalities of systemic treatment, chemotherapy has been mainly used for recurrent tumors after the surgical and radiation options have been exhausted. Different chemotherapeutic agents such as hydroxyurea, bevacizumab, temozolomide, and irinotecan, which were deemed to have the benefit of preventing recurrence, have been used in patients with high-grade meningioma but have

Table 3. Case Series Summary of the Intraventricular Malignant/Anaplastic Meningiomas

Case Number	Reference	Sex/Age (years)	Presentation	Location	Maximum Diameter (cm)	Duration of Symptoms
1	Criscuolo and Simon, 1986[21]	NA	NA	NA	NA	NA
2	Kamiya et al., 1989[14]	M/67	L hemiparesis, urinary incontinence	R-trigone	6.5	1 month
3	Greenberg et al., 1993[15]	M/8	headache, vomiting, and deterioration of mental status	R-trigone	4.5	NA
4	Peh and Fan, 1995[9]	F/34	Headache and right upper quadrantanopia	L-trigone	NA	NA
5	Chen et al., 2003[22]	M/74	Weakness of the left limbs, dizziness, and memory impairment	R-frontal horn	5	1 month
6	Erman et al., 2003[18]	M/65	Headache and seizure	R-trigone	NA	NA
7	Darwish et al., 2004[20]	F/53	Dizziness	R-trigone	2	No
8	Li and Zhao, 2006[12]	NA	NA	NA	NA	NA
9	Shintaku et al., 2007[8]	F/61	Right occipital headache	R-trigone	2	7 months
10	Eom et al., 2009[19]	F/42	Headache and gait disturbance	L-trigone	6.2	2 months
11	Kim et al., 2009[13]	NA	NA	NA	NA	NA
12—14	Kim et al., 2009[13]	NA	NA	NA	NA	NA
15	Garcia-Conde et al., 2009[16]	M/44	Headache, disorientation, 2 episodes of sphincter relaxation	R-trigone	5	NA
16	Tao et al., 2014[7]	F/51	Headache and blurring of vision	R-trigone	7	NA
17	Ma et al., 2014[10]	F/47	Headache	R	52	NA
18	Ma et al., 2014[10]	M/35	Headache, nausea/vomiting	R	50	NA
19	Fujimaki et al., 2016[17]	M/81	double vision, right facial nerve palsy, and truncal ataxia	L-trigone	NA	3 moths
20	Li et al., 2018[11]	NA	NA	NA	NA	NA

Table 3. Continued

Histology	Time to Recur (months)	Approach	Treatment for Intraventricular Lesion	Site of Metastasis	Duration of Metastasis (months)	Treatment for Metastasis Lesions	Follow-Up (months)	Outcome
Malignant	10 weeks	NA	Surgery	NA	NA	NA	NA	Dead
Malignant	No	Temporoparietal craniotomy	GTR+RT	Spine (T9-T10)	6	GTR+RT	12	Dead
Malignant	2	NA	1st -GTR, 2nd-RT+ chemotherapy	Multiple (brain and spine)	2	RT +chemotherapy	6.5	Dead
1st-fibroblastic, 2nd-malignant and papillary, 3rd-malignant	1st-58, 2nd-62	Parieto-occipital craniotomy	1st-GTR, 2nd-GTR, 3rd-GTR+RT	L1-L5, both cerebellopontine angles	70	Partial remove +RT	74	Dead
Malignant	NA	Bilateral frontal craniotomy	GTR+RT	No	No	No	12	Dead
Anaplastic	No	Parieto-occipital craniotomy	GTR	No	No	No	0	Dead
1st-atypical, 2nd-atypical, 3rd-anaplastic	1st-4, 2nd-6, 3rd-9.5	Temporal craniotomy	1st-GTR, 2nd-GTR, 3rd-SR+RT	Multiple (brain, spine, subgaleal)	9.5	SR+RT	10.5	Alive
Malignant	NA	NA	GTR	NA	NA	NA	NA	NA
1st-transitional, 2nd-anaplastic, 3rd-anaplastic	1st-52, 2nd-54 3rd-56	NA	1st-GTR, 2nd-GTR, 3rd- Gamma Knife surgery	Multiple (fourth ventricle, spine T11)	52	SR+RT	58	Alive
1st-atypical, 2nd-malignant	1st-38	Temporal craniotomy	1st-GTR, 2nd-GTR+RT	Spine (multiple)	54	STR+RT	59	Dead
Malignant	1st-24	NA	GTR+RT	NA	NA	NA	63	NA
Malignant	NA	NA	GTR+RT	NA	NA	NA	NA	NA
1st-atypical, 2nd-atypical, 3rd-anaplastic	1st-2, 2nd-5	Parieto-occipital craniotomy	1st-GTR, 2nd-GTR+RT 3rd-SR	Liver	5	Biopsy	7	Dead
Anaplastic	1st-12, 2nd-18	Parieto-occipital craniotomy	1st-GTR, 2nd-GTR, 3rd-STR	Left lung, spinal (C2)	18	SR	19	Dead
Anaplastic	NA	NA	GTR+RT	NA	NA	NA	Lost	NA
Anaplastic	No	NA	GTR+RT	No	No	No	4	Alive
Fibrous and anaplastic	NA	No	Postmortem	Multiple (brain and spine)	NA	NA	53 days	Dead
Anaplastic	NA	NA	GTR+RT	No	No	No	15	Dead

NA, not available; M, male; R, right; GTR, gross total resection; RT, radiation therapy; F, female; SR, surgical resection; L, left; STR, subtotal resection.

potential therapeutic option. Thus, further clinical studies are needed to verify their efficacy.

CONCLUSIONS

LIAMs are rare tumors with a malignant nature and devastating prognosis. Female and right trigone area predominance were found in our case series. Imaging examination, especially MRI, can provide helpful information to diagnose intraventricular malignant meningiomas. Nevertheless, the exact diagnosis requires histologic results. Shorter duration of symptoms, irregular tumor shape, peritumoral edema, and heterogeneous enhancement may indicate an aggressive feature and fast growth pattern of the tumor. Patients with LIAMs represent a management challenge, and the optimal treatment of AMs is not well established. Maximal safe resection followed by radiation therapy may be the best strategy for patients with LIAM. Long-term clinical follow-up and serial imaging are recommended. Further study based on a large number of patients is needed for a thorough understanding of LIAMs.

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REFERENCES

1. Rockhill J, Mrugala M, Chamberlain MC. Intracranial meningiomas: an overview of diagnosis and treatment. *Neurosurg Focus*. 2007;23:E1.
2. Moliterno J, Cope WP, Vartanian ED, et al. Survival in patients treated for anaplastic meningioma. *J Neurosurg*. 2015;123:23-30.
3. Grujicic D, Cavallo LM, Somma T, et al. Intraventricular meningiomas: a series of 42 patients at a single institution and literature review. *World Neurosurg*. 2017;97:178-188.
4. Wang X, Cai BW, You C, He M. Microsurgical management of lateral ventricular meningiomas: a report of 51 cases. *Minim Invasive Neurosurg*. 2007; 50:346-349.
5. Zhang WH, Xie M, Liu H, Wang X, Lin MH. Surgical challenges for lateral ventricle meningiomas: a consecutive series of 21 patients. *J Huazhong Univ Sci Technolog Med Sci*. 2015;35: 742-746.
6. Bertalanffy A, Roessler K, Koperek O, et al. Intraventricular meningiomas: a report of 16 cases. *Neurosurg Rev*. 2006;29:30-35.
7. Tao CY, Wang JJ, Li H, You C. Malignant intraventricular meningioma with craniospinal dissemination and concurrent pulmonary metastasis. *World J Surg Oncol*. 2014;12:238.
8. Shintaku M, Hashimoto K, Okamoto S. Intraventricular meningioma with anaplastic transformation and metastasis via the cerebrospinal fluid. *Neuropathology*. 2007;27:448-452.
9. Peh WC, Fan YW. Case report: intraventricular meningioma with cerebellopontine angle and drop metastases. *Br J Radiol*. 1995;68:428-430.
10. Ma J, Cheng L, Wang G, Lin S. Surgical management of meningioma of the trigone area of the lateral ventricle. *World Neurosurg*. 2014;82:757-769.
11. Li Z, Li H, Jiao Y, et al. Clinical features and long-term outcomes of pediatric intraventricular meningiomas: data from a single neurosurgical center. *Neurosurg Rev*. 2018;41:525-530.
12. Li XZ, Zhao JZ. [Operation of lateral ventricular meningiomas of the trigone]. *Zhonghua yi xue za zhi*. 2006;86:2321-2323 [in Chinese].
13. Kim EY, Kim ST, Kim HJ, Jeon P, Kim KH, Byun HS. Intraventricular meningiomas: radiological findings and clinical features in 12 patients. *Clin Imaging*. 2009;33:175-180.
14. Kamiya K, Inagawa T, Nagasako R. Malignant intraventricular meningioma with spinal metastasis through the cerebrospinal fluid. *Surg Neurol*. 1989;32:213-218.
15. Greenberg SB, Schneck MJ, Faerber EN, Kanev PM. Malignant meningioma in a child: CT and MR findings. *AJR Am J Roentgenol*. 1993;160: 1111-1112.
16. Garcia-Conde M, Roldan-Delgado H, Martel-Barth-Hansen D, Manzano-Sanz C. Anaplastic transformation of an atypical intraventricular meningioma with metastases to the liver: case report. *Neurocirugia (Asturias, Spain)*. 2009;20:541-549.
17. Fujimaki M, Takanashi M, Kobayashi M, et al. Cerebrospinal fluid dissemination of anaplastic intraventricular meningioma: report of a case presenting with progressive brainstem dysfunction and multiple cranial nerve palsies. *BMC Neurol*. 2016;16:82.
18. Erman T, Gocer AI, Tuna M, Erdogan S, Zorludemir S. Malignant meningioma of the lateral ventricle. Case report. *Neurosurg Focus*. 2003; 15:Ecp2.
19. Eom KS, Kim HS, Kim TY, Kim JM. Intraventricular malignant meningioma with CSF-disseminated spinal metastasis : case report and literature review. *J Korean Neurosurg Soc*. 2009;45: 256-259.
20. Darwish B, Munro I, Boet R, Renaut P, Abdelaal AS, MacFarlane MR. Intraventricular meningioma with drop metastases and subgaleal metastatic nodule. *J Clin Neurosci*. 2004;11:787-791.
21. Criscuolo GR, Symon L. Intraventricular meningioma. A review of 10 cases of the National Hospital, Queen Square (1974-1985) with reference to the literature. *Acta Neurochir (Wien)*. 1986;83:83-91.
22. Chen NF, Lin GY, Wang YC, Leu CH, Kwan PC. Intraventricular malignant meningioma: one case report. *J Clin Neurosci*. 2003;10:616-620.
23. Louis DN, Perry A, Reifenberger G, et al. The 2016 World Health Organization classification of tumors of the central nervous system: a summary. *Acta Neuropathol*. 2016;131:803-820.
24. Liu M, Wei Y, Liu Y, Zhu S, Li X. Intraventricular meninigiomas: a report of 25 cases. *Neurosurg Rev*. 2006;29:36-40.
25. Bhatoe HS, Singh P, Dutta V. Intraventricular meningiomas: a clinicopathological study and review. *Neurosurg Focus*. 2006;20:E9.
26. Menon G, Nair S, Sudhir J, Rao R, Easwer H, Krishnakumar K. Meningiomas of the lateral ventricle—a report of 15 cases. *Br J Neurosurg*. 2009; 23:297-303.
27. Odegaard KM, Helseth E, Meling TR. Intraventricular meningiomas: a consecutive series of 22 patients and literature review. *Neurosurg Rev*. 2013; 36:57-64 [discussion: 64].
28. Sanverdi SE, Ozgen B, Oguz KK, et al. Is diffusion-weighted imaging useful in grading and differentiating histopathological subtypes of meningiomas? *Eur J Radiol*. 2012;81:2389-2395.
29. Jelinek J, Smirniotopoulos JG, Parisi JE, Kanzer M. Lateral ventricular neoplasms of the brain: differential diagnosis based on clinical, CT, and MR findings. *AJR Am J Roentgenol*. 1990;155:365-372.
30. Majos C, Cucurella G, Aguilera C, Coll S, Pons LC. Intraventricular meningiomas: MR imaging and MR spectroscopic findings in two cases. *AJNR Am J Neuroradiol*. 1999;20:882-885.
31. Vuckovic N, Kozic D, Vulekovic P, Vuckovic D, Ostojic J, Semnic R. MR and MRS characteristics of intraventricular meningioma. *J Neuroimaging*. 2010;20:294-296.
32. Nanda A, Bir SC, Maiti TK, Konar SK, Missios S, Guthikonda B. Relevance of Simpson grading system and recurrence-free survival after surgery for World Health Organization grade I meningioma. *J Neurosurg*. 2017;126:201-211.
33. Rosenberg LA, Prayson RA, Lee J, et al. Long-term experience with World Health Organization grade III (malignant) meningiomas at a single institution. *Int J Radiat Oncol Biol Phys*. 2009;74:427-432.
34. Balasubramanian SK, Sharma M, Silva D, et al. Longitudinal experience with WHO Grade III (anaplastic) meningiomas at a single institution. *J Neurooncol*. 2017;131:555-563.
35. Sughrue ME, Sanai N, Shangari G, Parsa AT, Berger MS, McDermott MW. Outcome and survival following primary and repeat surgery for World Health Organization Grade III meningiomas. *J Neurosurg*. 2010;113:202-209.
36. El-Khatib M, El Majdoub F, Hoevels M, et al. Stereotactic LINAC radiosurgery for incompletely resected or recurrent atypical and anaplastic

meningiomas. *Acta Neurochir (Wien)*. 2011;153:1761-1767.

37. Pollock BE, Stafford SL, Link MJ, Garces YI, Foote RL. Stereotactic radiosurgery of World Health Organization grade II and III intracranial meningiomas: treatment results on the basis of a 22-year experience. *Cancer*. 2012;118:1048-1054.

38. Dziuk TW, Woo S, Butler EB, et al. Malignant meningioma: an indication for initial aggressive surgery and adjuvant radiotherapy. *J Neurooncol*. 1998;37:177-188.

39. Milosevic MF, Frost PJ, Laperriere NJ, Wong CS, Simpson WJ. Radiotherapy for atypical or malignant intracranial meningioma. *Int J Radiat Oncol Biol Phys*. 1996;34:817-822.

40. Hug EB, Devries A, Thornton AF, et al. Management of atypical and malignant meningiomas: role of high-dose, 3D-conformal radiation therapy. *J Neurooncol*. 2000;48:151-160.

41. Stafford SL, Pollock BE, Foote RL, et al. Meningioma radiosurgery: tumor control, outcomes, and complications among 190 consecutive patients. *Neurosurgery*. 2001;49:1029-1037 [discussion: 1037-1038].

42. Mattozo CA, De Salles AA, Klement IA, et al. Stereotactic radiation treatment for recurrent nonbenign meningiomas. *J Neurosurg*. 2007;106:846-854.

43. Nayak L, Iwamoto FM, Rudnick JD, et al. Atypical and anaplastic meningiomas treated with bevacizumab. *J Neurooncol*. 2012;109:187-193.

44. Chamberlain MC. Hydroxyurea for recurrent surgery and radiation refractory high-grade meningioma. *J Neurooncol*. 2012;107:315-321.

45. Gupta V, Su YS, Samuelson CG, et al. Irinotecan: a potential new chemotherapeutic agent for atypical or malignant meningiomas. *J Neurosurg*. 2007;106:455-462.

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