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Surgical resection of metastatic intraventricular tumors

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Metastasis from a systemic (noncerebral) primary cancer must be considered in the differential diagnosis of an intraventricular mass. Although less common than metastases that occur within the brain parenchyma, metastatic brain tumors located within the cerebral ventricles are a unique challenge for neurosurgical oncologists. Because of the deep location of these tumors and their juxtaposition to critical brain structures, the management of patients with intraventricular metastases is generally more complex than that of most patients with intraparenchymal brain metastases. Nevertheless, continued experience with intraventricular surgery has resulted in a progressive improvement in the surgical treatment of intraventricular metastases. In addition, the development of stereotactic radiosurgery offers a less invasive nonsurgical alternative for small intraventricular metastatic tumors.

Despite these complexities, there is a paucity of information regarding the clinical features and surgical treatment of intraventricular metastases. Indeed, the literature on this topic is essentially limited to case reports [1–21] or to a few examples within larger series of intraventricular tumors in general [22–24]. Consequently, the purpose of this article is to review the unique features and surgical management strategies pertinent to intraventricular metastatic brain tumors based primarily on an analysis of our institutional experience with these lesions.

Clinical Features

Classification

True intraventricular metastases are distinct tumor masses that arise within the ventricle and originate most commonly from the choroid plexus or from focal attachment to the ependyma/subependyma. Parenchymal tumors with secondary extension into the ventricle should be classified as intraparenchymal metastases. More importantly, nodular deposits, even if large, that develop in patients with meningeal carcinomatosis (eg, Khoshyomn et al [25] and Bugiani et al [26]) should not be classified as intraventricular metastases, because the treatment and prognosis of these lesions differ markedly from the treatment and prognosis of true intraventricular metastatic tumors [27].

Incidence

When only true metastatic focal tumors are considered, brain metastases to the ventricles are rare, and although the exact incidence is difficult to determine, best estimates suggest that intraventricular metastases comprise about 6% of all intraventricular tumors (Kohno et al [13]) and occur in less than 5% of patients with cancer [13,16,28,29]. Arendt and colleagues [29] found 7 cases of intraventricular metastasis (4.6%) among 150 autopsied cancer patients. Kohno and colleagues [13] reported that tumors metastatic to the lateral ventricle comprised 0.9% of brain metastases based on a review of the Brain Tumor

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Registry of Japan. Even less usual is the occurrence of a single intraventricular brain metastasis. Schreiber and colleagues [28] reported that intraventricular metastases were found in 2.6% of patients with cancer at autopsy but that single intraventricular lesions were found in only 1 (0.14%) of the 737 cases analyzed.

Table 1 lists the cases of intraventricular metastases reported in the literature. A total of 23 cases have been described, with the largest series comprising 3 cases. Excluded from this list are cases identified as being part of a larger series of intraventricular tumors [22–24]; these cases are omitted because the reports typically focus on the radiographic features or the surgical aspects of resecting or biopsying intraventricular tumors in general and not on the specifics of metastatic lesions. For example, Kelly and coworkers [30] reported on the use of computer-assisted stereotactic surgery in the removal of 58 intraventricular tumors, 3 of which were intraventricular metastases; detailed descriptions of these cases were not given.

A search of the database of the Department of Neurosurgery at the University of Texas M.D. Anderson Cancer Center (M.D. Anderson) identified 35 patients (1.8%) with true intraventricular metastases among a group of 1930 patients with brain metastases treated during the 10-year period between June 1993 and February 2003 (Table 2). Thirty-one of the 35 patients had an intraventricular metastasis at the first presentation of brain metastasis, whereas 4 presented first with an intraparenchymal metastasis and subsequently developed an intraventricular lesion. Of the 31 patients with an intraventricular lesion at initial presentation, 12 (0.6% of all patients with metastases) had single intraventricular metastatic tumors and 19 had multiple lesions (2 patients had 2 intraventricular lesions, 11 patients had 1 intraventricular lesion and 1 intraparenchymal lesion, and 6 patients had 2 or more [range: 2–11] intraparenchymal lesions in addition to the intraventricular lesion). This population undoubtedly represents an underestimation of the total number of patients with intraventricular lesions seen at our institution, because some patients with intraventricular metastases may have been treated by medical or radiation oncologists without neurosurgical consultation.

Presentation and diagnosis

Patients with intraventricular metastases either are known to have systemic cancer at the time of presentation of the brain lesion (metachronous presentation) or the brain lesion is part of the initial presentation of the cancer (synchronous presentation of brain metastasis). In both groups, MRI of the brain is the critical diagnostic test.

In patients with known systemic cancer, the finding of a mass showing gadolinium contrast enhancement within the ventricle must be considered a metastasis until proven otherwise. The presence of multiple lesions virtually assures the diagnosis; thus, high-quality MRI is critical. In our series of 35 patients, 33 were known to have cancer before the diagnosis of brain metastasis, and the median interval from time of diagnosis of the primary tumor to presentation with the intraventricular brain metastases was 23 months (range: 1.4–84 months). For the 18 cases reported in the literature in which the presenting interval was described (see Table 1), 11 arose in patients with known cancer (metachronous presentation) and the median interval to diagnosis of the brain metastasis was 48 months. Both of these sets of data suggest that the time from diagnosis of the primary tumor to occurrence of intraventricular metastasis is longer than that observed for intraparenchymal metastases, probably because of the unique histologies of intraventricular metastases [31]. It is noteworthy that 6 of the cases in our series were identified during routine surveillance for systemic metastases in asymptomatic patients, demonstrating the value of this screening approach.

In patients without known systemic cancer (synchronous presentation), the differential diagnosis of an intraventricular lesion is obviously broader than in patients with known cancer. Distinctions between metastasis and other intraventricular tumors may be difficult based on imaging. It has been suggested [7] that the presence of extensive peritumoral edema within the brain parenchyma is more characteristic of brain metastases than other intraventricular lesions (eg, meningioma). Although this feature has not been specifically analyzed in a large study of intraventricular lesions to our knowledge, the presence of marked peritumoral brain edema should suggest the possibility of an intraventricular metastasis. Indeed, of the 20 cases reported in the literature that comment on this feature, brain edema was documented in 70%. Patients with intraventricular tumors without a documented primary cancer, particularly if in the fifth to seventh decades of life, should be evaluated for the possibility of systemic cancer. This evaluation typically includes

a careful history, physical examination, routine laboratory tests, and plain chest radiographs. A more extensive search for a primary cancer (eg, CT of the chest and abdomen) is probably not warranted until the brain lesion is proven to be a metastasis [32]. Although only two of our patients did not have a history of cancer at the time of diagnosis of the brain metastasis (see Table 2), 37% of the cases in the literature were found in patients without a diagnosis of cancer (see Table 1). This difference is undoubtedly a result of the different referral patterns of our tertiary cancer center and the hospitals reported in the literature.

With regard to specific symptoms, patients with intraventricular metastases present with the same symptoms as patients with other intraventricular tumors [31]. In our series of patients, most patients presented with symptoms of elevated intracranial pressure, including headache (49%) and nausea/vomiting (17%). In contrast, focal symptoms were rare, and seizures occurred in 5.6% of patients. Headache (47%) was also the most common symptom in the cases reported in the literature (see Table 1). Although not often recognized, hemorrhage as the cause of the symptoms is not uncommon for patients with intraventricular metastases [9,33]. Nakabayashi and colleagues [9] were the first to report hemorrhage in an intraventricular metastasis. Since then, several other reports have verified such intratumoral hemorrhages (see Table 1) [1–21]. In our series, four patients experienced significant intratumoral hemorrhages. Spetzger and colleagues [12] reported a noteworthy case of subarachnoid and intraventricular hemorrhage in a patient with incidental bilateral posterior communicating artery aneurysms, in whom the cause of the bleeding was eventually and correctly attributed to a fourth ventricular metastatic carcinoma.

Histology of primary tumor

A striking feature of intraventricular metastases is the high frequency of renal cell carcinoma (Fig. 1). Among the cases reported in the literature, nine metastases (39%) were renal cell carcinomas. In our series, 46% of intraventricular metastases were renal cell carcinomas, followed by melanoma (14%), breast cancer (14%), and lung cancer (9%) in decreasing order of frequency (see Table 2). This distribution is in contrast to the distribution of intraparenchymal brain metastases, among which lung cancer typically predominates (30%–60%), followed by breast cancer (10%–30%), melanoma (5%–21%), and, less commonly, renal cell carcinoma (1%–2%) [31].

The high frequency of intraventricular renal carcinomas suggests that there may be a tropism of this tumor type for the ventricle, specifically for the choroid plexus, from which most of them appear to arise. Matsumora and colleagues [15] pointed out that renal cell carcinomas are divided into two types: the "rapidly progressive type," which is often fatal within a few years of diagnosis, and the "slowly progressive type" in which patients survive for long periods with an indolent tumor. The long time between diagnosis of the brain metastases and the initial diagnosis of renal cell carcinoma in the kidney that is common in the cases reported in the literature suggests that metastasis to the ventricle (choroid plexus) from renal cell cancer is more prevalent in the slowly progressive type. Taken together, these observations suggest that there may be a biologic basis for the tendency of certain renal cell carcinomas to metastasize to the ventricle. Notably, the kidney and the choroid plexus function as plasma filtering systems, and this suggests, albeit speculatively, that there may be a cellular and molecular interaction between renal cell carcinoma and the cells comprising the choroid plexus that is more important than simple mechanical forces, such as blood flow. To our knowledge, the nature of this interaction has not been determined.

Location

In the literature (see Table 1) and our series (see Table 2), intraventricular metastases were observed to arise most commonly in the lateral ventricle (68% of our cases), whereas metastases to the fourth ventricle (21%) (Fig. 2) and the third ventricle (11%) (Fig. 3) were less usual. Within the lateral ventricle, the trigone was the most common site of metastasis (60% of our cases), followed by the body (28%). In our series, 18 of the 25 lateral ventricle tumors arose on the left side, whereas there was less of a propensity for localization in the dominant hemisphere in the reports in the literature.

The distribution of intraparenchymal brain metastases (ie, cerebral hemispheres [80%–85%], cerebellum [10%–15%], and brain stem [3%–5%]) roughly parallels the relative tissue and blood volume of these regions of the brain. Using this

Table 1
Published cases of intraventricular brain metastases[a]

Reference (year) [language if not English]	Sex/age (years)	Site of primary tumor (pathology)	Time from diagnosis of primary (months)	Presenting symptoms	Bleeding/ edema	No. metastases	Location in ventricle	Surgical procedure	Outcome
Healy and Rosenkrantz (1980)	F/73	Lung (oat cell carcinoma)	8	Decreased consciousness	No/?	2	Bilateral trigones	None (autopsy)	Died 1 day after CT was done
Kendall et al (1983)	F/?	Breast (?)	?	?	No/+	1	Right trigone	?	?
	?/?	Skin (melanoma)	?	Decreased consciousness	Yes/+	1	Fourth ventricle	Approach not specified	?
Killebrew et al (1983)	F/55	Kidney (renal cell carcinoma)	156	Headache	No/+	1	Left trigone	Parietal craniectomy	GTR, postoperative bleed, reoperation; required shunting; alive at 4 years with mild hemiparesis
Kart et al (1986)	M/61	Lung (poorly differentiated epithelial carcinoma)	60	Asymptomatic	Yes/+	1	Left trigone	Stereotactic biopsy	Radiation therapy to primary lung lesion; died 2 months after primary diagnosis
Mertens et al (1987) [German][b]	?/newborn	? (neuroblastoma)	?	?	?/?	?	Right trigone	?	Received multiagent chemotherapy; no relapse at 2 years
Shigemori et al (1987) [Japanese][b]	M/58	Kidney (renal cell carcinoma)	32	Headache, motor weakness	No/−	1	Right body (near foramen)	Transventricular	Postoperative subdural hematoma; died on postoperative day 3
Tanimoto et al (1991)	M/64	Lung (large cell carcinoma)	0	Headache	No/+	1	Right trigone	Transcortical (middle temporal gyrus)	Rapid regrowth of tumor, progressive hemiplegia; died because of acute MI before reoperation
Mizuno et al (1992)	F/59	Kidney (renal cell carcinoma)	48	Headache	No/+	1	Left lateral body	Posterior interhemispheric transcallosal	Tumor recurrence at 19 months, bedridden
Nakabayshi et al (1994)	M/64	Gastric (adeno-carcinoma)	0	Decreased consciousness, ? seizure	Yes/−	1	Left center body	Anterior interhemispheric (transcallosal)	Died 2 months after surgery from respiratory complications

Suetake et al (1994) [Japanese][b]	M/78	Kidney (renal cell carcinoma)	4	Decreased consciousness	Yes/+	1	Right trigone	Stereotactic biopsy	Vegetative state
Berkow and Kelly (1995)	F/13 months	Mediastinum (mixed malignant germ cell tumor–mature teratoma)	12	Decreased consciousness	No/?	?	?	Autopsy	Received chemotherapy, then presented with brain herniation from intraventricular metastasis
Spetzger et al (1995)	F/60	Kidney (renal cell carcinoma)	48	Headache, nausea, decreased consciousness	Yes/−	1	Fourth ventricle (floor)	Suboccipital craniotomy	Local rebleed on postoperative day 2, meningitis 1 week after surgery, recurrence at 18 months
Kohno et al (1996)	M/45	Colon (adenocarcinoma)	36	Hemiparesis, aphasia, hemianopsia	No/+	1	Left trigone	Transcortical (parietal)	Improved hemiparesis and speech after gross total resection, followed by postoperative radiation therapy
	M/66	Kidney (renal cell carcinoma)	84	Hemiparesis, disorientation and memory disturbance	No/+	1	Right trigone	Interhemispheric (transcallosal)	Gross total resection, postoperative radiation therapy
	M/66	Lung (adeno-carcinoma)	0	Seizures	No/+	1	Right inferior horn	Transcortical (temporal)	Gross total resection, postoperative radiation therapy
Brandicourt et al (1997) [French][b]	?/64	Colon (adenocarcinoma)	0	?	No/+	1	Third ventricle	?	Died 7 months later
Matsumura et al (1997)	M/68	Kidney (renal cell carcinoma)	84	Headache	No/−	1	Right lateral body	Transventricular via small corticotomy (frontal)	Disease-free at 30 months
Raila et al (1998)	F/47	Kidney (renal cell carcinoma)	0	Headache and somnolence	Yes/+	1	Right trigone	Approach not specified	Death at 3 weeks from secondary complications
Arbelaez et al (1999)	F/48	? (melanoma)	?	Headache	No/−	1	Left trigone	Transcortical (temporal)	Partial resection, no primary found; stable at 3 months

(*continued on next page*)

Table 1 (*continued*)

Reference (year) [language if not English]	Sex/age (years)	Site of primary tumor (pathology)	Time from diagnosis of primary (months)	Presenting symptoms	Bleeding/ edema	No. metastases	Location in ventricle	Surgical procedure	Outcome
Iwatsuki et al (1999) [Japanese][b]	F/75	Kidney (renal cell carcinoma)	0	Headache, decreased consciousness	Yes/+	1	Left trigone	Approach not specified	Improved condition?
Qasho et al (1999)	M/40	Bladder (adenocarcinoma)	0	Seizure	No/+	1	Right lateral ventricle	Transcortical (temporal)	Gross total resection
Escott (2001)	M/32	? (melanoma)	?	Headache	No/–	1	Left trigone	Gamma Knife radiosurgery	Lesion decreased in size after radiosurgery

Abbreviations: F, female; GTR, gross total resection; M, male; MI, myocardial infarction; –, absent; +, present.

[a] References were excluded for the reasons indicated: [42] article written in German, unable to confirm; [26] article written in Italian, unable to rule out meningeal carcinomatosis; [43] clearly meningeal carcinomatosis; and [25] clearly meningeal carcinomatosis.

[b] English abstract only.

same logic, the high proportion of atrial lesions seems to correlate with the large amount of choroid plexus within the trigone (often referred to as the glomus of the choroid plexus). Because metastases are generally believed to reach the brain via the blood stream (hematogenous spread), this higher proportion of choroid plexus may account for their frequent location at the trigone. If one considers the production of cerebrospinal fluid (CSF) to be the filtered product of blood (or plasma) passing through the choroid plexus, it is logical to hypothesize that tumor emboli may be trapped in this filtering system. On review of the operative notes of our cases, an attachment of the metastasis to the choroid plexus was confirmed in 11 of 24 cases operated on (46%), which supports this concept. Likewise, choroid plexus involvement was documented in all the cases reported in the literature. In most of these cases, cerebral angiography confirmed that the primary blood supply of the lesion arose from the choroidal vessels. Nevertheless, this simple "trapping hypothesis" cannot entirely explain the occurrence of tumors in the ventricle, because the choroid is affected less commonly than would be predicted by its significant vasculature [34]. Moreover, the low rate of metastasis from lung cancer (the most common systemic tumor) and the high rate of metastasis from renal cell cancer (a more rare cancer) suggest that other biologic factors must govern the occurrence of intraventricular metastases.

Surgical management strategies

Similar to its role in the treatment of the more common intraparenchymal metastases [32], surgical resection is an important component in the management of patients with intraventricular metastases. The overall goal of management is to "cure" the brain lesion(s) while avoiding significant morbidity to the patient. Although surgery is a critical treatment modality, the surgeon must also consider the role of other options, particularly whole-brain radiotherapy (WBRT) and stereotactic radiosurgery, when recommending the most appropriate treatment. Deciding which patients are appropriate for surgery requires that clinicians weigh the immediate risk of surgical intervention against the long-term benefits of quality survival. Thus, surgical decision making for patients with intraventricular

Table 2
Summary characteristics of patients at the University of Texas M.D. Anderson Cancer Center with intraventricular metastases

		Single metastasis	Multiple metastases
Number of patients[a]		12 (34%)	23 (66%)[a]
Age (years)	Median (range)	64 (36–69)	50 (20–69)
Sex	Male	9 (75%)	12 (52%)
	Female	3 (25%)	11 (48%)
Intraventricular metastases	At presentation	12 (100%)	19 (83%)
	Developed subsequently	0 (0%)	4 (17%)
Presentation (with respect to primary)	Synchronous	1 (8%)	1 (4%)
	Metachronous	11 (92%)	22 (96%)
Time from diagnosis of primary (months)	Median (range)	30.5 (0–84)	14.8 (0–22.8)
Presenting symptoms[b]	Headache	6 (50%)	11 (48%)
	Nausea and vomiting	2 (17%)	4 (17%)
	Decreased consciousness	1 (8%)	2 (9%)
	Ataxia	2 (17%)	4 (17%)
	Seizure	0 (0%)	2 (9%)
	Motor weakness	1 (8%)	4 (17%)
	Other	3 (25%)	2 (9%)
	Asymptomatic	2 (17%)	4 (17%)
Hemorrhage		2 (17%)	2 (9%)
Location in ventricle[c]	Lateral	10 (27%)	15[c] (40%)
	Trigone	8 (21%)	7 (18%)
	Body	1 (3%)	6 (16%)
	Anterior horn	0 (0%)	1 (3%)
	Temporal horn	1 (3%)	1 (3%)
	Third	1 (3%)	3 (8%)
	Fourth	1 (3%)	7 (19%)
Side of lateral ventricle	Left	8 (32%)	10 (50%)
	Right	2 (8%)	5 (10%)
Primary (histology)	Breast (adenocarcinoma)	1 (8%)	4 (17%)
	Colon (adenocarcinoma)	2 (17%)	0 (0%)
	Esophagus (adenocarcinoma)	0 (0%)	1 (4%)
	Kidney (renal cell carcinoma)	7 (58%)	9 (39%)
	Lung (adenocarcinoma)	1 (8%)	2 (9%)
	(sarcoma)	0 (0%)	1 (4%)
	Thyroid (papillary carcinoma)	0 (0%)	2 (9%)
	Skin (melanoma)	1 (8%)	4 (17%)

[a] Nineteen of the 23 patients with multiple metastases had an intraventricular metastasis at the initial diagnosis of brain metastases, whereas 4 patients presented with an intraparenchymal metastasis and subsequently developed intraventricular metastases.
[b] Patient may have had more than one symptom.
[c] Two patients had 2 intraventricular tumors (total number of tumors = 37).

metastases must take into account the fact that intraventricular lesions are deep within the brain; thus, surgical resection of these lesions may be associated with a slightly higher risk than for superficially located intraparenchymal lesions. Ultimately, the appropriate candidates for surgery are selected by carefully analyzing the clinical status of the patient, pertinent radiographic studies, and the histology of the tumor. Each of these areas has been analyzed in detail elsewhere [32], but they are reviewed here as they specifically relate to intraventricular metastases.

Clinical assessment

The status of the systemic disease (the primary tumor and noncerebral metastases) is the most important determinant of overall

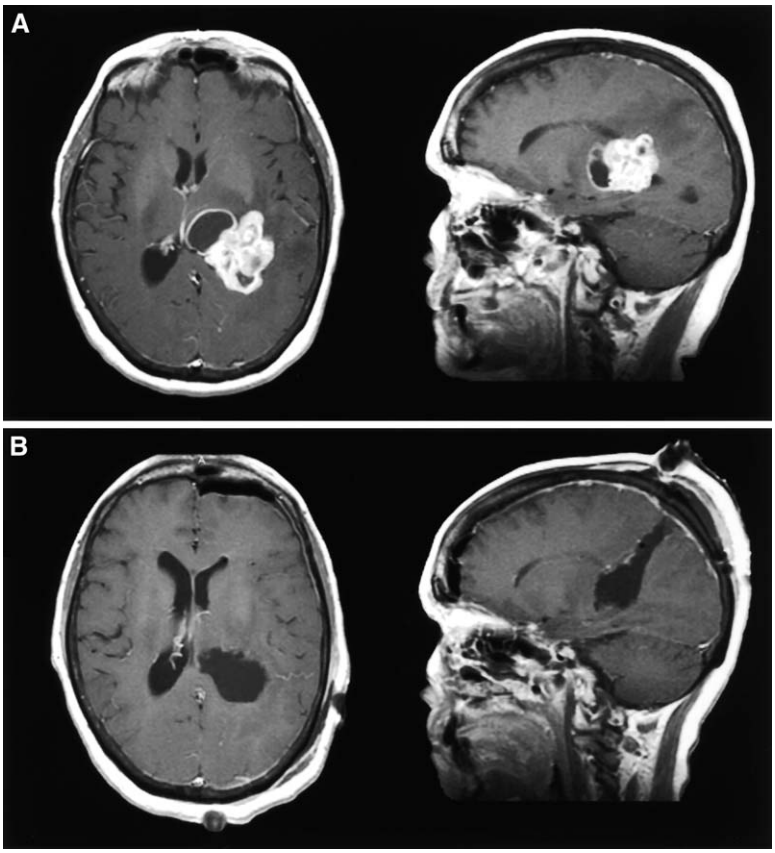

Fig. 1. (*A*) Preoperative axial (left) and sagittal (right) contrast-enhanced MRI scans of a 50-year-old man with known renal cell carcinoma and a left atrium/trigone lesion. (*B*) Corresponding immediate postoperative MRI scans after a gross total resection via a transcortical superior lobule approach. The trajectory of this approach is evident.

survival in patients with cerebral metastases. Up to 70% of patients undergoing surgery for single metastases die from progression of the systemic disease rather than from neurologic causes [35]. Consequently, surgery is generally considered only in patients with absent, "controlled," or "limited" systemic cancer. Although the definition of controlled or limited systemic cancer is clearly subjective, patients who are expected to survive more than 4 months are generally considered appropriate candidates for surgical resection. This consideration is particularly important for patients with deep lesions, such as those in the ventricle, because their recovery time from such surgery may be somewhat longer than for patients with superficially located lesions, which may reduce the benefit of surgical intervention.

Radiographic assessment

Radiographic assessments are used to determine the number of lesions and the size of each lesion.

Single intraventricular metastases

Patients with single brain metastases are the most appropriate surgical candidates. Indeed, two independent prospective randomized studies demonstrated that surgical resection is superior to WBRT in the treatment of single brain metastases in terms of morbidity, recurrence, and overall survival [35,36]. Although these studies did not specifically focus on intraventricular metastases, it is probably appropriate to conclude that surgical resection of intraventricular metastases is likely to be superior to WBRT as long as the lesion can be

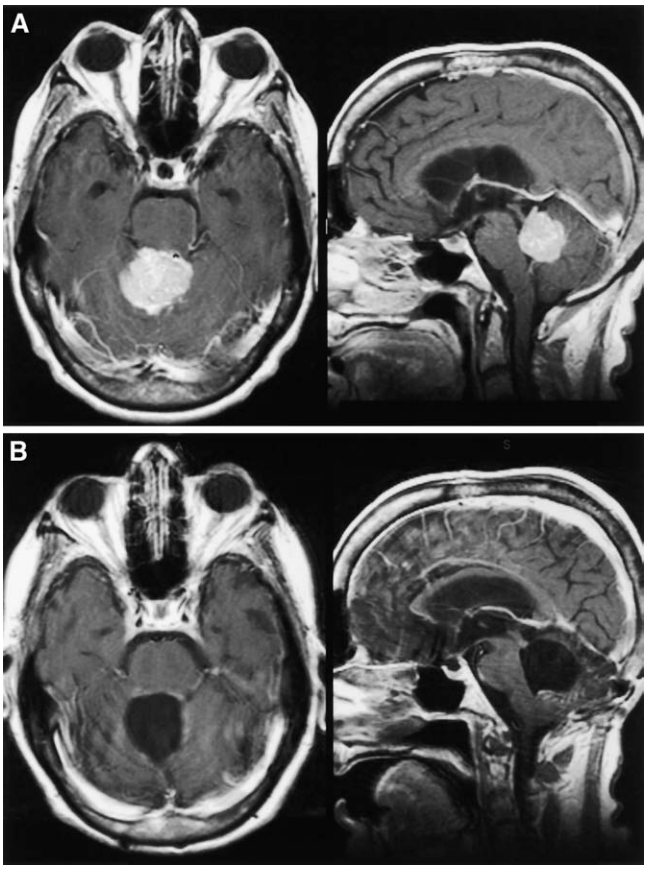

Fig. 2. (*A*) Preoperative axial (left) and sagittal (right) contrast-enhanced MRI scans of a 65-year-old woman with known breast cancer and a fourth ventricular metastasis. (*B*) Corresponding immediate postoperative MRI scans after a gross total resection via a midline suboccipital approach.

resected completely and with minimal morbidity (see Fig. 1).

More recently, however, it has been suggested that stereotactic radiosurgery may be an effective alternative to surgery in the treatment of single brain metastases [37]. Indeed, the deep location of intraventricular metastases makes radiosurgery particularly attractive because it is less invasive. To date, however, there has been no randomized trial comparing conventional surgery with stereotactic surgery in the treatment of brain metastases. Until such a trial is completed, it remains our contention that surgery offers significant advantages over stereotactic radiosurgery even for deep-seated intraventricular lesions. First, surgical resection provides histologic confirmation that the lesion is a metastasis, whereas tissue is not obtained with radiosurgery. Second, surgery is effective regardless of tumor size, whereas radiosurgery is not indicated for lesions greater than 3 cm in maximum diameter, and recent studies suggest that good tumor control is achieved primarily for lesions less than 1 cm in diameter [38]. Thus, radiosurgery may be best applied to relatively small lesions. Third, because surgery rapidly removes the lesion, it reverses symptoms more efficiently than radiosurgery and reduces the complications associated with long-term corticosteroid use. Fourth, surgery is effective regardless of tumor histology, whereas the effects of radiosurgery are less predictable, particularly for lesions that commonly produce ventricular metastases, such as renal cell carcinoma. Lastly, the risk of delayed radiation injury that can occur with radiosurgery is avoided with surgical intervention. The consequence of this injury may be

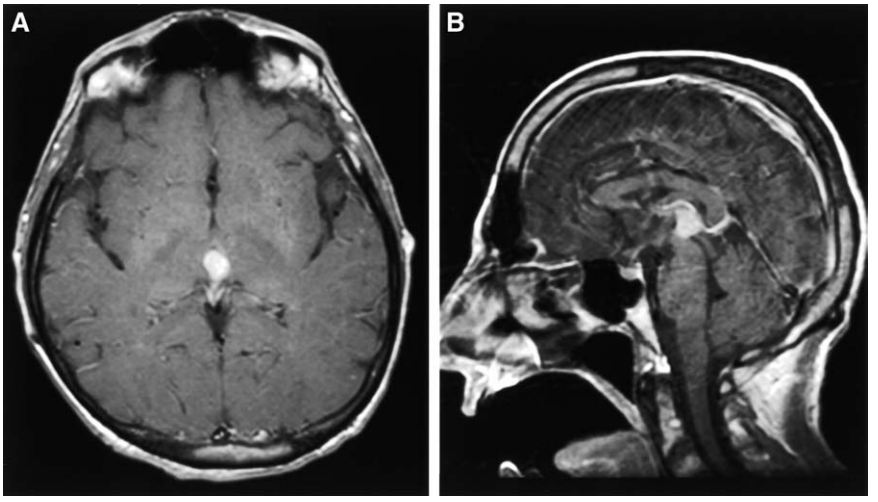

Fig. 3. Contrast-enhancing axial (*A*) and sagittal (*B*) MRI scans demonstrating a third ventricular tumor in a 42-year-old man with a history of thyroid cancer. The patient initially presented with an intraventricular hemorrhage that was treated with ventricular drainage and a ventriculoperitoneal shunt. The images in this figure were obtained 2 months after the initial presentation when the hemorrhage had resolved. The patient was treated with stereotactic radiosurgery because of the deep location and small size of the lesion.

more pronounced for intraventricular lesions that are near vital structures, such as the thalamus and fornices.

Thus, given our present knowledge, our preferred treatment of single intraventricular brain metastases is surgical resection (see Figs. 1 and 2). We reserve stereotactic radiosurgery for patients with uncontrolled or widespread systemic disease or with medical conditions that preclude surgery. In addition, we often recommend radiosurgery for asymptomatic patients with intraventricular lesions less than 1 cm in maximum diameter that are found incidentally during screening. Consistent with this philosophy, of the 12 patients with single intraventricular metastases treated at our institution (see Table 2), 11 underwent conventional surgery as the first line of therapy, whereas 1 was treated with stereotactic radiosurgery because of the small tumor size (see Fig. 3).

Multiple intraventricular metastases

Although the presence of more than one brain metastasis has traditionally been considered a contraindication to surgery, more recently, surgical resection has been used in the treatment of patients with "multiple" (ie, 2–4) brain metastases. This approach is based on a retrospective study from M.D. Anderson demonstrating that removal of multiple metastatic lesions was as effective as resection of single metastases provided that all lesions were removed [39]. Resection of an intraventricular metastasis in the presence of multiple brain metastases requires careful consideration, however. In fact, in our series of 35 cases, 19 patients presented with multiple brain lesions. Two of these patients had two intraventricular lesions; both lesions in 1 patient were treated initially with WBRT, and both lesions in the other patient received stereotactic radiosurgery. Of 11 patients who had both an intraventricular lesion and an intraparenchymal lesion, only 3 were treated with resection of the intraventricular lesion, whereas 8 had an intraventricular lesion treated with radiosurgery and 1 received WBRT. Lastly, 7 patients presented with an intraventricular metastasis plus two or more intraparenchymal lesions; 4 patients underwent surgical resection of their symptomatic intraventricular lesions. Thus, of the 19 patients with multiple lesions that included an intraventricular tumor, only 7 (37%) were treated initially with surgery. Indeed, given the complexity of resecting multiple lesions, less invasive strategies, such as radiosurgery, are an attractive alternative.

Histologic assessment

It is important to consider the radiosensitivity and chemosensitivity of the primary tumor before proceeding to surgery. Metastases from small cell

lung cancer and germ cell tumors are particularly sensitive to radiation and chemotherapy and are probably best treated with these modalities. These tumor types, however, rarely occur as intraventricular lesions. Melanoma, renal cell carcinoma, and most sarcomas are essentially resistant to fractionated radiation and are best treated with surgery. The most common type of cancer producing intraventricular metastases, renal cell carcinoma, is usually resistant to fractionated radiation therapy and to most chemotherapeutic agents; thus, surgery is the preferred treatment modality. Tumors like non-small cell lung cancer and breast cancer are intermediately sensitive to radiation, and surgery should be considered as part of a multidisciplinary scheme. In addition, it must be remembered that the responsiveness of tumors to single high-dose radiosurgery may differ from their responsiveness to fractionated radiotherapy. Indeed, radiosurgery may be an effective treatment for many of the more "resistant" tumors, including renal cell carcinoma.

Surgical Techniques

Successful removal of intraventricular cerebral metastases is safely accomplished in the modern era because of advances in surgical technique. Better understanding of the surgical anatomy of these lesions has led to safer operative approaches, and accurate localization of lesions on MRI has been translated into better intraoperative localization using image-guided methods. Although the approaches to intraventricular tumors have been discussed elsewhere in this issue and certainly apply to metastatic tumors, certain technical aspects unique to metastatic tumors are worthy of note.

Surgical anatomy

Several anatomic features unique to intraventricular metastases must be recognized for safe and effective resection. Intraventricular metastases are typically well-defined lesions that are invariably attached to the choroid plexus. This attachment may be quite broad, and infiltration of the choroid is common. Consequently, removal of the choroid back to a zone that appears normal may be required to prevent recurrence of the lesion. In addition, attachment or infiltration of the wall of the ventricle may occur because of the malignant nature of these tumors. Metastases typically have a gliotic pseudocapsule, however, and circumferential dissection in this gliotic plane generally ensures gross total resection, because there are typically no tumor cells in this zone. Lastly, intraventricular metastases almost invariably receive their blood supply from the choroidal arteries and drain via the choroidal veins. These vessels are usually at the base of the lesion at a position farthest from the initial surgical exposure. Thus, entering an intraventricular metastasis at the beginning of the resection without interrupting the blood supply results in significant hemorrhage (especially if a renal cell carcinoma) and obscures vision. Consequently, we generally prefer to perform a circumferential dissection and to identify the attachment to the choroidal arteries before entering the lesion. En bloc removal is also preferred to an "inside-out" approach because it reduces the possibility of shedding tumor cells into the ventricular system. Nevertheless, the size of the lesion and the small deep surgical corridor preclude en bloc removal in many cases. In these situations, circumferential dissection is performed as widely as possible and internal debulking is done. Progressive circumferential dissection and internal debulking are undertaken until the supplying blood vessels can be isolated, coagulated, and cut. Bleeding from the tumor stops when complete resection is achieved and the choroidal vessels are secured. The presence of bleeding invariably signals residual tumor. Cottonoids are used to prevent blood from spilling throughout the ventricles.

Surgical approaches

The surgical approach to metastatic intraventricular tumors depends on the location of the lesion within that ventricular compartment. A variety of surgical approaches have been described for different locations in the ventricles, and each is discussed elsewhere in this issue. All approaches to the ventricle require transgressing normal brain structures at some point. Therefore, our general philosophy is to use an approach that limits neurologic injury, even if the approach requires a longer surgical corridor.

Because most intraventricular metastatic tumors arise within the atrium/trigone of the lateral ventricle, special attention to this location is in order. For lesions in the dominant hemisphere, the atrium of the lateral ventricle is one of the more complex areas to access, because the surrounding cortical structures are critical to language and visual functions. Interhemispheric

approaches usually do not provide enough lateral exposure; thus, transcortical approaches are invariably required. Although transtemporal and lateral transparietal approaches have been suggested for dominant hemisphere atrial lesions [40,41], these approaches usually result in significant aphasia and visual field cuts because of the important role of the posterior temporal gyrus and the underlying white matter fibers in these functions. Approaches through the inferior temporal gyrus are generally too low to provide access to the atrium. Consequently, we generally attack these lesions through the superior parietal lobule, typically splitting the adjacent sulcus before entering the brain. Computer-assisted stereotactic guidance is used to plan the craniotomy and to maintain the corridor during surgery. The use of a computer-driven robotic microscope (eg, SurgiScope, Intelligent Surgical Instruments and Systems, Saint Martin D'Heres, France) is particularly applicable in these cases. Functional mapping of the position of the sensory cortex ensures passage through the superior parietal lobule and prevents injury to important motor and sensory fiber tracts. A corridor of 2 cm $\times$ 2 cm usually provides the necessary exposure to the lesion. This approach typically avoids aphasia and spares the visual projection fibers. In contrast, for lesions in the nondominant (right) hemisphere, violation of the superior parietal lobule results in visual-spatial dysfunction that manifests at least partly by dressing apraxia. Consequently, for right-sided atrial lesions, we typically use a middle temporal gyrus or superior temporal sulcal exposure.

Surgical complications and outcome

Because of the relatively short lifespan of patients with systemic cancer, it is important that surgical resection of brain metastases, including intraventricular metastases, be undertaken with minimal morbidity. Review of the cases in the literature (see Table 1) demonstrates that postoperative complications from intraventricular surgery in the past have been significant. Nevertheless, in the modern era, resection of intraventricular tumors can be achieved with low mortality ($< 5\%$) and morbidity ($< 10\%$) [22]. In our M.D. Anderson series of 24 intraventricular tumors operated on by several surgeons, there was no operative mortality and three patients (12%) experienced significant neurologic complications.

The outcome of patients with intraventricular metastases has not been specifically analyzed heretofore. In our series of 11 patients with single intraventricular metastases who were treated with surgical resection, the median survival time was 13.6 months. Thus, the survival of these patients seems to be similar to that of the more general population of surgically treated patients with single intraparenchymal metastases [31,32]. Of course, our patients with intraventricular tumors had a predominance of renal cell carcinomas, which may be prognostic for a longer survival interval [32]. Interestingly, despite having a tumor within the ventricle, only 2 of 11 patients with single brain metastases eventually developed meningeal carcinomatosis. In all, resection of deep-seated intraventricular tumors seems to be as effective as resecting more superficially located brain metastases.

Summary

The ventricle is a rare site of brain metastases. Renal cell carcinoma has a higher propensity to metastasize to the ventricle compared with more common metastatic tumors (eg, lung cancer). The trigone is the predominant location for intraventricular metastases, presumably because of the high concentration of choroid plexus in this region. Surgical resection is an important component of the management of these lesions, particularly if there is only a single intraventricular lesion. Despite the deep location of these tumors within the ventricle, survival in patients undergoing surgery for them is comparable to that in patients receiving surgery for intraparenchymal metastases.

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References

[1] Healy JF, Rosenkrantz H. Intraventricular metastases demonstrated by cranial computed tomography. Radiology 1980;136(1):124.
[2] Kendall B, Reider-Grosswasser I, Valentine A. Diagnosis of masses presenting within the ventricles on computed tomography. Neuroradiology 1983; 25(1):11–22.
[3] Killebrew K, Krigman M, Mahaley MS Jr, Scatliff JH. Metastatic renal cell carcinoma mimicking a meningioma. Neurosurgery 1983;13(4):430–4.

[4] Kart BH, Reddy SC, Rao GR, Poveda H. Choroid plexus metastasis: CT appearance. J Comput Assist Tomogr 1986;10(3):537–40.
[5] Mertens R, Muhler E, Heimann G. Disseminated neuroblastoma with intracerebral metastasis in a newborn infant. Klin Padiatr 1987;199(6):424–8.
[6] Shigemori M, Shimamoto H, Noguchi S, Yoshitake Y, Sugita Y, Kuramoto S. Choroid plexus metastasis of renal cell carcinoma. CT Kenkyu 1987;9(5): 603–6.
[7] Tanimoto M, Tatsumi S, Tominaga S, Kamikawa S, Nagao T, Tamaki N, et al. Choroid plexus metastasis of lung carcinoma—case report. Neurol Med Chir (Tokyo) 1991;31(3):152–5.
[8] Mizuno M, Asakura K, Nakajima S, Sampei T, Sayama I, Kawamura S, et al. Renal cell carcinoma metastasizing to choroid plexus of lateral ventricle; a case report. No Shinkei Geka 1992;20(4): 469–4.
[9] Nakabayashi H, Murata K, Sakaguchi M, Nakajima K, Katsuyama J. Choroid plexus metastasis from gastric cancer—case report. Neurol Med Chir (Tokyo) 1994;34(3):183–6.
[10] Suetake K, Shinya T, Takeda M. A choroid plexus metastasis of renal cell carcinoma: a case report. No Shinkei Geka 1994;3:436–41.
[11] Berkow RL, Kelly DR. Isolated CNS metastasis as the first site of recurrence in a child with germ cell tumor of the mediastinum. Med Pediatr Oncol 1995;24(1):36–9.
[12] Spetzger U, Mull M, Sure U, Gilsbach J. Subarachnoid and intraventricular hemorrhage caused by hypernephroma metastasis, accompanied by innocent bilateral posterior communicating artery aneurysms. Surg Neurol 1995;44(3):275–8.
[13] Kohno M, Matsutani M, Sasaki T, Takakura K. Solitary metastasis to the choroid plexus of the lateral ventricle. Report of three cases and a review of the literature. J Neurooncol 1996;27(1):47–52.
[14] Brandicourt P, Toussaint P, Le Gars D, Depriester D, Deramond H. Metastasis to the 3rd ventricle of colonic adenocarcinoma. Presse Med 1997;26(2):75.
[15] Matsumura H, Yoshimine T, Yamamoto S, Maruno M, Hayakawa T, Ono Y, et al. Single solitary metastasis of the slowly progressive type of renal cell carcinoma to the choroid plexus–case report. Neurol Med Chir (Tokyo) 1997;37(12):916–9.
[16] Raila FA, Bottoms WT Jr, Fratkin JD. Solitary choroid plexus metastasis from a renal cell carcinoma. South Med J 1998;91(12):1159–62.
[17] Gaab MR, Schroeder HW. Neuroendoscopic approach to intraventricular lesions. J Neurosurg 1998; 88(3):496–505.
[18] Arbelaez A, Castillo M, Armao DM. Imaging features of intraventricular melanoma. AJNR Am J Neuroradiol 1999;20(4):691–3.
[19] Iwatsuki K, Sato M, Taguchi J, Fukui T, Kiyohara H, Yoshimine T, et al. Choroid plexus metastasis of renal cell carcinoma causing intraventricular hemorrhage: a case report. No Shinkei Geka 1999; 27(4):359–63.
[20] Qasho R, Tommaso V, Rocchi G, Simi U, Delfini R. Choroid plexus metastasis from carcinoma of the bladder: case report and review of the literature. J Neurooncol 1999;45(3):237–40.
[21] Escott EJ. A variety of appearances of malignant melanoma in the head: a review. Radiographics 2001; 21(3):625–39.
[22] Morita A, Kelly PJ. Resection of intraventricular tumors via a computer-assisted volumetric stereotactic approach. Neurosurgery 1993;32(6):920–6.
[23] Chou MS, Tsai TC, Yang CW, Liu GC, Howng SL. Ventricular tumors—CT evaluations of 28 cases. Gaoxiong Yi Xue Ke Xue Za Zhi 1993;9(3):143–52.
[24] Majos C, Coll S, Aguilera C, Acebes JJ, Pons LC. Intraventricular mass lesions of the brain. Eur Radiol 2000;10(6):951–61.
[25] Khoshyomn S, Braff SP, McKenzie MA, Florman JE, Pendlebury WW, Penar PL. Metastatic intraventricular melanoma. Case illustration. J Neurosurg 2002;97(3):726.
[26] Bugiani O, Bava GL. Metastasis of bronchial carcinoma to the choroid plexus and the roots of the cranial and spinal nerves. Anatomo-clinical observation. Sist Nerv 1968;20(6):403–7.
[27] Aparicio A, Chamberlain MC. Neoplastic meningitis. Curr Neurol Neurosci Rep 2002;2(3):225–35.
[28] Schreiber D, Bernstein K, Schneider J. Metastases of the central nervous system: a prospective study. 3rd communication: metastases in the pituitary gland, pineal gland, and choroid plexus. Zentralbl Allg Pathol 1982;126(1–2):64–73.
[29] Arendt A, Dieck I, Fuchs U. Frequency of metastases of extracranial tumours in the choroid plexus. Zentralbl Allg Pathol 1980;124(5):395–7.
[30] Kelly PJ. Resection of intraventricular tumors via a computer-assisted volumetric stereotactic approach. Neurosurgery 1993;33(4):771–2.
[31] Sawaya R, Bindal RK. Metastatic brain tumors. In: Kay AH, Laws ER, editors. Brain tumors: an encyclopedic approach. Edinburgh: Churchill Livingstone; 1995. p. 923–46.
[32] Lang FF, Sawaya R. Surgical management of cerebral metastases. Neurosurg Clin North Am 1996;7(3):459–84.
[33] Taheri SA, Wani MA, Lewko J. Uncommon causes of intraventricular hemorrhage. Clin Neurol Neurosurg 1990;92(3):195–202.
[34] Takakura K, Sano K, Hojo S, Hirano A. Metastatic tumors of the central nervous system. Tokyo: Igaku Shoin; 1982.
[35] Patchell RA, Tibbs PA, Walsh JW, Dempsey RJ, Maruyama Y, Kryscio RJ, et al. A randomized trial of surgery in the treatment of single metastases to the brain. N Engl J Med 1990;322(8):494–500.
[36] Vecht CJ, Haaxma-Reiche H, Noordijk EM, Padberg GW, Voormolen JH, Hoekstra FH, et al. Treatment of single brain metastasis: radiotherapy

alone or combined with neurosurgery? Ann Neurol 1993;33(6):583–90.

[37] Kondziolka D, Lunsford LD. Brain metastases. In: Apuzzo MLJ, editor. Brain surgery: complication avoidance and management. New York: Churchill Livingstone; 1993. p. 615–41.

[38] Chang EL, Hassenbusch SJ, Shiu AS, Lang FF, Allen PK, Sawaya R, et al. The role of tumor size in the radiosurgical management of patients with equivocal brain metastasis. Neurosurgery 2003; 53:272–81.

[39] Bindal RK, Sawaya R, Leavens ME, Lee JJ. Surgical treatment of multiple brain metastases. J Neurosurg 1993;79:210–1.

[40] Santoro A, Salvati M, Frati A, Polli FM, Delfini R, Cantore G. Surgical approaches to tumours of the lateral ventricles in the dominant hemisphere. J Neurosurg Sci 2002;46(2):60–5.

[41] Andoh T, Shinoda J, Miwa Y, Hirata T, Sakai N, Yamada H, et al. Tumors at the trigone of the lateral ventricle—clinical analysis of eight cases. Neurol Med Chir (Tokyo) 1990;30(9): 676–84.

[42] Faber V. Fall von carcinomatos entartetem papillom des seit. Frankf Z Pathol 1934;47:168–72.

[43] Al-Anazi A, Shannon P, Guha A. Solitary metastasis to the choroid plexus. Case illustration. J Neurosurg 2000;92(3):506.