Infiltration of the carotid artery by cavernous sinus meningioma

MARK J. KOTAPKA, M.D., KAMAL K. KALIA, M.D., A. JULIO MARTINEZ, M.D., AND LALIGAM N. SEKHAR, M.D.

Departments of Neurological Surgery and Pathology (Neuropathology), University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania

Intracranial meningiomas are known to infiltrate surrounding structures such as the calvaria and dural sinuses, and the brain itself. The issue of whether meningiomas invade major intracranial arteries is of clinical importance, particularly in the case of meningiomas of the cavernous sinus. If a meningioma has not invaded the carotid artery wall, complete tumor removal may be accomplished with careful dissection from the carotid artery; however, if the tumor has infiltrated the wall of the carotid artery, complete removal may require sacrifice of the artery.

To determine whether cavernous sinus meningiomas invade the carotid artery, the authors retrospectively reviewed the histopathology of 19 consecutively treated individuals whose carotid artery was sacrificed during removal of a meningioma involving the cavernous sinus. Patients were selected for carotid artery resection based on preoperative magnetic resonance imaging studies demonstrating complete encasement of the artery. Reconstruction of the carotid artery was planned depending on the results of preoperative balloon test occlusion with blood flow determinations.

None of the 19 patients had pathological evidence of malignant tumor. Eight individuals (42%) were found to have infiltration of the carotid artery by meningioma. In five cases, focal involvement of the adventitia of the carotid artery wall was noted and, in three, the vessel was infiltrated up to the tunica muscularis. In no case was the tunica muscularis invaded by tumor. Thus, meningiomas of the cavernous sinus do infiltrate the internal carotid artery and, in order to completely resect these lesions and effect a surgical cure, it may be necessary to sacrifice the carotid artery with or without reconstruction.

Key Words • carotid artery • cavernous sinus • meningioma • artery reconstruction

Meningioma is the tumor most frequently involving the cavernous sinus. Encasement of the carotid artery represents one of the greatest obstacles to complete removal of these meningiomas, especially when the artery has been invaded by tumor. Little information exists in the literature on the frequency or extent of carotid artery invasion by meningioma, knowledge that would define the necessity for the use of reconstructive techniques, such as saphenous vein bypass grafting, in such cases. This study was conducted to investigate the frequency and extent of invasion of the carotid artery in 19 patients whose carotid artery was sacrificed as part of a planned attempt at complete resection of a cavernous sinus meningioma.

Clinical Material and Methods

Between 1983 and 1992, 111 individuals underwent surgery at this institution for meningioma involving the cavernous sinus. The surgical indications, preoperative assessment, operative technique, and results of therapy have been reported elsewhere, and will be summarized here only briefly.

Indications for attempted resection of cavernous sinus meningiomas consisted of radiographically documented tumor growth and/or a progressive neurological deficit. Preoperative imaging studies included computerized tomography (CT) with bone windows, magnetic resonance imaging with contrast enhancement, and cerebral angiography. These studies allowed determination of the degree of carotid artery invasion by the tumor. To assess the functional importance of a tumor-involved internal carotid artery (ICA), a preoperative balloon test occlusion was performed with stable xenon/CT determination of cerebral blood flow. The criteria for sacrifice of the ICA consisted of either no reduction or moderate reduction in cerebral blood flow (range 15 to 35 ml/100 gm/min) without neuro-
Cavernous sinus meningioma infiltration of carotid artery

Of the 111 patients with meningioma involving the cavernous sinus, 23 underwent resection of the cavernous carotid artery. The excised carotid arteries were fixed in formalin and embedded in paraffin. Sections of artery 6 to 8 µm thick were prepared with hematoxylin and eosin, Masson trichrome, and Verhoeff-Van Gieson stains. Histological material was not available for review in four patients, thus this study involves the histopathological analysis of the carotid arteries of 19 patients.

Results

The clinical details and pathological findings of the 19 cases are summarized in Table 1. All patients had preoperative radiographic evidence of encasement of the carotid artery and in 17 cases cerebral angiography revealed narrowing of the carotid artery. The carotid artery wall was invaded by meningioma in eight cases (42%). In five instances, tumor infiltrated only the outer layers of the adventitia (Fig. 1 left). Meningioma infiltrated the adventitia up to the level of the tunica muscularis in three individuals (Fig. 1 right); however, in no case did tumor grow through the tunica muscularis. No evidence of invasion of the carotid artery wall by the neoplasm was demonstrated in the remaining 11 cases.

In addition to the cavernous sinus, other anatomical regions were involved by tumor as follows: the middle fossa in 14 cases; the posterior fossa in 12; the sella turcica in eight; Meckel’s cave in three; and the orbit in three. Histopathological examination revealed no evidence of malignant meningioma such as frank invasion of the cerebral cortex, a high mitotic index, foci of necrosis, or other indicators of aggressive biological behavior.7

This operation was the initial attempt at tumor removal in 15 (79%) of the 19 cases. Three of the four with previous surgery had no evidence of tumor infiltration of the carotid artery wall. The remaining re-operated case exhibited tumor infiltration of the outer adventitia only. The decision to perform saphenous vein bypass grafting in 16 patients was based either on preoperative balloon test occlusion results or intraoperative changes in electrophysiological parameters.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Pathology Grade*</th>
<th>Preop Radiology of Carotid Wall</th>
<th>Bypass Graft</th>
<th>Previous Surgery</th>
<th>Tumor Location†</th>
<th>Location†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>MC/S</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>no</td>
<td>MC/S</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>MC/S</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>yes</td>
<td>yes no</td>
<td>S</td>
<td>yes no</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>MF</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>MF/PF</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>yes</td>
<td>yes yes</td>
<td>yes</td>
<td>MF/PF</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>yes no</td>
<td>yes no</td>
<td>S/MF/PF</td>
<td>MF/PF</td>
<td>S/MF/PF</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>yes</td>
<td>yes yes</td>
<td>yes</td>
<td>MF/PF</td>
<td>MF/PF</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>yes no</td>
<td>yes yes</td>
<td>MF/PF</td>
<td>S/MF/PF</td>
<td>MF/PF</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>MF</td>
<td>O/MF/PF</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>MF</td>
<td>O/MF/PF</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>MF</td>
<td>O/MF/PF</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>MF/PF</td>
<td>MF/PF</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>yes</td>
<td>yes no</td>
<td>MF/S</td>
<td>S/MF/PF</td>
<td>MF/S</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>yes</td>
<td>yes no</td>
<td>S/MF/PF</td>
<td>MF/PF</td>
<td>MF/PF</td>
</tr>
<tr>
<td>17</td>
<td>0</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>MF/PF</td>
<td>MF/PF</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>O/MF/PF</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>0</td>
<td>yes</td>
<td>yes no</td>
<td>no</td>
<td>MF/PF</td>
<td></td>
</tr>
</tbody>
</table>

* Pathology graded as follows: 0 = no evidence of tumor infiltration of carotid wall; 1 = tumor involving the outer adventitia only; 2 = tumor infiltrating adventitia up to the media.

† Tumor location: MF = middle fossa; PF = posterior fossa; MC = Meckel’s cave; S = sella turcica; O = orbit.
Discussion

The present report documents frequent involvement of the ICA wall by meningioma of the cavernous sinus. Infiltration of the carotid artery was found in eight (42%) of the 19 cases studied.

Study Design

The pathological material presented in this paper was reviewed retrospectively. There was no attempt by the surgeon to remove the cavernous carotid artery en bloc; instead, the tumor was resected piecemeal, with all fragments submitted for pathological examination. Because of the piecemeal removal, true serial section analysis of the entire cavernous carotid was not possible; however, the carotid artery specimens were always of full thickness from lumen to adventitia, and frequently contained complete cross sections of the vessel. Although the senior authors of this study (A.J.M. and L.N.S.) were aware of the potential importance of arterial invasion by meningioma, these patients were treated before the present study had been designed. Therefore, it is likely that the actual frequency of meningioma infiltration of the carotid artery wall is higher than reported here.

Nature and Extent of Tumor Invasion

The depth of meningioma invasion of the carotid artery wall varied. Of the eight patients with artery invasion, tumor had invaded the carotid artery adventitia up to the media in three; the remaining five had tumor infiltration of the outer adventitia only. Thus, although this report documents that meningiomas of the cavernous sinus do invade the adventitia of the cavernous carotid artery, it does not appear that meningiomas invade the media of the cavernous carotid artery. Standard neuropathology and neurosurgery texts have documented the frequent invasion by meningioma of adjacent bone, dura mater, and venous sinuses. However, invasion of the intracranial carotid artery by meningioma has not been well recognized.

Meningioma infiltration of the cavernous segment of the internal carotid artery has been described by Shaffrey (M. Shaffrey, unpublished data) in seven cases. He found, as we did in this series, that tumor invasion was limited to the adventitia in all involved cases. Shaffrey also noted tumor infiltration of the vasa vasorum of the carotid artery and suggested that the integrity of the vessel wall could be compromised by arterial wall ischemia secondary to tumor invasion.

Clinical Implications

It has long been recognized that, if the carotid artery is encased by tumor, complete operative removal of tumor may be impossible without damaging the vessel wall. Al-Mefty drew attention to the importance of an intact arachnoid in determining the resectability of meningiomas that originate at or near the anterior clino- noid process and encase the ICA. He noted complete resection of meningiomas with an intra-arachnoid origin in 20 of 21 patients. However, complete resection was not possible in three patients whose tumor originated at the undersurface of the clino- noid process, where the extracavernous intracranial carotid artery is not yet invested in arachnoid (clino- noidal segment). Similarly, the cavernous portion of the ICA is not invested in arachnoid.

Clinical reports emphasize the difficulty of resecting cavernous sinus tumors encasing the carotid artery. Do- lenc, et al., reported incomplete resection in 18 of 63 patients with cavernous sinus neoplasms, the majority of which were meningiomas. In nine of these 18 cases the limiting factor was tumor infiltration of the carotid artery wall. Thus, the presence or absence of an arach- noidal membrane may be important in determining the likelihood of invasion of the carotid artery by menin- gioma.

In cases of carotid artery wall invasion by tumor, it is likely that even with modern microsurgical tech- niques tumor removal will result in injury to the vessel wall. In addition to laceration of the artery with potentially significant hemorrhage, the adventitia or tu- nica muscularis of the vessel wall may be damaged. The long-term effects of such injury to the carotid artery following the removal of meningioma are not known. Sutton, et al., studied the effects on the carotid artery of microsurgical removal of cranio-opharyngiomas. In a series of 31 children undergoing radical at- tempted removal of cranio-opharyngiomas, nine patients (29%) had fusiform dilatations of the carotid artery on follow-up neuroimaging studies; however, during the mean follow-up period of 3.7 years, all patients re- mained asymptomatic from their arterial lesions. The authors hypothesized that dissection of the tumor capsule from the vessel wall weakened the adventitia, perhaps through injury to the vasa vasorum. They noted that longer patient follow-up periods are needed to estab- lish the natural history of such lesions.

The frequent invasion of the cavernous carotid artery by meningioma, the well-known relationship between completeness of resection of meningiomas and tumor recurrence, and the uncertain long-term significance of damage to the cavernous carotid artery by tumor infiltration or removal have stimulated the development of various treatment strategies for tumors encasing the carotid artery. Direct vein-graft reconstruction of the ICA has been developed to facilitate complete resection of cavernous sinus neoplasms involving the carotid ar- tery with preservation of the cerebral circulation. Sen and Sekhar reported 30 cases of ICA reconstruction for a variety of lesions. In 17 cases of meningioma of the cranial base, this technique enabled complete resection to be accomplished in 13 patients (76%). Lin- skey, et al., have reviewed other revascularization pro- cedures that are applicable to the problem of cavernous sinus meningioma resection.

Conclusions

The cavernous segment of the ICA may be directly infiltrated by meningioma. In such cases, invasion of the artery wall is limited to the adventitia; however, complete removal of these lesions may require resec-
Cavernous sinus meningioma infiltration of carotid artery

tion of the involved artery. In selected cases with cavernous sinus meningioma resection, reconstructive cerebrovascular procedures may be needed to preserve physiological cerebral blood flow and prevent the ischemic complications of carotid artery sacrifice.

References


Manuscript received April 9, 1993.
Accepted in final form December 10, 1993.
Address for Dr. Sekhar: Department of Neurosurgery, George Washington University Medical Center, Washington, DC.
Address reprint requests to: Mark J. Kotapka, M.D., Division of Neurosurgery, Hospital of the University of Pennsylvania, 3400 Spruce Street, Philadelphia, Pennsylvania 19104.