Efficacy of induced hypotension in the surgical treatment of large cavernous sinus cavernomas

KENJI OHATA, M.D., ALAA EL-NAGGAR, M.D., TOSHIRO TAKAMI, M.D., MICHIHARU MORINO, M.D., YOUSRY EL-ADAWY, M.D., KANAN EL-SHEIK, M.D., YUICHI INOUE, M.D., AND AKIRA HAKUBA, M.D.

Departments of Neurosurgery and Radiology, Osaka City University Medical School, Osaka, Japan; and Department of Neurosurgery, University of Alexandria, Alexandria, Egypt

Object. Cavernous sinus cavernomas are rare lesions associated with high rates of intraoperative mortality and morbidity resulting from profuse bleeding. In this paper, the authors report their experience in treating five patients with histologically confirmed cavernous sinus cavernomas and describe the efficacy of induced hypotension in facilitating excision of the lesion.

Methods. All five patients were women ranging in age from 25 to 54 years, with an average age of 42 years. The mass was small in one and large (> 3 cm in diameter) in four. In one patient with a large mass, cardiac arrest occurred after the craniotomy, and remarkable reduction in the size of the cavernoma was evident on postmortem examination. The other three large lesions were successfully removed piecemeal after induction of hypotension (60–80 mm Hg systolic pressure), which remarkably reduced the mass and the bleeding during surgery. In the remaining patient, who had a small lesion, the cavernoma was removed in one piece.

Conclusions. Cavernous sinus cavernoma can be thought of as a cluster of sinusoidal cavities, the size of which varies depending on the systemic blood pressure. During surgery, reduction of the mass and control of bleeding from the cavernoma can be achieved by inducing hypotension, which enables the safe excision of this lesion. This technique should be considered by surgeons resecting a cavernous sinus tumor, especially when cavernoma is suspected.

Key Words • cavernous sinus • cavernoma • induced hypotension • middle fossa • surgery

Extraaxial cavernomas are rare vascular lesions comprising 0.4 to 2% of all intracranial vascular malformations and most commonly occurring during the patient’s fourth decade of life; women are predominantly affected. Although extraaxial cavernomas share identical histopathological features with intraxial lesions, they are a distinct clinical entity with respect to presentation, radiological features, and management. The middle fossa is the site most commonly affected by these lesions, which arise from within the cavernous sinus. Therefore, the term “cavernous sinus cavernoma” has been recommended to replace “middle fossa cavernoma.” Unlike intraaxial cavernomas, cavernous sinus cavernomas rarely present with hemorrhage but grow slowly like tumors, compressing and distorting the structures in and around the cavernous sinus. These lesions tend to attain a large size before the patient manifests signs and symptoms.

Although these lesions are well demarcated by the presence of a fibrous pseudocapsule as a dissection plane, the perioperative mortality rate is very high as a result of uncontrollable bleeding, with 12.5% in the 65 cases reported. Surgery has frequently been halted due to profuse bleeding once the pseudocapsule is incised. One-piece removal of the cavernoma without incising the pseudocapsule is ideal but impossible if the lesion is large. Although advances in imaging technology and skull base surgery have gradually improved diagnostic and operative results, surgical removal of cavernous sinus cavernomas remains challenging because of their hemorrhagic nature and the complex neurovascular structure of the cavernous sinus. The purpose of this paper is to report our surgical experience with five cases, including one autopsy of a patient who died during surgery, and to describe the efficacy of induced hypotension in controlling intraoperative bleeding from large lesions during piecemeal removal.

Clinical Material and Methods

Patient Population

Since 1988, we have performed surgery in five patients with cavernous sinus cavernomas. All patients were wom-
Cavernous sinus cavernoma

**Summary of characteristics in five patients with cavernous sinus cavernoma***

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Sex</th>
<th>Age (yrs)</th>
<th>Duration of Disease (mos)</th>
<th>Neurological Deficits</th>
<th>Size of Lesion (cm)</th>
<th>Angiographic Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>45</td>
<td>15</td>
<td>disorientation, lt blindness, rt CN III–VI palsy, rt CN III &amp; IV palsy, rt hemiparesis</td>
<td>5.2 × 7.2 × 7.2</td>
<td>vascular</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>42</td>
<td>3</td>
<td>none</td>
<td>1.5 × 1.7 × 1.5</td>
<td>avascular</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>54</td>
<td>3</td>
<td>decrease in rt visual acuity, rt homonymous hemianopsia, rt CN III, IV, &amp; VI palsy, rt exophthalmos</td>
<td>4.5 × 7.1 × 6.5</td>
<td>slightly vascular</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>45</td>
<td>5</td>
<td>rt CN VI palsy</td>
<td>2.5 × 3.0 × 2.8</td>
<td>not performed</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>25</td>
<td>11</td>
<td>lt blindness, lt CN III–VI palsy</td>
<td>7.5 × 5.0 × 6.2</td>
<td>avascular</td>
</tr>
</tbody>
</table>

* CN = cranial nerve.

The cavernous sinus was peeled away to reveal the inner wall, tense on T2-weighted images. The mass compressed and displaced the C4 and C3 segments of the internal carotid artery (ICA) medially and anteriorly, respectively. In three patients (Cases 3–5) the intracavernous ICA was enveloped by the pseudocapsule of the mass. Angiographic findings consisted of an avascular mass in two patients, slight tumor staining in one, and blushed staining in one (Table 1).

**Operative Approach**

All lesions were surgically removed by radical resection as follows. Patients were placed on the operating table in a semisitting position. The lesion was approached via a frontotemporal craniotomy with or without orbitozygomatic osteotomy, with drilling of the lesser sphenoid wing, the roof of the optic canal, and the anterior clinoid process. The cavernoma was exposed via a combined epidural and subdural approach, which has been described as the preferred method for exposure of the intracavernous region, because these lesions originate in the cavernous sinus.8,9,36 Via an epidural approach, the lateral wall of the cavernous sinus was peeled away to reveal the inner wall, including the oculomotor, trochlear, trigeminal, and abducen nerves, which were draped over the surface of the cavernoma. The sylvian fissure was opened widely via a subdural approach, and the medial triangle formed by the ICA, the oculomotor nerve, and posterior clinoid process was opened to expose the lesion surface.

**Results**

**Case Report: Intraoperative Death**

Our first patient (Case 1) was incorrectly diagnosed as having a sphenoid ridge meningioma (Fig. 1). During the craniotomy, the dura was very tight despite the lowered venous intracranial pressure (ICP) induced by placing the patient in the semisitting position and administering mannitol. Immediately after the craniotomy, the patient suffered cardiac arrest with no distinct cause. We noted that the tension of the dura, which was very tight during craniotomy, became remarkably looser as the blood pressure decreased. The autopsy results showed a significant reduction in the volume of the lesion in comparison with preoperative images (Fig. 2). The histologically confirmed diagnosis was cavernoma (Fig. 3).

Considering the operative findings and the autopsy data in Case 1, we speculated that the arterial blood pressure might maintain the volume of the cavernoma by expanding its sinusoidal cavities and, accordingly, that induced hypotension might be useful to decrease the volume of the lesion during the operation as well as to decrease its bleeding. We devised a surgical strategy for large cavernous sinus cavernomas: to induce hypotension before their removal so that ICP as well as the mass of the lesion and intraoperative bleeding could decrease.

**Summary of Surgical Results in Four Subsequent Cases**

Anesthesia was induced by intravenous injection of 5 mg/kg thiopental, and endotracheal intubation was performed after intravenous injection of 4 mg pancuronium bromide. Anesthesia was maintained by the continuous inhalation method. Intermittent hypotension (systolic pressure 60–80 mm Hg) was induced during resection by intravenous administration of thiopental (an initial dose of 0.5 mg/kg, followed by 0.25 mg/kg/hour). The ICP was maintained at 10–15 mm Hg. At the end of the operation, the ICP was reduced to 10–15 mm Hg, and hypotension was stopped. The patient was weaned from the ventilator without difficulty and was discharged from the intensive care unit on the second postoperative day.
1–3 mg/kg), which was repeated two to three times, according to the patient’s response, to obtain the desired systolic blood pressure. A maintenance dose of 1 to 2 mg/kg/hour was then given until the bleeding became controllable or the feeding artery was coagulated. Protective agents against brain ischemia, including 1 mg/kg mannitol, 500 mg vitamin E, phenytoin 500 mg, and 1 g methylprednisolone, were also administered. Thiopental was selected as the primary agent for inducing hypotension because of its brain-protective effects. In Cases 3 and 5, a calcium channel blocker (nicardipine) was administered intravenously in addition to a maintenance dose of thiopental to stabilize the hypotension.

The orbitozygomatic infratemporal approach was used in Cases 2 and 3 and the frontotemporal approach in Cases 4 and 5. The cavernoma was completely removed in Cases 2 and 4 and subtotally removed in Cases 3 and 5. The small cavernoma in Case 2 was removed in one piece through the space between the ophthalmic and maxillary nerves in the lateral wall of the cavernous sinus via the epidural approach without induction of hypotension. Blood loss ranged from 500 to 2400 ml during the surgical procedures, and the amounts of blood transfused ranged from 0 to 2200 ml (Table 2).

In Cases 3, 4 and 5, a combined epidural and subdural approach was used and the lesion was removed piecemeal via the widened spaces between stretched cranial nerves. Before opening the dura mater, mild hypotension of between 80 and 90 mm Hg systolic pressure was induced and maintained, which helped to decrease brain bulging. The tension of the dura could not be decreased by further

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Approach/ Craniotomy</th>
<th>Blood Loss (ml)</th>
<th>Extent of Resection</th>
<th>Follow Up (yrs)</th>
<th>Functional Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>orbitozygomatic infratemporal</td>
<td>800</td>
<td>total</td>
<td>10.2</td>
<td>no deficit</td>
</tr>
<tr>
<td>3</td>
<td>orbitozygomatic infratemporal</td>
<td>2400</td>
<td>subtotal</td>
<td>6.1</td>
<td>decrease in rt visual acuity, improvement of rt CN III &amp; VI palsy, transient panhypopituitarism</td>
</tr>
<tr>
<td>4</td>
<td>frontotemporal</td>
<td>500</td>
<td>total</td>
<td>1.5</td>
<td>unchanged</td>
</tr>
<tr>
<td>5</td>
<td>frontotemporal</td>
<td>2100</td>
<td>subtotal</td>
<td>1.1</td>
<td>transient panhypopituitarism</td>
</tr>
</tbody>
</table>

* CN = cranial nerve.
elevation of the patient’s head. Massive bleeding was encountered after cutting the pseudocapsule and was well controlled by intermittent induced hypotension of between 60 and 80 mm Hg systolic pressure and insertion of a fibrin glue–soaked gelatin sponge into the sinusoidal cavities. The lesion was well demarcated over most of its surface in all cases because of the presence of the thin fibrous pseudocapsule over the mass surface.

In Cases 3, 4, and 5, the C3 and C4 segments of the ICA were medially and anteriorly displaced by the cavernoma, so the medial triangle could safely be opened after reduction of the main lesion located laterally. Dissection of the intracavernous ICA from the cavernoma was relatively easy to perform because the fibrous pseudocapsule intervened between the cavernoma and ICA. The petrous or the cervical segment of the ICA was exposed at the beginning of surgery in Cases 2 and 3, respectively, for proximal control of the ICA, which ultimately was not required in either case. The abducent nerve was observed to be displaced inferiomedially in two patients (Cases 2 and 4), and it was encased by the mass in the other two (Cases 3 and 5).

In Cases 3 and 5, the intrasellar as well as the suprasellar components of the lesion were not removed because of the lack of a pseudocapsule and tight adhesion of the mass to the pituitary gland and stalk. We believed that attempts to remove these parts could injure the vital structures. Transient panhypopituitarism occurred in the immediate postoperative period. These two patients have been closely followed for radiological or clinical evidence of regrowth of the lesion, which would indicate a need for repeated surgery.

Illustrative Case

Case 2

The preoperative diagnosis in the patient in Case 2 was either meningioma or cavernous sinus cavernoma (Fig. 4).
The influence of circulatory change on the clinical manifestation of cavernous sinus cavernoma has been described by Dolenc. He observed that the clinical symptoms and signs became more pronounced during physical exertion and suggested that the cause was an increase in the size of the lesion and consequent pressure on the cranial nerves. In addition, several reports have shown that the onset of symptoms first appears during pregnancy, and this may result from the increased size of the lesion secondary to the hyperdynamic circulation associated with pregnancy. The mechanism of these phenomena is engorgement of the sinusoidal cavities in the lesion because of elevation of the systemic blood pressure rather than venous congestion.

Pathological studies have shown that cavernomas consist of endothelium-lined vascular spaces with no muscular wall and only a small amount of poorly organized elastic tissue, ranging from capillary to cavernous in dimension. The internal elastic membrane as well as stromal cells are absent. These pathological features are in good agreement with the reported operative findings that the lesion is spongelike and also support our concept that the size of sinusoidal vascular spaces is not fixed but can be reduced by decreasing systemic blood pressure. If the lesion is large, even a small reduction of volume in each sinusoidal cavity may contribute to a noticeable reduction of the cavernoma.

Reported mechanisms of growth of the cavernous sinus cavernoma include: 1) capillary outgrowth at the periphery of the lesion; 2) gradual ectasia of vascular spaces; and 3) thrombosis with organization and progressive sclerosis. We concur with the first two mechanisms, because in our clinical experience even large lesions resembled a cluster of small balloons.

**Origin and Pattern of Growth**

For safe surgical treatment of the cavernous sinus cavernoma, knowledge of the commonly accepted microsurgical anatomy of the lesion is required. Cavernous sinus cavernomas grow endophytically within the cavernous sinus and extend into the middle fossa by elevating the floor of the dura. The lesion may extend to the orbit through the superior orbital fissure and may even erode into the sella turcica. The surface of the lesion consists of two layers: the lateral wall of the cavernous sinus, or the dura of the middle fossa outside, and the fibrous pseudocapsule inside. The cranial nerves within the lateral wall of the cavernous sinus are stretched over the surface of the lesion, and the cavernous ICA and the abducens nerve may be encased. The cavernous ICA can also be compressed medially rather than encased. Alternatively, in some reported cases, the cavernomas grow exophytically outside the cavernous sinus, and the cranial nerves in the lateral wall of the cavernous sinus are embedded in the mass.

Considering the anatomical features of the cavernous sinus cavernoma, surgical excision should be easy because of the noninvasive nature of the lesion and the presence of its pseudocapsule, if bleeding from the mass is controllable. Linskey and Sehkar29 recommended surgical treatment that avoids piecemeal resection and early devascularization of the mass. In relatively small cavernous sinus cavernomas, total excision in one piece via the epidural approach after coagulating the surface and feeding vessels is possible.

**Role of Induced Hypotension During Surgery**

In some reported cases, the pseudocapsule was incomplete, and severe bleeding occurred after the dura mater was incised. A pseudocapsule firmly enclosing the mass might not always be present, rendering surgical treatment difficult. Even if the pseudocapsule is present, dissection between it and the dura is not always technically easy. In fact, diffuse bleeding occurred in several reported cases due to rupture of the pseudocapsule. Furthermore, in large cavernomas, piecemeal resection of the lesion cannot be avoided if one wishes to preserve the surrounding neural structures. In the 72 reported cases, surgical intervention was performed in 65 of them. In these 65 patients, surgical intervention was frequently halted because of profuse bleeding. As a result, in at least 20 patients only exploratory craniotomy, biopsy, or partial removal was performed. Intraoperative death, mainly caused by the uncontrollable bleeding, occurred in eight patients.

Induced hypotension during surgery in the cavernous sinus cavernoma was used in one case described by Rosenblum, et al., prior to the present report. They reported on a patient with a small cavernous sinus cavernoma that was successfully resected piecemeal with induced hypotension, although details were not described. Especially in patients with large lesions, induced hypotension helps to decrease brain bulging and reduces the size of the lesion as well as its vascularity, facilitating its removal via a combined epi- and subdural approach.

Cavernous sinus cavernoma is commonly misdiagnosed as meningioma. Although the advent of MR imaging has facilitated accurate preoperative diagnosis of cavernous sinus cavernoma, the lesion appears low to isointense on T₁-weighted images and markedly hyperintense on T₂-weighted images and shows intense enhancement after injection of contrast material. Therefore, we have still experienced difficulty in the preoperative diagnosis of cavernous sinus lesions. We advocate that induction of hypotension be considered whenever a patient with a suspected cavernous sinus cavernoma is going to undergo operation.

Radiation therapy has been recommended as the primary treatment or as an adjuvant therapy to decrease the size and vascularity of the mass. Our opinion is that these lesions are nonneoplastic and therefore radiation therapy should not be considered in their primary management, except in rare circumstances in which surgical excision is impossible or the patient has some contraindication to surgery.

**Surgical Procedure**

Although huge lesions tend not to be well encapsulated, they are easily stripped from the involved structures. The oculomotor, trochlear, and trigeminal nerves are stretched over the mass and can easily be separated because these nerves are contained and protected in their dural sleeves. In some reported cases, the abducens nerve was found to be within the mass and therefore was diffi-
Cavernous sinus cavernoma

cult to preserve.11,25–40 Because this nerve is not protected by a dural sheath, inserting hemostatic material into the lesion for control of bleeding without predicting the course of the abducens nerve might sever it even in cases in which it is not embedded in the mass.

The autopsy and operative findings in our study indicate that the ICA was not inside the lesion initially but became enveloped by the pseudocapsule as the lesion grew. Therefore, dissection of these structures from a cavernoma is easier than from a meningoia. We propose that proximal control of the ICA is not necessary if the preoperative diagnosis of a cavernous sinus cavernoma is confirmed on radiological studies.

The blood supply usually comes from branches of the intracavernous ICA or the external carotid artery via the middle meningeal or accessory meningeal arteries.19,25,44 Linskey and Sekhar25 advocated that initial dissection should be concentrated on the medial aspect of the mass via a superior approach to the cavernous sinus to devascularize the lesion by coagulating its ICA blood supply. To shorten the duration of induced hypotension, we agree that such a surgical procedure should be attempted for the removal of relatively small lesions. In our experience, however, the exposure of the cavernous ICA via a superior or approach at the early operative stage is quite difficult in large lesions until internal decompression is completed from the lateral approach. For the safe resection of large lesions, internal decompression of the mass by piecemeal resection is mandatory, and for this purpose induced hypotension is essential.

Conclusions

Our surgical experience in five patients with cavernous sinus cavernoma indicates that this lesion can be clinically viewed as a cluster of small balloons fluctuating in size depending on systemic arterial pressure. For surgery, we recommend induction of hypotension to decrease the size and vascularity of the lesion, making its piecemeal removal relatively easy. Small cavernous cavernomas can be removed in one piece after coagulating the surface and blood supply via an epidural approach. Large cavernomas should be removed piecemeal with adequate internal decompression via a combined epi- and subdural approach. Because of the impossibility of an absolutely accurate preoperative diagnosis, cavernous sinus cavernoma should always be considered when investigating a suspected lesion in the cavernous sinus, especially in women.

References


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