Consequences of Preoperative Evaluation of Patterns of Drainage of the Cavernous Sinus in Patients Treated Using the Anterior Transpetrosal Approach

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Abstract

Extradural procedures in an anterior transpetrosal approach (ATPA) may interrupt the route of drainage from the superficial middle cerebral veins (SMCVs) and the cavernous sinus (CS) to the pterygoid venous plexus at the temporal skull base. Patterns of drainage of the SMCV and the CS and the results of surgery were examined in 12 patients with petroclival lesions treated using the ATPA between 2000 and 2008. The angiographic patterns of drainage of the SMCV were examined in 22 sides of the 12 patients. The SMCV drained into the sphenoparietal sinus in 12 sides, the sphenobasal veins in 4 sides, and the cortical veins in 6 sides. The patterns of drainage of the CS were examined on 12 sides in which the SMCV drained into the sphenoparietal sinus. The CS drained into the inferior petrosal sinus (IPS) in 7 sides and equally into the pterygoid plexus and IPS in 3 sides. The CS drained mainly into the pterygoid plexus in 2 sides of 2 patients, who both suffered temporal lobe swelling postoperatively. The pattern of venous drainage of the CS must be considered in planning surgical approaches to petroclival lesions. In patients with a well-developed pterygoid plexus, surgical interruption of this drainage route may be a cause of injury of the temporal lobe.

Key words: angiography, anterior transpetrosal approach, cavernous sinus, skull base surgery, superficial middle cerebral vein

Introduction

Dural anatomy is important in areas where it is duplicated. Important and well-defined spaces between leaves of the dura in the petroclival region are the superior petrosal sinus (SPS), the inferior petrosal sinus (IPS), venous channels draining the posterior compartment of the parasellar space to the SPS and IPS, the walls of Meckel's cave, and venous sinuses within the broad expanse of the tentorium laterally and along its free edge. The cavernous sinus (CS) receives blood flow from the superior and inferior ophthalmic veins and the superficial middle cerebral vein (SMCV) via the sphenoparietal sinus, anteriorly. Posteriorly, the CS drains into the IPS and thence into the internal jugular vein. The CS also has an anastomosis with the pterygoid venous plexus by way of the sphenoid emissary veins via the emissary sphenoid foramen in the root of the greater sphenoid wing medial to the foramen ovale. The emissary sphenoid foramen is present in 20% of individuals, and the presence of this foramen, which contains an emissary vein connecting the CS and the pterygoid venous plexus, may hinder lateral extradural approaches to the skull base.

The anterior transpetrosal approach (ATPA) to skull base lesions requires extradural subtemporal procedures, including elevation of the temporal dura from the third division of the trigeminal nerve (V3) at the foramen ovale and anterior displacement of the nerve to adequately expose the petrous apex, which may interrupt the inferior route of drainage from the CS via the sphenoid emissary veins to the pterygoid venous plexus.

The present study assessed patterns of drainage of the SMCV and the CS, and their relationships to the results of surgery in patients with petroclival lesions treated through the ATPA.

Materials and Methods

Twelve patients, 9 women and 3 men aged 21–72 years (mean 52.2 years) with tumor in the petroclival...
Table 1 | Drainage patterns of the superficial middle cerebral vein (SMCV) and the cavernous sinus (CS), and surgical results

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Histology</th>
<th>Drainage pattern on ipsilateral side of the lesion</th>
<th>Drainage pattern on contralateral side of the lesion</th>
<th>Tumor removal</th>
<th>Complication</th>
<th>Outcome (GOS)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>F</td>
<td>neurinoma</td>
<td>cortical</td>
<td>IPS</td>
<td>partial</td>
<td>none</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>M</td>
<td>neurinoma</td>
<td>sphenoparietal</td>
<td>IPS</td>
<td>partial</td>
<td>none</td>
<td>5</td>
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<tr>
<td>3</td>
<td>70</td>
<td>F</td>
<td>neurinoma</td>
<td>sphenoparietal</td>
<td>IPS/pterygoid</td>
<td>sphenobasal</td>
<td>5</td>
<td></td>
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<tr>
<td>4</td>
<td>52</td>
<td>F</td>
<td>pituitary adenoma</td>
<td>sphenoparietal</td>
<td>pterygoid</td>
<td>NA</td>
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<tr>
<td>5</td>
<td>61</td>
<td>F</td>
<td>meningioma</td>
<td>cortical</td>
<td>IPS</td>
<td>total</td>
<td>none</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
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<td>meningioma</td>
<td>sphenoparietal</td>
<td>IPS</td>
<td>total</td>
<td>none</td>
<td>5</td>
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<tr>
<td>7</td>
<td>40</td>
<td>F</td>
<td>epidermoid cyst</td>
<td>sphenoparietal</td>
<td>IPS/pterygoid</td>
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<td>subtotal</td>
<td>III palsy (transient)</td>
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<td>8</td>
<td>72</td>
<td>M</td>
<td>meningioma</td>
<td>sphenoparietal</td>
<td>pterygoid</td>
<td>sphenoparietal</td>
<td>IPS</td>
<td>total</td>
</tr>
<tr>
<td>9</td>
<td>69</td>
<td>F</td>
<td>neurinoma</td>
<td>sphenoparietal</td>
<td>IPS</td>
<td>total</td>
<td>none</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>F</td>
<td>meningioma</td>
<td>sphenoparietal</td>
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<td>5</td>
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<tr>
<td>11</td>
<td>50</td>
<td>F</td>
<td>meningioma</td>
<td>cortical</td>
<td>IPS</td>
<td>partial</td>
<td>III palsy (permanent)</td>
<td>5</td>
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<tr>
<td>12</td>
<td>71</td>
<td>F</td>
<td>chondrosarcoma</td>
<td>cortical</td>
<td>sphenobasal</td>
<td>subtotal</td>
<td>none</td>
<td>5</td>
</tr>
</tbody>
</table>

CSF: cerebrospinal fluid, GOS: Glasgow Outcome Scale, IPS: inferior petrosal sinus, NA: not available, III: oculomotor nerve.

region underwent craniotomy for surgical resection through the ATPA between 2000 and 2008 (Table 1). Hospital charts, outpatient clinic records, and operative records were retrospectively examined for all patients. The tumors were five meningiomas, four neurinomas, one pituitary adenoma, one epidermoid cyst, and one chondrosarcoma. Patterns of drainage of the SMCV and CS were established by carotid angiography. The drainage of the SMCV was classified according to Hacker’s classification into the sphenoparietal sinus, the sphenobasal veins, the sphenopetrosal vein, or the cortical veins with absence of definite SMCV.

Surgical technique was as follows. The patient is positioned supine with a pad placed under the shoulder. The head is placed laterally and fixed in the head holder. A question mark-shaped or horseshoe-shaped skin incision is made around the ear. The zygomatic arch is removed to increase inferior retraction of the temporal muscle and improve exposure of the temporal base. After frontotemporal or temporal craniotomy is created, the dura of the temporal base is peeled from the skull until the petrous ridge is identified. The middle meningeal artery is coagulated and divided near the foramen spinosum. Then the meningeal dura of the temporal base is lifted from the lateral wall of the CS, and V3 is exposed at the foramen ovale. Control of bleeding from the sphenoid emissary veins with coagulation and hemostatic agents is required around V3. V3 is retracted anteriorly to provide wide exposure of the petrous apex. The bone of Kawase’s triangle is removed by drilling. After removal of the anterior pyramidial bone is completed, dural incisions are made above and below the superior petrosal sinus, which is incised after ligation. Patency of the petrosal vein is preserved, so care must be taken to place the junction of the petrosal vein as far in the posterior part of the sinus as possible. The tentorium is cut until the tentorial notch is opened.

Results

Table 1 summarizes the patterns of drainage of the SMCV and CS. The patterns of drainage of the SMCV were examined on 22 sides (12 ipsilateral to the lesion and 10 contralateral to the lesion) in the 12 patients. The SMCV drained into the sphenoparietal sinus and CS in 12 of the 22 sides. The SMCV drained into the sphenobasal veins in 4 of the 22 sides, all contralateral to the lesion. The SMCV drained into the cortical veins in 6 of the 22 sides, 5 of 6 ipsilateral to the lesion. The patterns of drainage of the CS were examined on 12 sides in which the SMCV drained into the CS via the sphenoparietal sinus. The CS drained into the IPS in 7 of the 12 sides (Fig. 1A). The CS drained equally into the pterygoid plexus and IPS in 3 sides (Fig. 1B). The CS drained mainly into the pterygoid plexus via the sphenoid emissary veins, and the IPS was poorly formed in 2 sides in Cases 4 and 8 (Fig. 2A).

Rates of tumor removal and postoperative results are listed in Table 1. Surgical mortality was zero. Postoperatively, oculomotor nerve paresis was
Fig. 1 Case 2 with right facial neurinoma. Right (A) and left (B) carotid angiograms in the venous phase showing the superficial middle cerebral vein draining into the cavernous sinus (CS) via the sphenoparietal sinus and the CS draining into the inferior petrosal sinus (IPS) on the right, and the CS draining equally into the pterygoid plexus (arrow) and the IPS on the left.

Fig. 2 Case 8 with right petroclival meningioma. A: Right carotid angiogram in the venous phase showing the cavernous sinus draining into the pterygoid plexus (arrow), with the poorly formed inferior petrosal sinus as a plexus of veins (asterisk). B: Preoperative T1-weighted magnetic resonance (MR) image with contrast medium. C: T2-weighted MR image 4 days after surgery showing edema of the right temporal lobe. D: Fluid-attenuated inversion recovery MR image 3 months after surgery.

Drainage Pattern of the CS and the Transpetrosal Approach

Discussion

The ATPA is best suited for upper petroclival lesions located anteriorly and superiorly to the internal auditory canal and superiorly to the inferior petrosal sinus. Various modifications of the ATPA to improve exposure of the petroclival region have been described, including additional zygomatic osteotomy, anterior mobilization of V3, and extensive middle fossa drilling.

To achieve improved exposure of the petroclival region through the middle fossa corridor, and to gain a wider operative corridor, the petrous apex must be totally resected. Elevation of the temporal dura from the V3 and Gasser ganglion, and anterior displacement of the nerve allow adequate extradural exposure and removal of the petrous apex. The procedure required for elevation of the temporal dura from V3 may injure the sphenoid emissary veins at the emissary sphenoidal foramen near the foramen ovale draining into the pterygoid venous plexus. This extradural procedure may interrupt the routes of drainage from the SMCV via the sphenobasal veins and the CS via the sphenoid emissary veins into the pterygoid venous plexus, and cause postoperative temporal lobe swelling in patients with the main route of drainage from the SMCV and CS via the pterygoid venous plexus.

Variations in the patterns of drainage of the SMCV are common. The four major variations are as follows: the vein may enter the sphenoparietal sinus to drain directly into the CS; the venous drainage may run parallel to the lesser wing of the sphenoid and divide into smaller branches that pass through the skull base to the pterygoid venous plexus, referred to as a sphenobasal vein; the vein may pass back along the floor of the middle cranial fossa to drain into the transverse sinus as a sphenopetrosal vein; and a well-formed vein may be absent. The most frequent pattern found in recent studies is drainage into the sphenoparietal sinus or directly into the CS in 61–69% of cases. The SMCV drains into the pterygoid venous plexus as present in 2 patients (one transient and one permanent). Leakage of cerebrospinal fluid was observed in one patient, requiring surgical repair. Postoperatively, edema of the temporal lobe was observed in two patients with well-developed pterygoid venous plexus as the main route of drainage from the CS (Cases 4 and 8, Fig. 2B–D). Case 8 exhibited headache, vomiting, and disturbance of consciousness 4 days after surgery, but subsequently recovered fully and returned to normal activities of living about 3 weeks after surgery.
sphenobasal veins, which pass through the bone of the middle cranial fossa, in 11–12% of cases. In the present study, the sphenobasal veins were the main route of drainage of the SMCV in 18% of cases. Since this pattern of drainage was observed contralateral to the lesion and surgical obliteration of the sphenobasal veins was not actually performed in our cases, we cannot draw conclusions regarding postoperative changes in the pattern of drainage of the SMCV and complications of surgical interruption of this venous drainage from the SMCV at the temporal skull base.

In the present study, the sphenoparietal sinus was the main route of drainage of the SMCV to the CS in 55% of sides examined. The CS usually drains into the IPS and the into the internal jugular vein. The IPS is poorly formed and exists as a plexus of veins in 7% of cases, and the main routes of drainage from the CS to the pterygoid venous plexus may pass via the foramen ovale and the emissary sphenoid foramen. Two of our patients with well-developed pterygoid venous plexus as the main route of drainage from the CS developed edema of the temporal lobe postoperatively. Surgical interruption of the main route of drainage from the CS by epidural procedures in the ATPA may result in venous congestion and edema of the temporal lobe, in addition to retraction damage to the temporal lobe.

The relationships of the venous drainage system on the inferior and lateral temporal lobes, the sigmoid-superior petrosal sinus, and the venous lakes encountered on the tentorium are also related to lateral cranial base approaches. Preservation of the vein of Labbe, the major lateral surface vein draining the temporal lobe, is essential for avoiding venous infarction. Sectioning of the tentorium may result in sacrificing the dependent venous drainage from the posterior-inferior temporal lobe and may be partly responsible for venous infarction. We should also consider that petroclival lesions invading the CS, superior and posterior petrosal sinuses, and cortical veins might be predominant routes of drainage from the temporal lobe.

Limitations of the present study include the small number of patients treated by the ATPA, and angiographical evaluation of patterns of drainage of the CS, which cannot provide accurate findings of communication of paired CSs and other collateral routes of drainage. The CSs are connected across the midline within the sella by the anterior and posterior intercavernous sinuses, which show variations in size and location. We were unable to precisely determine postoperative changes in the patterns of drainage of the CS after surgical interruption of the inferior venous drainage from the CS into the pterygoid venous plexus at the temporal skull base.

The present findings suggest that the patterns of venous drainage of the CS must be considered in planning less invasive surgical approaches to petroclival lesions. If the pterygoid venous plexus forms the main route of drainage of the CS and the IPS is poorly formed, surgical interruption of the inferior venous drainage from the CS into the pterygoid venous plexus by epidural procedures in the ATPA may be an additional cause of the injury of the temporal lobe. Surgeons should consider other surgical approaches, such as the posterior transpetrosal approach or lateral suboccipital approach, or to remove the petrous apex by drilling without epidural procedures around the foramen ovale.

References


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Drainage Pattern of the CS and the Transpetrosal Approach


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Commentary

This article is overall cautionary, rather than directive. The authors have tried to decipher the not-easily identifiable venous drainage of the cavernous sinus. In general, all vascular structures, venous or arterial, have functions and need to be preserved during surgery. Anterior transpetrosal approach is a standard surgical avenue and any technical guide is most welcome. The function of ‘sponge-like’ or ‘caverns’ of venous spaces in the cavernous sinus and in the adjoining region are ill-understood. Cavernous sinuses primarily drain the orbital tissues. Their relative capaciousness, ability to stretch, and the interconnectedness are essential elements on which the fluid-filled chambers of the eyeball thrive.1–3) Despite the importance of veins and the need for preserving them, the premise that disrupting the venous drainage in the extradural compartment can cause temporal lobe edema appears to be far-fetched.

References

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