Occlusion of the sigmoid sinus after surgery via the presigmoidal–transpetrosal approach

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Object. In this paper the authors report on sigmoid sinus occlusion as a surgical complication in seven of 143 operations in which a presigmoidal–transpetrosal approach was used.

Methods. Five patients (Cases 1–5) developed occlusion within 40 days after surgery, and in the remaining two (Cases 6 and 7) occlusion was detected 5.4 and 6.4 years postsurgery by means of cerebral venography, which was performed in 40 of the remaining 138 patients. Of the two patients with occlusion of the hypoplastic transverse sinus, one (Case 1) did not develop symptoms and the other (Case 2) developed brain edema with transient aphasia. Of the three patients suffering from occlusion of the dominant sigmoid sinus, one (Case 3) developed severe intracerebral hemorrhages and had a poor prognosis; one (Case 4) developed profuse supra- and infratentorial brain edema with consciousness disturbance; and the other (Case 5) developed hemorrhagic infarction in the temporal lobe accompanied by aphasia. Two patients whose sinus occlusion was detected later (Cases 6 and 7) did not develop symptoms and displayed well-communicated transverse sinuses. In Case 7, a dural arteriovenous malformation formed at the site of the sinus occlusion. Laceration of the sigmoid sinus was suspected as the cause of occlusion in Cases 2, 3, and 7; compression of the sinus in Cases 5 and 6, sinus laceration and postoperative dehydration in Case 4; and laceration and compression of the sinus in Case 1.

Conclusions. Differences in the clinical course among these patients were attributed to anatomical variations in the venous system. Occlusion of the sigmoid sinus should be weighed as a potential complication when selecting candidates for the presigmoidal–transpetrosal approach.

KEY WORDS • occlusion • operative complication • presigmoidal–transpetrosal approach • sigmoid sinus • transverse sinus • venography

In the presigmoidal–transpetrosal approach, the exposed sigmoid sinus is retracted backward to widen the presigmoidal space or is transected after confirmation that the contralateral transverse sinus provides sufficient collateral circulation. By preserving the sigmoid sinus without transecting it, the complication of venous circulation failure due to postoperative occlusion of the sigmoid sinus can likely be avoided.

Intra- or postoperative occlusion of the sigmoid sinus can occur for various reasons, such as mechanical damage or heat injury caused by air drilling during exposure of the sigmoid sinus, subsequent compression with the spatula, or drying caused by exposure to air. Samii and Tatagiba reported on a case of sigmoid sinus occlusion accompanied by brain edema that resulted in convulsion 5 days after the patient underwent surgery via the presigmoidal–transpetrosal approach. Sasaki, et al., reported another case accompanied by the formation of a dural arteriovenous malformation (AVM). In venous sinus occlusion, clinical manifestations depend on the cause, subsequent formation of thrombus, potential extension to the cortical vein, and individual differences in venous collateral circulation. However, it remains unclear how the presigmoidal–transpetrosal approach affects the sigmoid sinus and why the preserved sigmoid sinus sometimes becomes occluded.

In the present report, we analyzed patients in whom postoperative occlusion of the sigmoid sinus was demonstrated as a surgical complication of the presigmoidal–transpetrosal approach. The causes of occlusion, clinical presentation, and perioperative control are discussed for the purpose of improving surgical treatment of skull base lesions.

Clinical Material and Methods

Patient Selection

We used the presigmoidal–transpetrosal approach (retroauricular–transpetrosal approach) in 174 patients who underwent surgery between 1975 and 1997. Ninety-seven patients were treated using the presigmoidal–transpetrosal approach alone, and the remaining 77 were treated with a combination anterior (preauricular)/presigmoidal–transpetrosal approach.

The following criteria were used to diagnose sigmoid sinus occlusion as a surgical complication of the presigmoidal–transpetrosal approach: 1) patency of the sigmoid sinus and why the preserved sigmoid sinus sometimes becomes occluded.
sinus preoperatively confirmed by venographic studies; 2) no tumor development pre- and postoperatively in the transverse–sigmoid sinuses or jugular bulb; 3) no intentional sacrifice of transverse–sigmoid sinus during operation; and 4) occlusion of sigmoid sinus postoperatively confirmed on venographic studies or by direct observation during subsequent surgery. Of the 174 patients, 143 satisfied the first three conditions and were expected to have no postoperative complications in the sigmoid sinuses.

Within 40 days of surgery, sigmoid sinus occlusion was confirmed in five of these 143 patients, satisfying the fourth condition. Forty of the remaining 138 patients underwent cerebral venography post-surgery; seven of them underwent venography for preoperative examination of tumor recurrence or other intracranial diseases, and the remaining 33 patients had given informed consent to undergo venography sometime between 1994 and 1997 (Table 1).

The group of 45 patients consisted of 26 females and 19 males ranging in age from 6 to 65 years, with an average age of 37 years. On pathological examination it was found that 17 patients had a craniopharyngioma, 11 had a meningioma, seven had a vestibular schwannoma, two had a chordoma, and one each had a hamartoma, a hemangioblastoma, a pituitary adenoma, a choroid plexus papilloma, and a teratoma. The presigmoidal–transpetrosal approach was used in 15 cases, and a combined anterior/presigmoidal–transpetrosal approach was used in 30 cases.

Pre- and Postoperative Venography

At our institution, conventional angiography is performed using subtraction angiography with stereoscopic imaging and magnetic resonance (MR) venography with stereoscopic imaging. The bilateral carotid arteries and unilateral vertebral artery are usually examined if conventional angiography or digital subtraction angiography is used alone or in combination.

Postoperative venographic studies were performed in 44 of the 45 cases. In the remaining case, sigmoid sinus occlusion on the side of the operation was detected by direct observation during a reoperation 4 hours after the initial surgery. The period between surgery and evaluation of the sigmoid sinus ranged from 4 hours to 14.3 years and averaged 5.3 years.

**Table 1**

<table>
<thead>
<tr>
<th>Feature</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>total no. of cases</td>
<td>174</td>
</tr>
<tr>
<td>excluded from present study*</td>
<td>31 of 174</td>
</tr>
<tr>
<td>cases in which sigmoid sinus was expected to be patent postop</td>
<td>143 of 174</td>
</tr>
<tr>
<td>cases w/ sigmoid sinus occlusion detected in postop early stage</td>
<td>5 of 143</td>
</tr>
<tr>
<td>cases considered for retrospective study</td>
<td>40 of 138</td>
</tr>
</tbody>
</table>

* These cases did not fulfill criteria for sigmoid sinus occlusion as a complication.

Illustration of Anatomical Variations in the Venous System

In cases of postoperative occlusion, the venous system involved in collateral circulation, which consisted of the torcular herophili, bilateral transverse–sigmoid sinuses, occipital sinuses, vein of Labbé, and superficial middle cerebral vein on the affected side, was illustrated based on the results of preoperative stereoscopic venographic studies.

Investigation of the Cause of Sigmoid Sinus Occlusion

The origin of venous sinus occlusion reportedly consists of changes in the endothelial lining, blood flow, and blood constituents. We considered mechanical injury of the sigmoid sinus, method of repairing the injury, compression of the sigmoid sinus by filling materials for reconstruction of the skull base, and postoperative events such as dehiscence, infection, and hematological disease as possible contributing factors.

Surgical records and videotape recording of the surgical procedure were used as references for analysis of the findings in the 45 cases. Oozing hemorrhage caused by injury to the outer layer of the sinus by the air drill or dissector, which was frequently observed during exposure of the sigmoid sinus, was not considered to be a mechanical injury to the sinus.

Surgical Technique

A detailed description of the procedure for performing the presigmoidal–transpetrosal approach has been published previously. This surgical technique has been modified during the past 20 years. The basic procedure is described.

**Sigmoid Sinus Exposure.** Petroectomy was performed after craniotomy in every case. The outer table of the mastoid process was cut using a sagittal saw or chisel (splitting mastoidotomy) and replaced in its original position after the operation. The bone remaining around the sigmoid sinus was shaved using a high-speed air drill with a diamond burr and washed with physiological saline. The sigmoid sinus was exposed to the vicinity of the jugular bulb, leaving a thin layer of surrounding bone on the sinus. Blood oozing from the sigmoid sinus was stopped by covering with either a gelatin sponge (Gelfoam; Pharmacia & Upjohn, Bridgewater, NJ) or collagen sponge (Helisat; Colla Tec, Plainsboro, NJ) soaked in fibrinogen.

**Incision and Handling of the Dura Mater.** A dural incision was made from above the short horizontal segment of the sigmoid sinus, following the sigmoid sinus 5 mm away from the anterior margin and curving along the superior petrosal sinus 5 mm away from the inferior margin up to the lateral margin of the trigeminal nerve root. Another dural incision was made from the middle fossa and curved along the mandibular nerve up to the medial end of the previous incision. The superior petrosal sinus was then transected lateral to the trigeminal nerve, followed by tentoriotomy. The sigmoid sinus was covered with wet cottonoid, and the lesion was approached by pulling the cottonoid backward together with the cerebellar hemisphere by using a self-retaining retractor.

**Wound Closure.** The dura mater was closed and made
Sigmoid sinus occlusion

**Results**

Two cases of sigmoid sinus occlusion were encountered in a retrospective study of 40 patients. In total, five cases of early sinus occlusion and two cases of retrospectively detected occlusion were analyzed (Table 2).

Injury to the sigmoid sinus occurred in seven of the 143 cases (Table 3). Our present survey of 45 cases includes these seven. No serious infections or systemic complications were observed in any of the 45 cases.

**Illustrative Cases**

**Case 1**

This 61-year-old right-handed woman presented with a retrochiasmatic craniopharyngioma that was resected from the left side via the combined anterior/presigmoidal–transpetrosal approach. According to preoperative venographic studies, the left transverse sinus was hypoplastic.

The vein of Labbé and the superficial middle cerebral vein appeared to provide equal drainage from the lateral temporal lobe on the left side (Fig. 1). During surgery, the thin wall of the sigmoid sinus was lacerated.

The patient developed diabetes insipidus postoperatively; but it was well controlled with pitressin. Computerized tomography (CT) scanning performed 1 day postoperatively showed that the fat tissue filling the site of the petrosectomy was excessive, causing compression of the temporal lobe, although no neurological deterioration was observed. The MR venographic studies obtained 8 days postoperatively showed obliteration of the sigmoid sinus.

**TABLE 2**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Tumor Type</th>
<th>Interval to Occlusion</th>
<th>Possible Cause of SS Occlusion</th>
<th>Treatment</th>
<th>Outcome of SS Occlusion</th>
<th>Deficit†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61, F</td>
<td>craniopharyngioma</td>
<td>&lt;8 days sinus injury, comp by fat tissue</td>
<td>hypervolemia</td>
<td>improved</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>57, F</td>
<td>meningioma</td>
<td>4 days sinus injury</td>
<td>hypervolemia &amp; anticoagulation</td>
<td>improved</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>52, F</td>
<td>craniopharyngioma</td>
<td>immediate sinus injury</td>
<td>surgical repair</td>
<td>persistent</td>
<td>vegetative state</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>14, F</td>
<td>suprasellar teratoma</td>
<td>24–40 days sinus injury, dehydration</td>
<td>thrombolysis</td>
<td>persistent w/ chronic parenchymal hemorrhages</td>
<td>undetermined</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>57, F</td>
<td>meningioma</td>
<td>immediate comp by bone chip</td>
<td>surgical removal of bone chip</td>
<td>improved</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>46, M</td>
<td>choroid plexus papilloma</td>
<td>&lt;5.4 yrs</td>
<td>—</td>
<td>persistent</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>58, M</td>
<td>meningioma</td>
<td>&lt;6.4 yrs sinus injury</td>
<td>—</td>
<td>persistent w/ formation of dural AVM</td>
<td>none</td>
<td></td>
</tr>
</tbody>
</table>

* Comp = compression; SS = sigmoid sinus; — = not treated for sinus occlusion.
† Persistent neurological deficit caused by SS occlusion.

**TABLE 3**

<table>
<thead>
<tr>
<th>Tumor Type (case)</th>
<th>Type of Injury</th>
<th>Size of Injury (mm)</th>
<th>Op Assessment of Sigmoid Sinus</th>
<th>Type of Repair</th>
<th>Postop State of Sigmoid Sinus</th>
</tr>
</thead>
<tbody>
<tr>
<td>craniopharyngioma (1)</td>
<td>laceration by air drill</td>
<td>3 × 2; 3 × 2</td>
<td>thin sinus wall</td>
<td>sutured</td>
<td>occluded</td>
</tr>
<tr>
<td>meningioma (2)</td>
<td>laceration by air drill</td>
<td>3 × 3</td>
<td>thin sinus wall</td>
<td>sealed</td>
<td>occluded</td>
</tr>
<tr>
<td>craniopharyngioma (3)</td>
<td>cut by sagittal saw during mastoidotomy</td>
<td>7</td>
<td>protruded sinus, large emissary vein</td>
<td>sealed*</td>
<td>occluded</td>
</tr>
<tr>
<td>teratoma (4)</td>
<td>avulsion of emissary vein by air drill</td>
<td>4 × 3</td>
<td>protruded sinus, large emissary vein</td>
<td>sealed†</td>
<td>occluded</td>
</tr>
<tr>
<td>meningioma (7)</td>
<td>cut by chisel during mastoidotomy</td>
<td>5</td>
<td>protruded sinus</td>
<td>sutured</td>
<td>occluded</td>
</tr>
<tr>
<td>chordoma: 57, F</td>
<td>laceration by air drill</td>
<td>7 × 2</td>
<td>protruded sinus</td>
<td>sutured</td>
<td>patent</td>
</tr>
<tr>
<td>craniopharyngioma: 45, M</td>
<td>cut by retractor</td>
<td>10</td>
<td>no abnormality</td>
<td>sutured</td>
<td>patent</td>
</tr>
</tbody>
</table>

* Injury site was sealed with fibrinogen-soaked collagen sponge.
† Injury site was sealed with fibrinogen-soaked gelatin sponge.
on the side of the operation. The occluded sigmoid sinus was found to be reopened 14 days postoperatively.

Case 2

This 57-year-old right-handed woman presented with a petroclival meningioma on the left side that was resected via the combined anterior/presigmoidal–transpetrosal approach. Preoperative venographic studies showed that the left transverse sinus was hypoplastic but appeared to communicate with the well-developed occipital sinus at the torcular herophili (Figs. 1 and 2 upper). During surgery, the thin wall of the sigmoid sinus was lacerated. Four days postoperatively, the patient developed total aphasia although a CT scan showed no obvious lesion. Anticoagulation and hypervolemic therapy with heparin and albumin were initiated to counteract suspected venous infarction of the vein of Labbé. Although the total aphasia gradually improved, 6 days postoperatively MR venography showed obliteration of the sigmoid sinus on the side of the operation. The left inferior petrosal sinus became much more visible than on the preoperative MR venographic study, suggesting that it served as a collateral circulatory route, receiving the drainage of the lateral temporal lobe via deep middle cerebral veins. A CT scan performed on the same day revealed a low-density area in the left temporal lobe (Fig. 2 lower). Seven days postoperatively, a massive subcutaneous hematoma developed at the wound site and was removed by reincision. Fourteen days postoperatively, the sigmoid sinus was found to be reopened. Heparin therapy was terminated 18 days postoperatively, and warfarin therapy was continued for 1 year.

Case 3

This 52-year-old right-handed woman was surgically treated for recurrent retrochiasmatic craniopharyngioma via the combined anterior/presigmoidal–transpetrosal approach from the right side. According to the results of preoperative venography, the right transverse sinus was exclusively responsible for drainage from the superior sagittal sinus (SSS) and straight sinus (Figs. 1 and 3 upper). During splitting mastoidotomy, the large mastoid emissary vein and the protruding sigmoid sinus were injured. The brain appeared to be slightly swollen during the operation. The patient awoke from anesthesia immediately after surgery, but 4 hours postoperatively, her consciousness level deteriorated and she developed left-sided hemiplegia. An emergency CT scan revealed a large hemorrhage in the temporal lobe on the side of the operation (Fig. 3 lower). Removal of the intracerebral hematoma and external decompression were performed immediately. During this second operation, the sigmoid sinus on the side of the operation was observed to be occluded beneath the collagen sponge, and the laceration was repaired using a patch graft collected from the external jugular vein. After 1 week, a large intracerebral hematoma suddenly developed in the contralateral frontoparietal region. Despite surgical treatment, the patient became vegetative.

Case 4

This 14-year-old right-handed girl presented with a suprasellar malignant teratoma that had been treated previously with chemotherapy and radiotherapy. The tumor was excised from the right side by using the combined anterior/presigmoidal–transpetrosal approach. Preoperative venographic studies indicated that the right transverse sinus was exclusively responsible for drainage from the straight sinus and communication between the transverse sinuses appeared to be poor. The vein of Labbé and superficial middle cerebral vein appeared to provide equal drainage from the lateral temporal lobe on the right side (Fig. 1). During the operation, the protruding sigmoid sinus was lacerated. Postoperatively, hypervolemic therapy for ischemia of the thalamo-perforating arteries and persistent diabetes insipidus made control of the patient’s water balance difficult, resulting in congestive cardiac failure. Because dehydration was induced 24 days postsurgery, the patient’s consciousness fluctuated between drowsiness and coma. Forty days postoperatively, a CT scan revealed low-density areas in the cerebellum and bilateral cerebral hemispheres, and MR venographic studies demonstrated obliteration of the transverse and sigmoid sinuses on the side of the operation. A 7-day course of mannitol and
urokinase caused the brain edema to disappear gradually. However, occlusion of the transverse–sigmoid sinus persisted. By 3 months postsurgery, the patient was able to perform simple calculations. Three years later, chronic hemorrhaging was detected in the cerebellar vermis and left temporal lobe.

Case 5

This 57-year-old right-handed woman had a petroclival meningioma that was excised from the left side via the combined anterior/presigmoidal–transpetrosal approach. On preoperative venographic studies, the left transverse sinus appeared to be dominant in providing drainage from the SSS. However, some channels communicated between the SSS–left transverse sinus system and the right transverse sinus. The vein of Labbé and the superficial middle cerebral veins (arrowheads) are well developed with very little flow in the superficial middle cerebral vein. Lower Left: Magnetic resonance venographic study, anteroposterior view, obtained 6 days postoperatively showing obliteration of left sigmoid sinus. Note that the left vein of Labbé (large arrowhead) drains through the ipsilateral transverse sinus (open arrow) into the occipital sinus. The inferior petrosal sinus (small arrowheads) is much more visible than in the preoperative MR venographic studies (upper). Lower Right: Axial CT scan obtained 6 days postoperatively revealing a low-density area in the temporal lobe.

A CT scan revealed that the left sigmoid sinus protruded outward in cross-section (Fig. 4 upper).

A CT scan, obtained immediately after surgery, demonstrated severe contusional hemorrhaging in the left temporal lobe and medial displacement of a bone fragment placed in the bone gap. Three-dimensional CT venographic studies clearly showed that the bone fragment was compressing and occluding the junction of the transverse and sigmoid sinuses and the entrance of the vein of Labbé (Fig. 4 lower). A second operation was performed immediately to remove the bone chip, and reopening of the occlusion site was observed directly. Although the patient developed aphasia, it disappeared completely within 2 months. According to MR venographic studies obtained 1 month postoperatively, the transverse–sigmoid sinus and the entrance of the vein of Labbé were clear of occlusion.

Case 6

In this 46-year-old right-handed man, a choroid plexus papilloma in the left cerebellopontine angle was resected using the presigmoidal–transpetrosal approach. On preoperative venographic studies, the left transverse sinus appeared to be less dominant than the right for drainage from the SSS. However, these sinuses communicated well at the torcular herophili. The vein of Labbé provided the main drainage from the lateral temporal lobe on the left side (Fig. 1).

Postoperatively, no neurological abnormalities that would indicate sinus occlusion developed. Reoperation was performed for recurrent tumor at the cerebellopontine angle 5.4 years after the first operation. Occlusion of the left sigmoid sinus distal to the entrance of the vein of
revealed occlusion of the transverse–sigmoid sinus ac-
years after the first operation. Preoperative examination
Surgery for the pituitary adenoma was performed 6.4
well controlled by pitressin and resolved after 6 months.
Lacerated sigmoid sinus was drained.
angiogram, anteroposterior view, showing that both the SSS and
straight sinus drain primarily to the right transverse sinus. Note that
the left transverse sinus is faintly visualized with very little
drainage. Upper Right: Preoperative right internal carotid an-
angiogram, lateral view, showing that development of the vein of
Labbé is better than that of the superficial middle cerebral vein (arrowheads). Lower Left: A CT scan obtained immediately
after surgery, showing small contusional hemorrhage in the right
temporal lobe. Another hemorrhage is observed in the suprasellar
region. Lower Right: Axial CT scan obtained 4 hours postopera-
tively, demonstrating a large hemorrhage in the temporal lobe.

The right-sided meningioma was resected first via the
preoperative veno-
graphic studies showed that the bilateral transverse sinu-
es communicated well at the torcular herophili (Figs. 1
and 5 upper). During splitting mastoidotomy, the protrud-
ing sigmoid sinus was lacerated.

Postoperatively, diabetes insipidus developed but was
well controlled by pitressin and resolved after 6 months.
Surgery for the pituitary adenoma was performed 6.4
years after the first operation. Preoperative examination
revealed occlusion of the transverse–sigmoid sinus ac-
panied by the formation of a dural AVM (Fig. 5 lower). The dural AVM was not treated, but its course was
monitored.

Fig. 3. Case 3. Upper Left: Preoperative right internal carotid angiogram, anteroposterior view, showing that both the SSS and
straight sinus drain primarily to the right transverse sinus. Note that
the left transverse sinus is faintly visualized with very little
drainage. Upper Right: Preoperative right internal carotid an-
angiogram, lateral view, showing that development of the vein of
Labbé is better than that of the superficial middle cerebral vein (arrowheads). Lower Left: A CT scan obtained immediately
after surgery, showing small contusional hemorrhage in the right
temporal lobe. Another hemorrhage is observed in the suprasellar
region. Lower Right: Axial CT scan obtained 4 hours postopera-
tively, demonstrating a large hemorrhage in the temporal lobe.

Case 7

This 58-year-old right-handed man presented with two
tumors, a meningioma at the posterior clinoid process and a
nonfunctioning pituitary adenoma in the sella turcica.
The right-sided meningioma was resected first via the
presigmoidal–transpetrosal approach. Preoperative veno-
graphic studies showed that the bilateral transverse sinu-
es communicated well at the torcular herophili (Figs. 1
and 5 upper). During splitting mastoidotomy, the protrud-
ing sigmoid sinus was lacerated.

Postoperatively, diabetes insipidus developed but was
well controlled by pitressin and resolved after 6 months.
Surgery for the pituitary adenoma was performed 6.4
years after the first operation. Preoperative examination
revealed occlusion of the transverse–sigmoid sinus ac-
panied by the formation of a dural AVM (Fig. 5 lower). The dural AVM was not treated, but its course was
monitored.

Discussion

Severity of Symptoms Caused by Sigmoid Sinus Occlusion

Differences in symptoms caused by postoperative occlusion of the sigmoid sinus can be attributed primarily
to anatomical variations in the intracranial venous system
that comprises the collateral circulation. The venous sys-
tem involved in collateral circulation includes the torcu-
lar herophili, bilateral transverse–sigmoid sinus, vein of
Labbé, and superficial middle cerebral vein on the affect-
ed side. Of particular importance are the structure of the
torcular herophili and development of the bilateral trans-
verse sinuses. The size of the occluded sinus itself has no
direct relationship to the severity of symptoms.

Ishizaka10 classified the torcular herophili into three
types and reported that the freely communicating type
between the SSS and bilateral transverse sinuses comprised
63.5% of cases, the partially communicating type
with a small channel between the bilateral transverse si-
nuses comprised 13.5%, and the noncommunicating type
with no channel between the bilateral transverse sinuses
comprised 23%. In our series, two patients (Cases 6 and 7)
had freely communicating torcular herophili and did not
develop symptoms associated with occlusion of the well-
developed sigmoid sinus. In three patients (Cases 3–5)
with partially communicating torcular herophili, occlu-
sion of the dominant sigmoid sinus produced severe
complications. The presigmoidal–transpetrosal approach
should be used with caution if the lesion is located on the
same side as the dominant transverse–sigmoid sinus with
partially or noncommunicating torcular herophili. In the
case of a freely communicating torcular herophili, the
symptoms caused by occlusion of the sigmoid sinus might
be subclinical.

Regarding the size of the transverse sinus, right domi-
nance has been observed in 45 to 63.2% of patients, left
dominance in 13.6 to 29%, and symmetry in 19.2 to
41%.2,25,35 Bigelow, et al.,7 reported that an atretic or hy-
oplastic transverse sinus was observed on the left side in
14.3% of cases and on the right side in 2.3%. In the case
of an atretic or hypoplastic transverse sinus, ipsilateral
occlusion of the sigmoid sinus causes congestion of the
vein of Labbé, and contralateral occlusion causes circula-
tion failure in both cerebral hemispheres. In our series,
occlusion of the sigmoid sinus on the side of the hypoplas-
tic transverse sinus occurred in two patients (Cases 1 and
2), of whom one developed aphasia and the other had
no symptoms. This difference in symptoms depends on
the relationship between the development of the vein of
Labbé and degree of hypoplasia of the transverse sinus on
the side of the lesion.

The occipital sinus is large in 25% of newborns, but
shrinks with age and can generally be disregarded as sur-
gical anatomy.4,19 However, the occipital sinus acted as an
important collateral circulation route in Case 2. Therefore,
this structure should be considered at the time of evalua-
tion of the torcular herophili.

The symptoms caused by the postoperative occlusion of
the sigmoid sinus have also been associated with other
surgical complications, such as parenchymal damage to the temporal lobe caused by retraction, and injury to the venous system in the skull base that has the potential to provide collateral circulation when the sigmoid sinus is occluded.\textsuperscript{38,39} In the presigmoidal–transpetrosal approach, the superior petrosal sinus is occasionally sacrificed. Furthermore, other skull base sinuses, such as the spheno-basal or sphenopetrosal sinus, are at risk for injury during dural dissection or incision. Therefore, the symptoms caused by postoperative occlusion of the sigmoid sinus may be more severe than expected for simple occlusion of the sinus.

**Sigmoid Sinus Injury**

In this study we found that sigmoid sinus occlusion tended to be caused by injury to the sigmoid sinus, which occurred in seven (5\%) of our 143 cases. However, this number depends on the definition of injury. In practice, it is difficult to avoid causing small injuries to the sinus when using the presigmoidal–transpetrosal approach. Mechanical injury with the air drill and retractor or heat injury with the air drill can damage the outer and inner walls of the sigmoid sinus. Therefore, almost all patients who undergo operation via the presigmoidal–transpetrosal approach can be considered prone to thrombus caused by the preparatory conditions. In addition, the denuded sigmoid sinus is easily compressed postoperatively because it has lost its surrounding bone support to maintain its original shape.

The possibility of injury to the sigmoid sinus during mastoidectomy increases when this structure is protrusive or cross-sectionally large, when the wall is thin, and when the mastoid emissary vein is well developed. Preoperative observations of the shape of the sigmoid groove, the distance from the outer table of the mastoid process, and the size and course of the mastoid canal should be completed with the aid of bone algorithm CT scanning. Exposure of the sigmoid sinus should be performed carefully, based on the CT findings.

Ichijo, et al.,\textsuperscript{18} classified sigmoid sinuses into three types based on their cross-sectional shape as seen on CT scans: protrusive, half-moon, and saucer. They reported that the protrusive type, in which the sigmoid sinus protrudes outward, is observed on the right side 80\% of the
time and on the left side 20% of the time. Our results indicate that the protrusive sinus is at risk for postoperative occlusion because it is susceptible not only to injury during exposure, but also to compression from filling materials postoperatively.

The safest technique for management of the large mastoid emissary vein is to expose it at its origin on the sigmoid sinus by drilling out the surrounding bone, and then to perform ligation or coagulation.15,16 If the emissary vein ruptures at its origin, control is very difficult because the sigmoid sinus is also injured.15 In recent studies investigators have applied osteoplastic mastoidotomy to reduce the time of surgery and achieve better reconstruction.8,24,32 However, the risk of sigmoid sinus injury when performing osteoplastic mastoidotomy is undoubtedly higher than when performing mastoidectomy. Safe exposure of the origin of the mastoid emissary vein and sigmoid sinus can be ensured only prior to cosmetic mastoidotomy.

The conventional technique for the repair of sinus injury is suturing.9,21 However, suturing is not easy when the sinus wall is thin or contusion of the wall is present around the laceration. We managed three cases of sinus injury by covering the site with a collagen or gelatin sponge soaked in fibrinogen solution. However, postoperative occlusion of the sigmoid sinus was observed in all three of these patients. Because the materials we used have a strong hemostatic effect, thrombi can form inside the wall of the sinus.7 When the injury site of the sigmoid sinus cannot be sutured directly, angioplasty should be performed using a vein graft.

**Treatment of Postoperative Occlusion of the Sigmoid Sinus**

Of the seven patients described, the sigmoid sinus in four of them was occluded during the acute stage, within 8 days of surgery. In two cases of retrospectively detected

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**Fig. 5. Case 7.** Upper Left: Preoperative right internal carotid angiogram, anteroposterior view, showing that the bilateral transverse sinuses are of approximately equal size and communicate well with each other and with the SSS at the torcular herophili. Upper Right: Preoperative right internal carotid angiogram, lateral view, showing a well-developed superficial middle cerebral vein in contrast to the hypoplastic vein of Labbé. Lower: Studies obtained in Case 7 at 6 years postsurgery. Lower Left: A digital subtraction angiogram obtained in late venous phase after right internal carotid injection, anteroposterior view, showing obliteration of the right transverse–sigmoid sinus. Lower Right: A digital subtraction angiogram obtained in arterial phase after right external carotid injection, anteroposterior view, demonstrating formation of a dural AVM in the region of the occluded transverse–sigmoid sinus.
Sigmoid sinus occlusion

Sinus occlusion, the sigmoid sinus appeared to have been occluded during the acute stage as a result of compression by bone fragments in Case 6 and sinus injury in Case 7, because no other causes for sinus occlusion could be detected after the acute stage. Thus, the acute postoperative stage appears to be associated with the highest risk for sigmoid sinus occlusion. Care and treatment for postoperative sigmoid sinus occlusion should be administered in the acute postoperative stage.

Treatment of sigmoid sinus occlusion differs depending on the cause. If the cause of occlusion is ineffective repair of an injured sigmoid sinus or its compression, prompt surgical intervention is indicated. The occlusion in Case 5 was treated successfully by immediate removal of the bone fragment compressing the sinus. Sinoojugal bypass might have been effective in Cases 3 and 4.46

Anticoagulation and fibrinolytic therapies have been administered for thrombosis of the venous sinus. These treatments are controversial because of the risk of hemorrhage in the brain.5,14,27,33 In the acute stage after skull base surgery, heparin therapy may be of questionable value considering the invasive manipulation that occurs during surgery. Anticoagulation therapy should be considered as a preventive or therapeutic measure for sigmoid sinus occlusion after the transpetrosal approach is performed in patients with obvious injury to the sigmoid sinus, those who tend toward dehydration postoperatively, those who have little brain contusion, or in those whom brain contusion has improved. In particular, this treatment should be considered when surgery is performed from the side of a dominant sigmoid sinus that has poor collateral circulation.

Changes in blood constituents may occur at any time during the postoperative course and can influence thrombus formation even after the acute stage, as in Case 4. Thus, the patient’s water balance should be controlled carefully not only in the acute stage, but also in the chronic stage postoperatively, especially in patients with apparent sinus injury.

Conclusions

Sigmoid sinus occlusion in seven of 143 patients treated via the presigmoidal–transpetrosal approach was caused by damage to the endothelium as a result of injury to the sinus, disturbance or obstruction of blood flow by compression, or postoperative dehydration. The severity of symptoms varied according to the anatomical structure of the torcular herophili and development of the bilateral transverse sinuses. Early detection and treatment of this condition is essential. Some cases of postoperative sigmoid sinus occlusion may be overlooked because of a lack of symptoms or falsely diagnosed as a brain contusion or contusional hemorrhage in the temporal lobe. Based on the present results, when selecting the appropriate approach to treat lesions in the skull base, the risk of sigmoid sinus occlusion in the presigmoidal–transpetrosal approach should be considered.

References


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