Superior Petrosal Sinus: Hemodynamic Features in Normal and Cavernous Sinus Dural Arteriovenous Fistulas

BACKGROUND AND PURPOSE: Normal hemodynamic features of the superior petrosal sinus and their relationships to the SPS drainage from cavernous sinus dural arteriovenous fistulas are not well known. We investigated normal hemodynamic features of the SPS on cerebral angiography as well as the frequency and types of the SPS drainage from CSDAVFs.

MATERIALS AND METHODS: We evaluated 119 patients who underwent cerebral angiography by focusing on visualization and hemodynamic status of the SPS. We also reviewed selective angiography in 25 consecutive patients with CSDAVFs; we were especially interested in the presence of drainage routes through the SPS from CSDAVFs.

RESULTS: In 119 patients (238 sides), the SPS was segmentally (anterior segment, 37 sides; posterior segment, 82 sides) or totally (116 sides) demonstrated. It was demonstrated on carotid angiography in 11 sides (4.6%), receiving blood from the basal vein of Rosenthal or sphenopetrosal sinus, and on vertebral angiography in 235 sides (98.7%), receiving blood from the petrosal vein. No SPSs were demonstrated with venous drainage from the cavernous sinus. SPS drainage was found in 7 of 25 patients (28%) with CSDAVFs. CSDAVFs drained through the anterior segment of SPS into the petrosal vein without draining to the posterior segment in 3 of 7 patients (12%).

CONCLUSIONS: The SPS normally works as the drainage route receiving blood from the anterior cerebellar and brainstem venous systems. The variation of hemodynamic features would be related to the relatively lower frequency and 2 different types of SPS drainage from CSDAVFs.

ABBREVIATIONS: CAG = carotid angiography; CSDAVF = cavernous sinus dural arteriovenous fistula; SPS = superior petrosal sinus; VAG = vertebral angiography
to the cavernous sinus and in 2 sides the posterior segment with venous drainage from the petrosal vein to the transverse sinus (Fig 2A–D). In 2 sides, the superficial middle cerebral vein was found to terminate into the anterior segment of sphenopetrosal sinus (Fig 2E, -F). In the remaining side, the whole SPS was demonstrated with the blood flow from the transverse sinus into the cavernous sinus via the SPS (Fig 3). On VAG, the SPS was demonstrated to receive blood from the petrosal vein in 235 sides (98.7%). Among these, the whole SPS was demonstrated in 116 sides (48.7%) and partially demonstrated in 119 sides (50%); of the 119 partial demonstrations, it appeared at the posterior segment in 82 sides (34.5%) and at the anterior segment in 37 sides (15.5%) (Figs 4 and 5). Additional findings included variations of the SPS, and duplication of the SPS and disconnection between the anterior segment (5 sides [2%]) and the posterior segments (6 sides [2.5%]) of the SPS was observed (Fig 6). Venous drainage from the cavernous sinus on both CAG and VAG was not demonstrated.

**Patients with CSDAVFs**

SPS drainage was found in 7 (28%) of 25 patients with CSDAVFs. Table 3 summarizes the hemodynamic status of the SPS in the 7 patients with SPS drainage from the CSDAVFs. Among these 7
patients, the CSDAVFs drained through the whole SPS into the transverse sinus in 3 patients (12%) (Fig 7) and through the anterior segment of the SPS into the tributaries of the petrosal vein without draining into the posterior segment of the SPS in 3 patients (12%) (Fig 8). In the remaining patient, the CSDAVF drained through the anterior segment of SPS into the superficial middle cerebral vein (sphenopetrosal sinus), in which duplication of the SPS was also found (Fig 9). In 18 CSDAVFs without SPS drainage, the SPS was partially observed at the posterior segment alone in 13 patients and at the anterior segment alone in 4 patients. The SPS was not found in 1 patient in whom other cerebellar veins were well developed.

Discussion

Embryologic Development and Hemodynamic Features of SPS
In the development of the cerebral venous system, the pro-
otic sinus participates in forming the cavernous sinus and foramen ovale venous plexus (pterygoid plexus) and re-
Fig 4. Schematic drawing of the hemodynamic types of the SPS based on vertebral angiography. A, Drainage from the petrosal vein (PV) into both the anterior and the posterior segment of the SPS (yellow arrow). B, Drainage from the PV into the posterior segment of the SPS to the transverse sinus (TS) alone (yellow arrow). C, Drainage from the PV into the anterior segment of the SPS to the cavernous sinus (CS) alone (yellow arrow). ACeV indicates anterior cerebral vein; ACV, anterior condylar vein; APMV, anterior pontomesencephalic vein; BV, bridging vein; BVR, basal vein of Rosenthal; DMCV, deep middle cerebral vein; ICV, internal cerebral vein; IPCV, inferior petroclival vein; IPS, inferior petrosal sinus; LMV, lateral mesencephalic vein; OS, occipital sinus; PP, pterygoid plexus; SMCV, superficial middle cerebral vein; SS, sigmoid sinus; StS, straight sinus; TPV, transverse pontine vein; TS, transverse sinus; UV, uncal vein; VG, vein of Galen.

Fig 5. Frontal view of the left vertebral angiography at venous phase. A, The whole SPS was demonstrated bilaterally (white arrows). B, The right SPS was demonstrated on the anterior segment alone (black arrows). The left SPS was demonstrated on the anterior segment alone (arrowheads).

Fig 6. Frontal views of the vertebral angiogram show variations of the SPS. A, The right SPS reveals duplication of the superior segment (arrows) and inferior segment (arrowheads). The inferior segment is connected to the cavernous sinus. B, The right SPS reveals disconnection of the anterior and posterior segments (arrow). Both segments drain individually into the transverse sinus and the cavernous sinus.
receives blood flow from the superior ophthalmic vein. After
developing to the prenatal stage, the tentorial sinus extends
medially and anastomoses with the cavernous sinus and
pericavernous venous plexuses or sinuses. Different expla-
nations have been presented regarding the development of
the SPS. In 1957, Butler demonstrated that the anasto-
motic vein around the trigeminal nerve (peritrigeminal
vein) and the anterior remnant of pro-otic sinus form the
SPS. This explanation, however, does not mention the pial
venous drainage. Padget proposed that the posterior part
of the SPS first develops as a drainage vein of the mesen-
cephalic vein (the petrosal vein). Later, the dorsal remnant
of the primitive tentorial sinus anastomoses between the
cavernous sinus and the SPS at the entrance of the petrosal
vein, which then becomes the anterior segment of the SPS.
This anastomosis is sometimes plexiform or poorly
developed.

According to the explanation of the development of the
SPS by Padget, the SPS develops primarily as a drainage route
from the petrosal vein, receiving blood from the anterior cer-
ebellar and brain stem venous systems. This corresponds well
to our results regarding the hemodynamic feature of the SPS.
In our results, demonstration of the SPS on carotid angiogra-
phy is highly associated with the variation of cerebral venous
drainage, including hypogenesis of the basal vein of Rosenthal
and the sphenopetrosal type of the superficial middle cerebral
vein (persistent primitive tentorial sinus), which also supports
Padget’s explanation. On VAG, approximately 50% of the SPS
demonstrated partially, at either the anterior segment or the
posterior segment, to receive blood from the petrosal vein.
Disconnection of the anterior and posterior segment of the
SPS was also seen in a few patients. These findings would rep-
resent hypoplasia or malformation of the anterior and posterior
segments of the SPS in development. Duplication of the SPS
would be due to the plexiform feature of the remnant of the
primitive tentorial sinus.

Relationship of the Types of SPS with SPS Drainage of
CSDAVFs
In our results, SPS drainage from CSDAVFs was found in 7
patients (28% of all 25 patients with CSDAVF and 37% of 16
patients with inferior petrosal sinus occlusion). Among the 7
patients with SPS drainage, CSDAVFs drained through the
whole SPS from the cavernous sinus in 3 patients. In the other
3 patients, DAVFs drained through the anterior segment of the
SPS into the tributes of the petrosal vein without draining into
the posterior segment of the SPS. Although stenosis of the
dural sinus may develop secondary to high-flow angiopathy
caused by the arteriovenous fistulas, SPS drainage and its
drainage patterns would be associated with variation of anat-
omy of the SPS. When CSDAVFs occur in patients with hyp-
oplasty of the posterior segment of the SPS, the fistulas have a
higher risk of venous reflux into the cerebellopontine veins com-
pared with the case in which the whole SPS is present. Regarding
transvenous embolization, an approach via the SPS is applied in
some patients. These variations of segmental hypoplasia and
plexiform features of the SPS could affect accessibility via the SPS.
Furthermore, multiplication of the SPS may have a risk of resid-
ual SPS drainage after transvenous embolization.

Conclusions
Our study suggests that the SPS normally works as a drainage
route receiving blood from the anterior cerebellar and brain
stem venous systems and does not work as a normal drainage
route from the cavernous sinus. More than half of the SPSs
have segmentally hypoplastic features on angiography. The
variation of the hemodynamic features would be related to the
relatively lower frequency and to the 2 different types of SPS
drainage from CSDAVFs.

Table 3: Patterns of SPS drainage in the cases of CSDAVF (n = 7)

<table>
<thead>
<tr>
<th>Drainage Patterns</th>
<th>Number of Cases</th>
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<tbody>
<tr>
<td>CS→SPS→SS</td>
<td>3</td>
</tr>
<tr>
<td>CS→SPS→PV</td>
<td>3</td>
</tr>
<tr>
<td>CS→SPS→SphS</td>
<td>1</td>
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Note: CS indicates cavernous sinus; PV, petrosal vein; SphS, sphenopetrosal sinus; SPS, superior petrosal sinus; SS, sigmoid sinus.

Fig 2. CSDAVF with SPS drainage. Frontal (A) and lateral (B) views of the left external carotid angiogram show the AVF draining into the left SPS (arrowheads). Additional drainage routes of the superior ophthalmic vein, the inferior petrosal sinus, the intercavernous sinus, and the superficial middle cerebral vein are also noted. C, Microcatheter is inserted into the right cavernous sinus via the left SPS (arrowheads) for the transvenous embolization.
References


Fig 8. CSDAVF with SPS drainage. Frontal (A) and lateral (B) views of the left internal maxillary angiogram show the AVF draining into the SPS (arrow) and the petrosal vein (arrowheads). Other drainage routes of the superior ophthalmic vein, the superficial middle cerebral vein, and the inferior petrosal sinus are also noted. C, Frontal view of the right vertebral angiogram shows no visualization of the right SPS and the obvious venous congestion of the right cerebellar hemisphere. D, Frontal view of the right vertebral angiogram after transvenous embolization shows normal venous drainage of the right SPS on the cavernous sinus side (arrows).

Fig 9. The duplication of the SPS in CSDAVF. Frontal (A) and lateral (B) views of the left internal maxillary angiogram show the CSDAVF draining into the left duplicated SPS (arrowheads). Additional drainage routes of the superior ophthalmic vein, the inferior petrosal sinus, and the superficial middle cerebral vein are also noted. C, Selective venography by the inserted microcatheter into the SPS shows the duplication of the SPS (arrowheads).