

## Original Article

# Absence of the superior petrosal veins and sinus: Surgical considerations

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## Abstract

**Background:** The superior petrosal vein, one of the most constant and largest drainage pathways in the posterior fossa, may result in complications if occluded. This study calls attention to a unique variant in which the superior petrosal veins and sinus were absent unilaterally, and the venous drainage was through the galenic and tentorial drainage groups.

**Methods:** This study examines one venogram and another anatomic specimen in which the superior petrosal vein and sinus were absent.

**Results:** The superior petrosal veins, described as 1–3 bridging veins, emptying into the superior petrosal sinus, are the major drainage pathways of the petrosal group of posterior fossa veins. In the cases presented, the superior petrosal vein and sinus were absent and venous drainage was through the galenic and tentorial groups, including the lateral mesencephalic or bridging vein on the tentorial cerebellar surface.

**Conclusions:** In cases in which the superior petrosal sinus and veins are absent, care should be directed to preserving the collateral drainage through the galenic and tentorial tributaries. Although surgical strategies for intraoperative management and preservation of venous structures are still controversial, knowledge of the possible anatomical variations is considered to be essential to improve surgical outcomes.

**Key Words:** Microsurgical anatomy, posterior fossa, retrosigmoid approach, superior petrosal sinus, superior petrosal vein, venous complications

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## INTRODUCTION

Venous drainage is an important consideration when selecting approaches to the cerebellopontine angle (CPA). Sacrifice of veins that limit operative exposure may result in postoperative venous complications, which are difficult

to predict due to the many anastomoses and variations in the venous system.

The veins that drain the cerebellum and brainstem merge to form three draining groups: Galenic, tentorial, and petrosal.<sup>[1]</sup> The superior petrosal veins, which drain into the

superior petrosal sinus, commonly number 1 to 3 bridging veins and are the major bridging vein of the petrosal group. The superior petrosal veins, known collectively as the “petrosal vein,” or “Dandy’s vein,” are one of the most constant and largest venous complexes in the posterior fossa and are often an obstacle during posterior fossa surgery.<sup>[2]</sup> Complications have followed sacrifice of the superior petrosal veins.<sup>[1,12,18,19,21,22,27,29,30,32,33,36,39,40,42]</sup> Anatomic studies have focused on preventing such complications.<sup>[14,23,35]</sup> This report calls attention to a unique variant in which the superior petrosal veins and sinus are absent, and the petrosal group of veins is drained by tributaries of the galenic and the tentorial groups. This report describes one anatomic specimen and another angiographic image of this variant.

## MATERIALS AND METHODS

One formalin-fixed adult head, in which the left superior petrosal veins and sinus were absent, provided the material for anatomic examination. The specimen was dissected using the operating microscope (Carl Zeiss Corp., Oberkochen, Germany) after injecting the arteries with red and the veins with blue latex. Bone drilling was performed with a Midas Rex drill (Midas Rex Institute, Fort Worth, TX).

An angiographic study of another patient without any cerebral lesion, in whom the superior petrosal veins and sinus were absent, was also analyzed in detail independently by a neurosurgeon and an interventional neuroradiologist. Biplane angiographic equipment (Infinix Celeve-i INFX-8000V; Toshiba Medical Systems, Tokyo, Japan) was used to obtain these digital subtraction carotid and vertebral venographic images. This patient was also included in the data of a previous report by Shimada *et al.*<sup>[31]</sup>

## RESULTS

### Basic anatomy of the superior petrosal veins and sinus

The superior petrosal veins are among the largest and most constant veins in the posterior fossa.<sup>[23,29]</sup> The superior petrosal venous complex is usually formed by 1–3 bridging veins that drain into the superior petrosal sinus. Each superior petrosal vein is usually formed by the convergence of multiple tributaries in the upper part of the CPA. Their most common tributaries are the pontotrigeminal vein and transverse pontine veins, and the veins of the cerebellopontine fissure and the middle cerebellar peduncle.

The superior petrosal veins and sinus are the main drainage route of the petrosal group, one of the three major drainage routes in the posterior fossa. The tributaries of the superior petrosal veins can be subdivided in four subgroups: (i) Petrosal subgroup with tributaries draining the fourth ventricle, lateral medulla,

middle cerebellar peduncle, and petrosal cerebellar surface facing the posterior surface of the temporal bone, such as veins of the cerebellopontine fissure and middle cerebellar peduncle; (ii) posterior mesencephalic subgroup with tributaries draining the walls of the cerebellomesencephalic fissure, located between the posterior surface of the midbrain and the opposing surface of the cerebellum, such as the pontotrigeminal and lateral mesencephalic veins; (iii) anterior pontomesencephalic subgroup with tributaries draining the anterior portion of the midbrain and pons, such as the transverse pontine veins; and (iv) tentorial subgroup with tributaries draining the lateral part of the cerebellar surface facing the tentorium and petrosal cerebellar surface facing the posterior surface of the temporal bone, such as the anterior lateral marginal vein.<sup>[22]</sup>

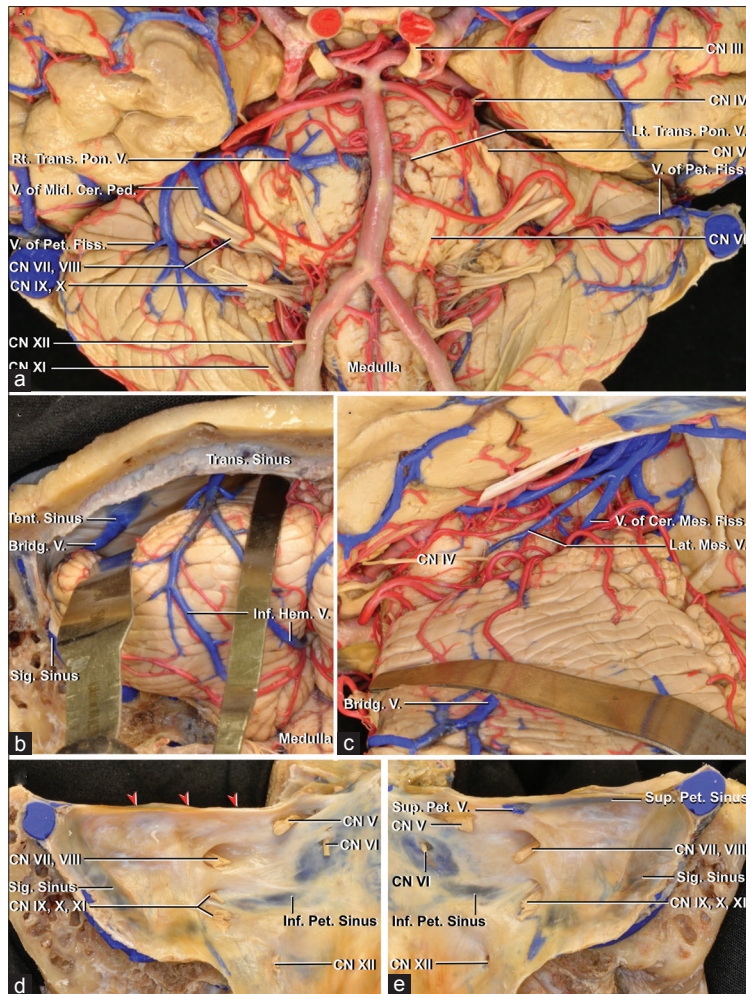
The superior petrosal sinus runs within the attachment of the tentorium cerebelli to the petrous ridge from the posterior end of the cavernous sinus to the transverse–sigmoid junction.<sup>[23,29]</sup> The superior petrosal sinus was divided into medial, lateral, and complete types based on whether the sinus emptied into either the cavernous sinus or transverse–sigmoid junction or both, respectively.<sup>[22]</sup>

### Cadaveric CPA [Figure 1]

The left superior petrosal vein and sinus were absent, and the tributaries that usually form the superior petrosal veins on this side drained into the tentorial sinuses, vein of Galen, and into the contralateral transverse pontine veins. The tributaries draining the petrosal cerebellar surface ran posteriorly and ascended on the anterolateral margin of the cerebellum toward the tentorial cerebellar surface [Figure 1a]. These veins, including the vein of the petrosal fissure and some tributaries on the tentorial cerebellar surface formed bridging veins that drained through a well-developed tentorial sinus into the transverse sinus [Figure 1b]. The pontotrigeminal and lateral mesencephalic veins ascended along the cerebellomesencephalic fissure and drained into the tributaries of the vein of Galen without descending to join with the superior petrosal vein [Figure 1c].

The right CPA had several tributaries that joined above cranial nerves (CNs) VII and VIII to form superior petrosal veins, as is usual. Its tributaries include the transverse pontine vein, the veins of the middle cerebellar peduncle, and the petrosal fissure. A well-developed right transverse pontine vein crossed the midline and drained the left and right anterior pons [Figure 1a].

After removing the cerebellum, neither a superior petrosal sinus or vein was identified in the left posterior fossa, but a right superior petrosal sinus and a single superior petrosal vein were identified [Figure 1d and e]. This superior petrosal sinus emptied into the transverse–sigmoid junction without connection to the cavernous sinus, being classified as the lateral type [Figure 1e].



**Figure 1:** (a) Anterior view of a cadaveric cerebellum with absence of the left superior petrosal veins and sinus. In the right cerebellopontine angle (CPA) the transverse pontine vein, and the veins of the middle cerebellar peduncle and petrosal fissure join to form a superior petrosal vein, above CNs VII and VIII. In the left CPA, the superior petrosal vein and sinus were absent, and their normal tributaries drained into the vein of Galen and the tentorial sinuses. The tributaries draining the petrosal cerebellar surface run posteriorly and ascend beyond the anterolateral margin of the cerebellum toward the tentorial cerebellar surface. The right transverse pontine vein coursed across the midline and drained the left and right anterior pons. (b) Posterior view of left cerebellum and posterior fossa. Tributaries on the tentorial and suboccipital cerebellar surfaces joined to form a bridging vein emptying into the transverse sinus through a well-developed tentorial sinus. (c) The pontotrigeminal and lateral mesencephalic veins ascend along the cerebellomesencephalic fissure, and drained into tributaries of the vein of Galen without descending to merge with the superior petrosal vein. (d) Posterior view of the left posterior fossa after removing the cerebellum. The superior petrosal sinus and vein were absent (red arrowheads). (e) Right posterior fossa. A single superior petrosal vein emptied into a superior petrosal sinus of the lateral type that emptied into the transverse-sigmoid junction without connection to the cavernous sinus. **Bridg:**Bridging; **Cer:** Cerebellar; **Cer. Mes:** cerebellomesencephalic; **CN:** Cranial nerve; **Fiss:** Fissure; **Hem:** Hemispheric; **Inf:** Inferior; **Lat:** Lateral; **Lt:** Left; **Mes:** Mesencephalic; **Mid:** Middle; **Ped:** Peduncle; **Pet:** Petrosal; **Pon:** Pontine; **Rt:** Right; **Sig:** Sigmoid; **Sup:** Superior; **Tent:** Tentorial; **Trans:** Transverse; **V:** Vein

### Venographic images showing the absence of the superior petrosal veins [Figure 2]

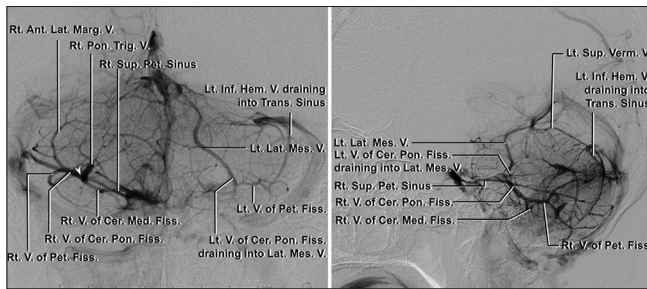
There was no superior petrosal sinus or vein seen in the left CPA by carotid or vertebral venography, but in the right CPA there was a single petrosal vein that drained into a superior petrosal sinus that crossed the full length of the petrous ridge and was classified as a complete type sinus. In the left CPA, the lateral mesencephalic vein drained into the tributaries of the vein of Galen, the inferior hemispheric vein formed a bridging vein on the tentorial cerebellar surface that emptied into the transverse sinus through a short tentorial sinus, and the vein of the

cerebellopontine fissure drained directly into the veins of the galenic group through the lateral mesencephalic vein.

## DISCUSSION

### Venous anatomy in the posterior fossa

The veins draining the brainstem and cerebellum form bridging veins that collect into three groups: (i) A galenic group that drains into the vein of Galen; (ii) a tentorial group that drains into the straight or transverse sinuses; and (iii) a petrosal group that drains into the petrosal sinuses.<sup>[11,23,29]</sup>



**Figure 2: Venographic images showing the absence of the left superior petrosal veins and sinus. On the right side, a complete type of the superior petrosal sinus and a single petrosal vein draining into the sinus were clearly identified (white arrowhead). The superior petrosal vein was formed by the pontotrigeminal and anterior lateral marginal veins, and the vein of the cerebellopontine fissure. However, on the left side, the superior petrosal sinus could not be identified. A well-developed left lateral mesencephalic vein drained into the veins of Galen, and the left inferior hemispheric vein formed a bridging vein on the tentorial cerebellar surface, that drained through a short tentorial sinus into the transverse sinus. The left vein of the cerebellopontine fissure drained directly into the tributaries of the vein of Galen through the lateral mesencephalic vein. Ant: Anterior; Cer. Med: Cerebellomedullary; Cer. Pon: Cerebellopontine; Fiss: Fissure; Hem: Hemispheric; Inf: Inferior; Lat: Lateral; Lt: Left; Marg: Marginal; Mes: Mesencephalic; Pet: Petrosal; Pon. Trig: Pontotrigeminal; Rt: Right; Sup: Superior; Trans: Transverse; V: Vein; Verm: Vermian**

The galenic group usually drains the tentorial cerebellar surface, the cerebellomesencephalic fissure, and the superior half of the roof of the fourth ventricle. This group includes the lateral mesencephalic and pontotrigeminal veins, and the vein of the superior cerebellar peduncle.

The tentorial draining group includes the veins that drain into the straight and transverse sinuses and the torcula, either directly or through a tentorial sinus.<sup>[23,29]</sup> The tentorial sinuses course within the tentorium, receive the drainage of the suboccipital cerebellar surface and the adjacent posterior part of the tentorial cerebellar surface, inferior cerebral veins, vein of Labbé, bridging veins to the tentorial edge, and the veins draining the tentorium itself.<sup>[24,26]</sup> The inferior hemispheric veins and the posterior group of the superior hemispheric veins often join to form a single bridging vein before emptying into the tentorial sinuses. These bridging veins are most frequently located along the intermediate third of each hemisphere rather than the medial or lateral third, and have anastomotic connections with the vermian bridging veins.<sup>[38]</sup>

The petrosal group includes the superior and inferior petrosal veins, which drain into the superior or inferior petrosal sinuses, respectively. The superior petrosal veins are 1–3 bridging veins that are formed by the convergence of multiple tributaries in the CPA and provide the main drainage route for this group, and the inferior petrosal veins are represented by few small bridging veins emptying into the inferior petrosal sinus and jugular bulb. The draining points of the superior

petrosal vein into the superior petrosal sinus were classified into medial, intermediate, or lateral groups based on whether they drain into the superior petrosal sinus in an intermediate location above the internal acoustic meatus, or medial or lateral to the meatus.<sup>[22,23]</sup> Tanriover *et al.*<sup>[35]</sup> modified this classification, focusing on the anatomical relationship to Meckel's cave, and reported that the draining points are mostly located between the lateral limit of the trigeminal nerve at Meckel's cave and the medial limit of the facial nerve at the internal acoustic meatus. Some previous clinical series of CPA meningiomas focusing on the superior petrosal vein introduced cases of the vein not being observed, which was considered to be encased and/or occluded by tumors.<sup>[18,25,40]</sup> However, this anomaly has not been reported in any previous studies of the normal anatomy of the superior petrosal vein, which includes studies involving as many as 50 sides.<sup>[4,14,22,23,35]</sup>

The superior petrosal sinus runs within the attachment of the tentorium cerebelli to the petrous ridge from the posterior end of the cavernous sinus to the transverse–sigmoid junction.<sup>[23,29]</sup> The superior petrosal sinus is divided into medial, lateral, and complete types based on whether it empties into either the cavernous sinus, transverse–sigmoid junction, or both, respectively.<sup>[23,29]</sup> Either the medial or lateral part may be absent in 40–50% of sinuses.<sup>[22,31]</sup> As for the relationship between this sinus and the opening of Meckel's cave, also known as the “porus trigeminus,” Tubbs *et al.*<sup>[37]</sup> reported three types in which the sinus courses superior to, inferior to, or around the opening to Meckel's cave. The sinus was found to course inferior to or around the opening of Meckel's cave in over 30% of the specimens, an important anatomical variation that has to be considered before and during subtemporal transtentorial and retrosigmoid suprameatal approaches.

### Venous consideration in posterior fossa surgery

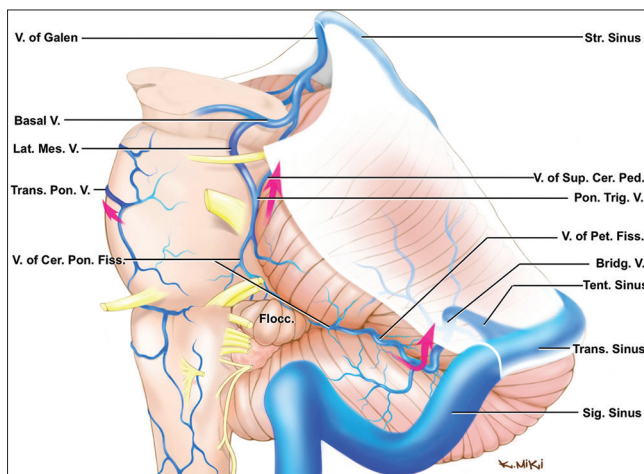
The superior petrosal vein often blocks access to the upper CPA during retrosigmoid approaches. The superior petrosal sinus is routinely sectioned during presigmoid approaches, and some of the bridging veins to the tentorial sinuses are unavoidably sacrificed during supracerebellar infratentorial approaches.

Several cases of complications after sacrifice of superior petrosal veins have been reported.<sup>[1,12,18,19,21,22,27,29,30,32,33,36,39,40,42]</sup> In a report by Koerbel *et al.*,<sup>[18]</sup> approximately 30% of patients had postoperative complications after petrous apex meningioma removal with superior petrosal vein sacrifice. Watanabe *et al.*<sup>[40]</sup> also reported complications in 31% of operations for removal of CPA meningiomas in which at least one petrosal vein was occluded, and emphasized that other bridging veins could play a critical role in providing drainage if the superior petrosal vein was occluded by tumor.

The risk of sacrificing the superior petrosal sinus has been mentioned by several authors, and a modified presigmoid approach has developed to avoid sectioning the superior petrosal sinus as a result of these risks.<sup>[3,8,9,20]</sup> To avoid sacrificing the superior petrosal sinus in the presigmoid approach, Hafez *et al.*<sup>[9]</sup> detached the sinus from the petrous ridge and were thus able to access petroclival tumors.

Others have reported and implied cerebellar infarction or hemorrhage after division of the bridging veins on the tentorial cerebellar surface.<sup>[13,17,28]</sup> Page<sup>[28]</sup> reported a case in which severe cerebellar swelling occurred after the division of one hemispheric and all vermian bridging veins in the median supracerebellar infratentorial approach. Jakola *et al.*<sup>[13]</sup> added two cases in which extensive venous infarction occurred after the sacrifice of a limited number of vermian veins and one hemispheric vein in the supracerebellar infratentorial approach.

In variants with the absence of the superior petrosal sinus or vein, drainage of the petrosal group was through the lateral mesencephalic and bridging veins on the tentorial cerebellar surface to the galenic and tentorial groups [Figure 3]. In such cases, the retrosigmoid or presigmoid approach could be utilized to approach the upper CPA, petrous apex region, and posterior part of the upper brainstem, to avoid venous obstruction. However, obliteration of the bridging vein on the tentorial cerebellar surface or the lateral mesencephalic vein



**Figure 3: Left lateral view. Drainage pattern with absence of the superior petrosal vein and sinus. The terminal end of the veins in the posterior fossa form bridging veins that collect into 3 draining groups: Galenic, tentorial, and petrosal. However, in CPAs in which the superior petrosal vein and sinus are absent, well-developed galenic and tentorial groups compensate for the absence of the petrosal group. The area normally drained by the superior petrosal veins drained instead into the vein of Galen, tentorial sinus, and contralateral transverse pontine vein (red arrows). Bridg: Bridging; Cer: Cerebellar; Cer. Pon: Cerebellopontine; Fiss: Fissure; Flocc: Flocculus; Lat: Lateral; Mes: Mesencephalic; Ped: Peduncle; Pet: Petrosal; Pon: Pontine; Pon. Trig: Pontotrigeminal; Sig: Sigmoid; Str: Straight; Sup: Superior; Tent: Tentorial; Trans: Transverse; V: Vein**

should be avoided in the supracerebellar infratentorial approach to minimize potential complications.

Complications related to venous occlusion are difficult to predict and their incidence is difficult to determine. Youssef *et al.*<sup>[41]</sup> emphasized the importance of the meticulous planning of the surgical approach and avoidance of the venous occlusion with a case of pineocytoma in which the vein of Galen was ligated without postoperative adverse sequelae. The question frequently arises whether to preserve the bridging veins and compromise exposure, or to sacrifice veins to obtain good exposure. The difficulty in predicting outcomes is due to the many variations of venous anatomy and multiple anastomotic connections, and other factors such as brain retraction.<sup>[4]</sup> Even with recent advances in preoperative venous assessment and intraoperative monitoring, it is difficult to determine whether a vein can be safely sacrificed. Some authors warn that the attempt to preserve veins may lead to excessive brain retraction and increase the risks of tumor resection and aneurysm clipping by compromising the exposure, or limiting the extent of resection.<sup>[5]</sup> Kasama and Kanno<sup>[15,16]</sup> reported that the risk of brain damage is higher with combined brain retraction and venous sacrifice than with either alone.

Currently the size of the vein obliterated may be the most valuable predictor of whether complications will follow. If a vein must be sacrificed, it is preferable to divide the smallest and the least number of veins necessary to gain adequate exposure. Recently, the temporary occlusion test with intraoperative neurophysiological monitorings or indocyanine green videoangiography has been used to assess the adequacy of venous collaterals.<sup>[6,7,42]</sup> Further studies are needed to establish venous occlusion tolerance.

Advances in preoperative venographic examination may also help. Neuroimaging studies known to be reliable for examining the superior petrosal veins, sinus, and the bridging veins include digital subtraction venography, or computed tomography or magnetic resonance venography.<sup>[3,10,14,22,25,34]</sup> Preoperative radiological examination may aid in selecting the approach.

## CONCLUSION

The superior petrosal vein and sinus are occasionally absent, and venous drainage is by tributaries of the galenic and tentorial groups in this circumstance. In such unique cases, adequate surgical exposure can be obtained through the retrosigmoid or presigmoid approach without obliteration of the superior petrosal sinus or vein. Consequently, occlusion of the bridging vein on the tentorial cerebellar surface or emptying through the lateral mesencephalic vein into the vein of Galen may lead to complications during supracerebellar infratentorial approaches. Surgical strategies for intraoperative management of venous structures are still

controversial, but an understanding of the variations of venous anatomy is essential, even with intraoperative monitoring and preoperative radiological assessment.

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