Microsurgical anatomy of the great cerebral vein of Galen and its tributaries

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Object. The deep cerebral veins may pose a major obstacle in operative approaches to deep-seated lesions, especially in the pineal region where multiple veins converge on the great cerebral vein of Galen. Because undesirable sequelae may occur from such surgery, the number of veins and branches to be sacrificed during these approaches should be minimized. The purpose of this study was to examine venous drainage into the vein of Galen with a view to surgical approaches. If a vein hampering surgical access must be sacrificed, it can therefore be selected according to the smallest draining territory.

Methods. The deep cerebral veins and their surrounding neural structures were examined in 50 cerebral hemispheres from 25 adult cadavers in which the arteries and veins had been perfused with red and blue silicone, respectively. Special consideration was given to the size and location of drainage of the vein of Galen and its tributaries.

Conclusions. When a surgeon approaches the pineal region, several veins may hamper the access route. From posterior to anterior, these include the following: the superior vermician and the precentral or superior cerebellar veins, which drain into the posteroinferior aspect of the vein of Galen; and the tectal and pineal veins, which drain into its anterosuperior aspect. The internal occipital vein is the main vessel draining into the lateral aspect of the vein of Galen. It may be joined by the posterior pericallosal vein, and in that case has an extensive territory. To avoid intraoperative venous infarction, it is important to use angiography to determine the venous organization before surgery and to estimate the permeability and size of the branches of the deep venous system.

Key Words • vein of Galen • internal cerebral vein • pineal region • basal vein • microsurgical anatomy

NEUROVASCULAR, particularly venous, relationships of the pineal region are the most complex in the cranium because the ICVs, BVs, and their tributaries converge at the vein of Galen. Horsley13 was the first to attempt the direct removal of a pineal tumor in 1910. Since then, various surgical approaches to the pineal region have been reported.32 Dandy6 emphasized the route used by Krause20 in 1926, which consisted of the infratentorial–supracerebellar approach to the pineal region. With these approaches, however, the deep cerebral veins may pose a major obstacle,12,46 and it may be necessary to sacrifice one of the veins that drains into the vein of Galen. This sacrifice may have no outward effect on the patient or it may result in a variety of symptoms including disorders of eye movement, edematous closure of the aqueduct of the mesencephalon, blindness resulting from edema of the colliculi and geniculate bodies, and extraocular palsies due to edema of the nuclei of the nerves or the central pathways in the brainstem.10 The veins are so dense that their identification during surgery may be difficult. To reduce the risk of complication following occlusion of a deep cerebral vein, it is important to have an understanding of venous anatomy and the draining territories. Knowledge of this anatomy is useful when selecting a vein to sacrifice to ensure that the one chosen has the smallest draining territory.

Materials and Methods

In this study the deep cerebral veins and their surrounding neural structures were examined in 50 cerebral hemispheres obtained from 25 adult cadavers. In all specimens the carotid and vertebral arteries were perfused with red silicone, and the jugular veins with blue silicone, to facilitate dissection performed using 3 to 40× magnification. Special attention was given to the size and location of drainage of the vein of Galen and its tributaries. Thus, in all specimens the existence of the following veins was systematically verified: the ICVs; BVs; medial, lateral, or common AVs; IOVs or OTVs; PPVs; STVs; PLHVs; collicular veins; pineal veins; PCVs; SVVs; and SCVs.

Linear measurements were directly obtained using an electronic digimatic caliper (± 0.01 mm), and the angle between the straight sinus and the vein of Galen was measured with the aid of a goniometer (± 1°). We measured the width of each vein at its termination and the distance between the location of the draining site of the vein and the origin of the vein of Galen. We also measured the distance between the origin of the vein of Galen and the most posterior point of the pineal body. By convention, we define as our reference point the origin of the vein of Galen, which corresponds to the union of both ICVs.
Microsurgical anatomy of the vein of Galen

Results

Neural Relationships

The vein of Galen is the largest vessel of the pineal region. The quadrigeminal cistern lay between the atrial portion of the paired choroidal fissures. The cistern had a pyramidal configuration defined by five walls (one anterior, two lateral, one superior [roof], and one inferior [floor]; Fig. 1).

The collicular plate was located on the midline of the anterior wall. The rostral portion of the anterior wall was formed by the pineal body, the habenular trigones, and the habenular commissure at the midline and the medial portion of the pulvinar laterally. The pineal body lay between the paired superior colliculi, in a slight depression formed by the superior expansion of the vertical part of the cruciform sulcus. The habenular trigone was located on the postero-medial surface of the pulvinar and was traversed by the habenular commissure, which crossed the midline in the upper half of the attachment of the pineal body (superior lamina of the pineal peduncle) to the posterior portion of the third ventricle. The habenular trigone and commissure constituted the rostral limit of the cistern, beyond which lay the entrance of the velum interpositum. The habenular or hippocampal commissure was a thin sheet of fibers interconnecting the medial margin of the crura of the fornix below the splenium of the corpus callosum. The caudal portion of the anterior wall was formed by the lingula of the vermis on the midline and the adjacent portion of the superior cerebellar peduncle laterally.

The roof of the quadrigeminal cistern was formed by the lower surface of the splenium of the corpus callosum and the broad membranous envelope surrounding the vein of Galen and its tributaries. This envelope was continuous with the tela choroidea, which surrounded the velum interpositum. The floor of the quadrigeminal cistern was formed by the superoventral portion of the cerebellum and consisted of the central lobule and culmen of the vermis on the midline and the quadrangular lobules of the hemispheres laterally. The cistern extended into the cerebellomesencephalic fissure, a cleft between the midbrain and the cerebellum.

The lateral walls had both an anterior and a posterior component. The anterior component was formed by the crus of the fornix as it wrapped around the pulvinar, midway between its medial and lateral borders. The posterior component was formed by the aspect of the occipital cortex located below the splenium of the corpus callosum on the medial surface of the cerebral hemisphere.

The top of the quadrigeminal cistern was formed by the angle between the floor and the roof and was related to the apex of the tentorium. In this area the vein of Galen exited and drained into the straight sinus.

Below the pulvinar the quadrigeminal cistern communicated inferolaterally with the ambient cisterns and superiorly with the posterior pericallosal cistern, which extended around the splenium between the cerebral hemispheres and sometimes communicated with the velum interpositum. Posteriorly, the quadrigeminal cistern opened into the superoventral portion of the cerebellum.

The trochlear nerves arose in the quadrigeminal cistern just caudal to the inferior colliculi and lateral to the frenulum veli modularis superioris, which was a white ridge prolonging the inferior end of the vertical part of the cruciform sulcus caudally to the superior medullary velum. These nerves curved around the lateral surface of the midbrain and entered the ambient cistern.

It is in the superomedial part of the cistern that the venous structures were more dense. The superomedial location of the veins contrasted with the inferolateral location of the arteries.

Internal Cerebral Veins and the Vein of Galen

The ICVs were encountered in all specimens (Fig. 2). They originated in the posterior aspect of the interventricular foramen of Monro, on each side of the midline, by union of the anterior septal and thalamostriate veins. Both veins coursed posteriorly along the roof of the third ventricle and above the medullaris stria of the thalamus. No bridging veins connected the ICVs. Rostrally, these veins coursed 1 to 2 mm from the midline, separating from each other posteriorly at the level of the pineal body and beneath the most inferior point of the splenium of the corpus callosum. They then coursed immediately above the lateral aspect of the pineal body and turned upward before joining to form the vein of Galen (Fig. 3). Most of this course was located between the two layers of the tela choroidea of the third ventricle. Sometimes the quadrigeminal cistern extended between the two layers of the tela choroidea, forming the cistern of the velum interpositum. The diameters of the ICVs increased as they passed posteriorly, ranging from 1.4 to 3.9 mm (mean 2.67 mm) just before the veins joined to form the vein of Galen. It is important to note that the posterior tip of the suprapineal recess was located at the junction of the ICVs in all of our specimens. Thus, in specimens in which both ICVs joined over the pineal body, the suprapineal recess was short; in specimens in which the venous junction was found most posterior, the suprapineal process was long.

The distance between the junction of the paired ICVs and the pineal body was 0 to 9.1 mm (mean 4.35 mm); the junction was located more or less posteriorly, below the splenium of the corpus callosum. Subsequently, the vein of Galen coursed posteriorly and superiorly to drain into the straight sinus with the inferior sagittal sinus. Its length varied from 3.1 to 25 mm (mean 10.33 mm), depending on the location of the junction of the ICVs. It was short in specimens in which it was formed above the splenium of the corpus callosum and long in those in which it was formed below that structure. Its diameter increased along its course as the vein received its tributaries. Its width ranged from 3.7 to 6.2 mm (mean 4.77 mm). In 10 specimens the vein of Galen drained into an enlargement of the straight sinus, which is known as a lacuna. In other specimens it drained directly into the straight sinus. The angle between the vein of Galen and the straight sinus varied from 16 and 117° (mean 75.25°), depending on the location of the apex of the tentorium. This angle was sharp, varying between 16 and 62° in nine cases (mean angle 41.1°). In these cases the vein of Galen coursed along the splenium of the corpus callosum and paralleled its curved contour. The origin of the vein was located 2.6 mm (range 0–5.3 mm) from the posterior tip of the pineal body. The degree of the angle approximated that of a right angle in 15 cases (range 75–104°). In those specimens the vein of Galen was not as closely apposed to the splenium of the corpus callosum. The distance between the refer-
Fig. 1. Postmortem study of the quadrigeminal cistern. A: Photograph depicting the posterior view of the midbrain. The quadrigeminal cistern has a pyramidal shape defined by five walls. The collicular plate is located at the center of the anterior wall. The rostral portion of the anterior wall is formed by the pineal body, habenular trigone, and habenular commissure at the midline and the medial portion of the pulvinar laterally. The caudal portion of the anterior wall is formed by the lingula of the vermis at the midline and the adjacent portion of the superior cerebellar peduncle laterally. The trochlear nerves emerge below the inferior colliculi on both sides of the frenulum veli. B: Photograph of the midsagittal view of the cerebrum demonstrating the anterior wall, floor, and roof of the quadrigeminal cistern. At the midline, the anterior wall consists of the collicular plate and the inferior medullary velum. The floor consists of the precentral lobule and the upper portion of the culmen. The roof of the quadrigeminal cistern is formed by the lower surface of the splenium of the corpus callosum. The cistern extends into the cerebellomesencephalic fissure, which is located between the midbrain anteriorly and the cerebellum posteriorly. The vein of Galen is located in the upper portion of the cistern around the posterior aspect of the splenium of the corpus callosum. C: Photograph demonstrating an enlarged view of the posterior aspect of the splenium of the corpus callosum. The vein of Galen and its main tributaries have been retracted posteriorly to show the continuity between the broad membranous envelope that surrounds the vein and its tributaries and the tela choroidea, which surrounds the velum interpositum under the corpus callosum. The lateral wall of the quadrigeminal cistern is formed by the portion of the occipital cortex that is located below the splenium of the corpus callosum. Arach. = arachnoid; Call. = callosum; Cer. = cerebellar or cerebral; Cer.Mes. = cerebellomesencephalic; CN = cranial nerve; Coll. = collicular or colliculus; Comm. = commissure; Corp. = corpus; Crucif. = cruciform; Fiss. = fissure; Fren. = frenulum; Hab. = habenular; Inf. = inferior; Int. = internal; Lat. = lateral; Lob. = lobule; Med. = medullary; Mes. = mesencephalic; Occip. = occipital; Ped. = peduncle; Post. = posterior; Precent. = precentral; Pulv. = pulvinar; Sag. = sagittal; Str. = straight; Sulc. = sulcus; Sup. = superior; Tent. = tentorium; Trig. = trigone; V. = vein; Vel. = velum; Vent. = ventricle.
The angle between the vein of Galen and the straight sinus was obtuse in one case (117°); here, the vein followed an almost horizontal course and not the contour of the splenium of the corpus callosum. The origin of this vessel was located 9.1 mm from the tip of the pineal body. We found no relationship between the length of the vein of Galen and the angle of or the distance between the reference point and the pineal body. In one case, the ICVs joined to form the vein of Galen, but the latter divided after a very short distance to end in the straight sinus as two independent vessels.

Tributaries that joined the vein of Galen in the 50 specimens that we examined included both ICVs (100%), the SCV (76%), the BV (62%), the IOV (54%), the collicular veins (44%), the PPV (35%), the OTV (33%), the medial or common AV (20%), both pineal veins (24%), the PLHV...
(18%), the PCV and SVV (16% each), and the STV (9%; Table 1).

**Basal Vein**

The BV originated on the surface of the anterior perforated space by a union of the anterior cerebral, deep middle cerebral, and inferior striate veins (Fig. 4). The BV coursed posteriorly, medially, and slightly inferiorly above the optic tract and the level of the uncus to reach the anterior aspect of the cerebral peduncle. It then turned laterally between the peduncle and the superior surface of the uncus and coursed on one side of the optic tract. Behind the level of the lateral mesencephalic sulcus, it turned around the inferior and posterior aspects of the pulvinar and entered the quadrigeminal cistern.

In our study, the BV was encountered in 37 (74%) of 50 specimens. At its terminus the diameter ranged from 1.3 to 3.2 mm (mean 2.21 mm). It usually drained into the vein of Galen (23 specimens) 0 to 15 mm (mean 3.25 mm) from the posterior tip of the pineal body.
Microsurgical anatomy of the vein of Galen

In 10 specimens the BV drained at the level of the origin of the vein of Galen by convergence with the ICVs. Usually, the BV drained into the vein of Galen more inferiorly than did the ICV. In the remaining 13 specimens the draining site was located between 1.7 and 15 mm (mean 5.91 mm) along the vein of Galen. The BV drained into the inferior lateral (17 specimens) or posterior (five specimens) aspect of the vein of Galen; however, in one case it drained into the anterior aspect of this vein between the two paired ICVs. In specimens in which the BV did not drain into the vein of Galen, it flowed directly into the straight sinus (one specimen) aspect, before the origin of the vein of Galen; however, in one case it drained into the superior sagittal sinus (three specimens) and anteriorly into the ICV (11 specimens). In these instances the location of the draining site was 1.6 to 9.8 mm (mean 6.23 mm) along the lateral (seven specimens), inferolateral (three specimens), or posterior (one specimen) aspect, before the origin of the vein of Galen. In 13 cases the posterior mesencephalic portion of the BV (third segment) did not exist and was replaced by the posterior mesencephalic vein (seven specimens), or the peduncular segment (second segment) drained into the lateral mesencephalic vein (six specimens).

Internal Occipital Vein

In all specimens an IOV originated on the inferior and medial surface of the occipital lobe and then coursed anteromedially to enter the quadrigeminal cistern (Fig. 4). This vein drained the medial surface of the occipital lobe, particularly the calcarine sulcus and its borders. The width of the IOV at its terminal part was 0.8 to 2.8 mm (mean 1.65 mm). The size of the vein was proportionate to the surface of its territory. In the seven specimens in which it was largest, the IOV was met by a vein draining the cuneus and the posterior portion (isthmus) of the cingulate gyrus. In five specimens the IOV was small and drained only the anterior border of the calcarine sulcus; the remaining occipital lobe was drained by the PPV. The IOV ended in the vein of Galen (27 specimens) 0 to 14.1 mm (mean 4.03 mm) posterior to the reference point, usually on its lateral aspect. In specimens in which the IOV did not terminate in the vein of Galen, it joined the ICV (13 cases), BV (five cases), medial AV (four cases), or PLHV (one case) 1 to 10 mm (mean 4.67 mm) before the reference point.

Atrial Vein

The medial AV originated from several branches lying on the medial wall of the atrium and the occipital horn of the lateral ventricle (Fig. 4). It perforated the medial aspect of the body and crus of the fornix and coursed transversely through the lateral portion of the quadrigeminal cistern in a medial direction along the surface of the pulvinar. The medial AV was found in 40 (80%) of 50 hemispheres. It usually drained upstream from the vein of Galen, at a distance of 1.5 to 25 mm (mean 9.85 mm) from the reference point, into the lateral or superolateral aspect of the ICV (23 specimens), the PPV (four specimens), the PLHV (three specimens), the BV (one specimen), or the IOV (one specimen). In eight specimens the medial AV drained into the vein of Galen at a junction 0 to 8 mm (mean 2.3 mm) after the origin of the latter vein.

The lateral AV originated from several branches lying on the lateral wall of the atrium of the lateral ventricle (Fig. 4). Usually, it exited through the choroid fissure and drained into the BV. When the lateral AV did not drain directly into the BV, it formed a common stem with the medial AV, which is known as the common AV. We encountered this configuration in 10 cases. The widths of the lateral and common AVs were 1.62 mm (range 1.1–2.1 mm) and 1.62 mm (range 1.2–2.2 mm), respectively. In seven specimens the common AV drained into the ICV; in one specimen it drained into the BV. It drained at a point 1.4 to 12.4 mm (mean 5.72 mm) before the origin of the vein of Galen. Twice, the lateral AV drained into the vein of Galen at the level of the junction of both ICVs.

| Table 1 |

<table>
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<tr>
<th>Vein</th>
<th>No. of Specs (%)</th>
<th>Vessel Width at Terminus (mm)†</th>
<th>No. of Specs (%)</th>
<th>Distance (mm)‡</th>
<th>No. of Specs (%)</th>
<th>Distance (mm)‡</th>
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<td>2.67 (1.4–3.9)</td>
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<td>BV</td>
<td>37 of 50 (74)</td>
<td>2.21 (1.3–3.2)</td>
<td>23 of 37 (62)</td>
<td>3.25 (0–15)</td>
<td>11 of 37 (30)</td>
<td>6.23 (1.6–9.8)</td>
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<td>medial AV</td>
<td>40 of 50 (80)</td>
<td>1.52 (0.8–2.3)</td>
<td>8 of 40 (20)</td>
<td>2.30 (0–8)</td>
<td>32 of 40 (80)</td>
<td>9.85 (1.5–25)</td>
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<td>25 of 25 (100)</td>
<td>8.90 (5–16)</td>
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<td>10 of 50 (20)</td>
<td>1.62 (1.2–2.2)</td>
<td>2 of 10 (20)</td>
<td>0</td>
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<td>5.72 (1.4–12.4)</td>
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<td>27 of 50 (54)</td>
<td>4.03 (0–14.1)</td>
<td>23 of 50 (46)</td>
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<td>pst mesencephalic vein</td>
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<td>7.62 (1.9–14.6)</td>
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* Data were obtained from 25 hemispheres containing unpaired (25) and paired (50) structures. Abbreviations: pst = posterior; specs = specimens; — = not applicable.
† Values are shown as the means (range).
‡ Distance from origin of the vein of Galen.
Fig. 4. Photographs of cadaveric specimens showing tributaries of the vein of Galen. A: Anterosuperior view of the left BV coursing through the ambient and quadrigeminal cisterns. The BV originates by union of the anterior cerebral, deep middle cerebral, and inferior striate veins. It courses posteriorly to enrich the cerebral peduncle. Behind the level of the lateral mesencephalic sulcus, the BV turns around the inferior and posterior aspects of the pulvinar and empties into veins in the quadrigeminal cistern. B: Posterior view of the quadrigeminal cistern. The IOV originates on the inferior and medial surface of the occipital lobe and courses anteromedially to enter the quadrigeminal cistern. In some cases, the IOV joins a vein draining the cuneus, the posterior portion of the cingulate gyrus, and the PPV. In this specimen, the trunk drains into the right ICV. C: The vein of Galen has been retracted medially to show the right ICV and a right STV. The right BV drains the posterior aspect of the right ICV. D: Posterior view of the quadrigeminal cistern. The tentorium has been retracted medially to show the vein constituting the galenic complex. A right lateral AV empties on the lateral aspect of the ICV. The third segment of the BV is absent. E: Posterior view of the cerebellomesencephalic fissure. A left posterior mesencephalic vein is anastomosed to the lateral mesencephalic vein and the left ICV. The superior collicular veins drain the superior portion of the collicular plate. F: The cerebellum has been retracted medially to expose the SCV, which drains into the vein of Galen on its posterior aspect. A. = artery; Bas. = basilar; Calc. = calcarine; Long. = longitudinal; Med. = medial; Mid. = middle; Parahippo. = parahippocampal; P.C.A. = posterior cerebral artery; P.Co.A. = posterior communicating artery; S.C.A. = superior cerebellar artery; Thal. = thalamic. See legends to Figs. 1 through 3 for additional abbreviations.
Microsurgical anatomy of the vein of Galen

Posterior Pericallosal Vein

The PPV was observed in 40 (80%) of 50 hemispheres (Fig. 4). It originated on the dorsal surface of the corpus callosum; extended around the splenium of the corpus callosum, where in some specimens it received a vein draining the isthmus of the cingulate gyrus; and entered the anterior portion of the vein of Galen in 14 specimens. The width of the PPV before draining was 0.6 to 2 mm (mean 1.25 mm). It drained at a site located 1 to 14 mm (mean 4.69 mm) past the origin of the vein of Galen. In other specimens it drained into the SVV (18 specimens), the IOV (seven specimens), or the PLHV (one specimen) 1.5 to 12.7 mm (mean 5.15 mm) before the reference point.

Posterior Longitudinal Hippocampal Vein

The PLHV was found in 44 (88%) of 50 hemispheres. It coursed along the posterior portion of the cingulate gyrus (Fig. 4). Its width before draining into a main vessel was 1 to 2.6 mm (mean 1.84 mm). In eight specimens it drained into the vein of Galen 0 to 6.8 mm (mean 2.27 mm) from the reference point. In the other specimens it drained into the BV, ICV, or medial or common AV 2.1 to 15 mm (mean 9.07 mm) before the origin of the vein of Galen.

Superior Thalamic Vein

The STV was the main draining vein of the thalamus (Fig. 4). It arose by a convergence of small veins in the superior portion of the thalamus and coursed along the medial aspect of the thalamus, near the medullar stria of the thalamus, below and lateral to the ICV. The STV drained into the ICV or the vein of Galen. It was found in 45 (90%) of 50 cases and its width was 1.1 to 1.5 mm (mean 1.15 mm) before the site at which it drained into a main vessel. In four specimens the STV drained into the vein of Galen between 0 and 3.9 mm (mean 1.9 mm) after the latter’s origin. In other specimens the STV drained into the ICV (25 specimens), BV (15 specimens), or medial AV (one specimen) 1 to 9.3 mm (mean 3.8 mm) before the origin of the vein of Galen.

Precentral Cerebellar Vein, SVV, and SCV

The PCV was an unpaired median vessel that was located within the cerebellomesencephalic fissure, between the central lobule posteriorly and the lingula anteriorly (Figs. 3 and 4). It originated from the union of two brachial veins located over the middle cerebellar peduncle and coursed medially over the superior cerebellar peduncle. The width of this vein before its drainage was 0.8 to 1.9 mm (mean 1.42 mm). We encountered it in all specimens and it drained independently into the vein of Galen in four of them. The site of drainage was 0 to 1 mm (mean 0.5 mm) from the reference point.

The SVV resulted from the union of several tributaries on the culmen and within the postcentral fissure between the central lobule and the culmen. The vein ran upward and backward within the cerebellomesencephalic fissure. The width of this vein before draining was 0.8 to 2.6 mm (mean 1.35 mm). In two specimens, the SVV drained into the vein of Galen, 1 to 1.5 mm (mean 1 mm) from the reference point. In these specimens the SVV entered the galenic system more anteriorly than did the PCV. In two other specimens the SVV drained into one of the BVs. Usually (21 specimens), the PCV and SVV united to form a single trunk called the SCV. The width of this vein before draining was 1.2 to 2.9 mm (mean 1.96 mm). Most often, it drained into the vein of Galen (16 specimens) 0 to 16.3 mm (mean 3.69 mm) from the latter’s origin. In other specimens the course of the SCV was paramedian, and it drained into one ICV (four specimens) or one BV (one specimen) 1.8 to 4 mm (mean 3.2 mm) before the reference point. In this latter case the BV coursed below the vein of Galen and drained into it just before the straight sinus.

Posterior Mesencephalic Vein

The posterior mesencephalic vein originated in the interpeduncular fossa or the lateral aspect of the midbrain and coursed posteronomedially and superiorly around the midbrain to drain into the posterior portion of the ICV or the vein of Galen (Fig. 4). It was present in 12% of the hemispheres (six of 50) in which the BVs or lateral mesencephalic veins were absent or hypoplastic, and thus replaced the posterior portion of the BV in these specimens. It never emptied into the vein of Galen, but instead flowed into the ICV (five specimens) or the PCV (one specimen). In these situations, the location of drainage was 4.6 to 9 mm (mean 6.83 mm) before the origin of the vein of Galen.

Collicular Vein

The collicular (tectal or quadrigeminal) veins originated on the collicular plate from a rich venous network (Figs. 1 and 4). These veins consisted of three to four small tributaries less than 1 mm wide (mean 0.65 mm), which were divided into superior and inferior tectal veins. The superior and inferior tectal veins ran backward and drained independently, or after forming a common trunk, into a main vessel of the quadrigeminal cistern. They generally drained into the PCV; however, in 11 specimens they drained into the vein of Galen. In some instances, they drained into the SCV, SVV, or ICV.

Pineal Vein

The veins draining the pineal body originated from the habenular trigone or from the junction between the habenular trigone and the pineal body. They coursed backward on the superolateral or inferolateral aspects of the pineal body, although they could be divided into superior and inferior pineal veins. The pineal veins were 0.3 to 1.5 mm wide (mean 0.72 mm). They drained independently, or after forming a single trunk, they drained into the ICV (19 specimens) or the vein of Galen (six specimens).

Summary of Results

When approaching the pineal region, several veins may hamper the surgical approach, including the infratentorial veins on the midline and the supratentorial veins in a paramedian location. The infratentorial veins that are encountered from posterior to anterior include the following: the SVV and the PCV or SCV, which drain into the posteroinferior aspect of the vein of Galen; and the tectal and pineal veins, which drain into its anterosuperior aspect. More laterally, the IOV, the medial or common AV, and the BV and posterior mesencephalic veins were encountered, from back to front, draining into the lateral aspect of the vein of Galen.
The ICVs were found to be the most anterior veins because they joined to form the vein of Galen.

**Discussion**

The deep cerebral veins may pose a major obstacle to surgical approaches to deep-seated lesions, especially in the pineal region where multiple veins converge on the vein of Galen. 3,23,32,46 The intentional or accidental sacrifice of the vein of Galen or its tributaries is dreaded by most neurosurgeons. Because approaches to the pineal region are followed less frequently, neurosurgeons are not as familiar with the anatomy of the deep venous system as they are with that of the superficial venous system or the dural sinuses. 1 The galenic system is a complex venous network. 15 Only a restricted view of its components is available during surgery, and anatomical variations can complicate the identification of the veins. The consequences of venous sacrifice are not well reported in the literature and thus contribute to the lack of knowledge.

**Vein of Galen and Its Tributaries**

According to most authors, the vein of Galen, also known as the great cerebral vein, originates from the junction of both ICVs, 22,23,37,46 which is located immediately above the pineal body where the posterior downward curve of the ICV turns upward. 7 As we also have shown, however, this segment belongs to the ICV. 27 Both the ICVs and BVs are major contributors to the vein of Galen. The ICVs and BVs are almost the same size and are very close to each other when they drain into the vein of Galen. Some authors have included the termination of both BVs in the origin of the vein of Galen 35 and have called the latter vein "the posterior venous confluent" because of the numerous veins that drain into it. 7

The vein of Galen terminates at the anterior falcotentorial junction, where it joins the inferior sagittal sinus to form the straight sinus. The angle of the junction between the vein of Galen and the straight sinus usually is acute or is more or less a right angle. 11,17,43,46 Thus, as the blood flows from the vein into the straight sinus it enters against the direction of flow in that channel. 37,38 Such a configuration is also seen with other cerebral veins that enter sinuses. Sometimes, the vein of Galen may drain into the straight sinus at an obtuse angle opening posteriorly. Johanson 27 found this configuration in 6 of 75 specimens. This angle depends on the location of the falcotentorial junction. It is nearly flat if the falcotentorial junction is located below the splenium and acute if it is located above that structure. 25

The length of the vein of Galen varies from 4 to 15 mm 17,32 to as long as 25 mm 44,46 depending on the location of the junction of the ICVs. In cases in which the ICVs join above the splenium, the vein of Galen is short 39 and the suprapineal recess is long. Conversely, in cases in which the ICVs join below the splenium, the vein of Galen is long and the suprapineal recess is short. Thus the length of the suprapineal recess is inversely proportional to the length of the vein of Galen.

**Can We Sacrifice Deep Cerebral Veins?**

Data from several experimental studies have shown that ligation of the vein of Galen produces no major consequence other than hydrocephalus in animals. 3,8 This was refuted in 1971 by Hammock and colleagues, 12 who found dilation of the main dural sinuses and cortical veins as well as the diencephalic veins. Earlier, Schlesinger 36 demonstrated macroscopic and microscopic alterations in the brain after ligation of the vein of Galen. The local parenchymatous hyperemia and vessel dilation found at the acute stage disappeared during the chronic stage. Results of all these experiments showed that the sacrifice of the vein of Galen in monkeys and dogs did not induce any venous infarction, because collateral veins function immediately and flow changes are tolerated.

Only spontaneous thrombosis and surgical sacrifice may produce the consequences of interruption of the vein of Galen and its branches in humans. Thrombosis of the deep venous system is more often associated with thrombosis of one or several superficial veins. Therefore a focal interruption is logically better tolerated than a spontaneous thrombosis, which tends to be extensive, thus decreasing the potential for collateral flow. 1 Moreover, after interruption, the ICV may drain retrogradely into the cortical veins, whereas the BV reverses its flow toward the temporal veins and the sphenoparietal sinus. 6 Samii, et al., 33 discussed four mechanisms for producing venous complication during surgery: lacerations of the venous sinuses, obliteration of veins or venous sinuses, brain retraction interfering with venous flow, and hemodynamic changes in the venous system due to removal of extensive lesions. The sacrifice of the major trunks of the deep venous system has variable effects. It can cause diencephalic edema, mental symptoms, coma, hyperpyrexia, tachycardia, tachypnea, myosis, rigidity of limbs, and exaggeration of deep tendon reflexes 30,21,25,38,40 or eye movement disorders, closure of the aqueduct of the mesencephalon, blindness, and extracocular palsies. 10 Neurosurgery has considerably improved since the time of Dan-dy; therefore, only more recent cases must be considered. Although the literature is not extensive, fatal complications seem to have disappeared and functional disorders have grown scarce. Nevertheless, although postoperative cortical venous infarction is one of the important complications occasionally affecting outcomes in patients with brain tumors, 18 complications after the intraoperative sacrifice of veins in the posterior fossa have not frequently been reported.

**Surgical Considerations**

Lesions of the pineal region may be reached from above the tentorium along the inferomedial surface of the occipital lobe (occipital–transventricular approach), 1,6,20 through the posterior portion of the lateral ventricle (posterior transventricular approach), 4,37 through the corpus callosum (posterior interhemispheral–transcallosal approach), 4,38 or from below the tentorium through the supracerebellar space (infratentorial–supracerebellar approach). 13,28,26,36,47 The selection of the best surgical approach for a lesion of the pineal region depends mainly on the location and extent of the tumor. 32,23,45

Data from a study of technical approaches to the pineal region have demonstrated that no approach can avoid dissection of one or several branches of the deep venous system. 1 Accidental injury to a venous trunk may occur; however, the surgeon may also intentionally sacrifice a vein hampering access, provided that this can be performed.
Microsurgical anatomy of the vein of Galen

without adverse consequences. Conversely, the vein may need to be preserved for fear of inducing a venous infarction.

The infratentorial–supracerebellar and occipital–transientorial approaches are the most common routes used to reach tumors of the pineal region. The deep venous system usually covers the top of the tumor and makes dissection of veins difficult and dangerous. The posterior transcallosal approach should be chosen if the lesion arises in the splenium above the vein of Galen. The posterior transventricular approach provides the best access to lesions of the atrium or glomus of the choroid plexus that extend into the pulvinar. In other cases, the tumor is most often hidden by the galenic system, which must be exposed.

The infratentorial–supracerebellar approach is the preferred method of access to tumors located in the midline, which extend into the lower half of the posterior incisural space and displace the collicular plate and the adjacent part of the cerebellum. This approach is not, or is at least less, obstructed by the deep venous system that caps the dorsal aspect of the pineal gland. Visualization of the inferior aspect of the vein of Galen is good. It may be necessary to sacrifice the SCV to reach deeper lesions. The SCV is formed by the union of the SVV and the PCV. Most authors view this vein as the PCV or as the vein of the cerebellomesencephalic fissure. Usually, it drains into the inferior aspect of the vein of Galen, but sometimes it follows a more paramedian course and drains into the ICV or the BV. Although we encountered the latter configuration in 25% of the specimens, Yamamoto and Kageyama did so in only 13.6% of cases, and they never found drainage into the BV. When the SCV is not present (16%), the SVV and the PCV drain independently. The PCV always drains into the vein of Galen, whereas the SVV drains into either the vein of Galen or the BV. In two of 131 specimens, the SVV joined the sinus 1 cm caudal to the orifice of the vein of Galen.5 Despite this rare variant, the location of the drainage of these veins is very close to the origin of the vein of Galen. Occasionally, the brachial veins do not unite, but drain independently into the vein of Galen.45

During surgery, Page could preserve the SCV in five of nine specimens, but this vein still remains an obstacle when approaching the pineal region. When necessary, the vein can be transected to provide a wider exposure. The paramedian approaches provide access to the pineal region and the cerebellar peduncles, while preserving the SCV, SVV, and PCV. Nevertheless, they can hamper these approaches when the SCV is in a paramedian location, as is the case when it drains into the ICV or the BV. Similarly, the lateral dorsal segment of the BV may pose a danger because it runs along the pineal gland and the lateral aspect of the ICVs before emptying into the vein of Galen.

Because the SCV hampers the surgical approach, it is usually sacrificed to reach deeper lesions. Stein and Yamamoto and Kageyama estimated that the SCV may be sacrificed without any clinical consequence. The venous complications that do occur during infratentorial supracerebellar approaches are mainly due to a division of vermian or hemispheric bridging veins.31

The occipital–transientorial approach is more often used for lesions centered on or above the tentorial edge or the vein of Galen if the lesions do not extend to the opposite side or into the posterior cerebral fossa. It requires elevation of the occipital lobe superiorly and laterally and sectioning of the edge of the tentorium 1 cm lateral to the straight sinus. This approach provides a better view of the splenium of the corpus callosum, the collicular plate, and the superior vermis from above. It affords an excellent visualization of the vein of Galen, but it is difficult to obtain a sufficiently wide view of the collicular plate on the contralateral side and to approach the contralateral BV.48

The IOV is at risk from brain retraction when the pineal region is approached via an occipital–transientorial route. Injury to this vein may result in a lateral homonymous hemianopsia. The IOV is quite constant, but the diameter of this vein is related to the size of its drainage territory. It drains the medial surface of the occipital lobe and flows into the lateral aspect of the vein of Galen in 54 to 77% of cases.45 When it is small, the drainage territory is limited to the anterior border of the calcarine sulcus, whereas when it is large, the territory is more extensive and may extend anteriorly along that of the PPV. In some instances (seven specimens in our study) the IOV may receive a vein draining the cuneus and the posterior portions of the cingulate gyrus, which usually drains into the PPV to form the cuneolimbic vein. According to Ben-Amor and Billewicz, the termination of the PPV is found in the region of the junction of the ICV and vein of Galen. When we consider the situation in which the PPV drains into the IOV (seven specimens in our study), the IOV receives at least the posterior portion of the territory of the PPV in 28% of cases. Transsecting this variant of vein during occipital lobe retraction may increase the risk of developing venous infarction and lateral homonymous hemianopsia.

To avoid intraoperative venous infarction, it is important to consider the venous organization on computerized tomography or magnetic resonance angiography before surgery and to estimate the permeability and size of the branches of the deep venous system. The major and presumably permeable branches must be preserved, whereas the occluded veins may be sacrificed.

References
