# Pineal Gland

*Last Updated: June 22, 2021*

## ABSTRACT

**OBJECTIVE**: A common approach to lesions of the pineal region is along the midline below the torcula. However, reports of how shifting the approach off midline affects the surgical exposure and relationships between the tributaries of the vein of Galen are limited. The purpose of this study is to examine the microsurgical and endoscopic anatomy of the pineal region as seen through the supracerebellar infratentorial approaches, including midline, paramedian, lateral, and far-lateral routes.

**METHODS**: The quadrigeminal cisterns of 8 formalin-fixed adult cadaveric heads were dissected and examined with the aid of a surgical microscope and straight endoscope. Twenty CT angiograms were examined to measure the depth of the pineal gland, slope of the tentorial surface of the cerebellum, and angle of approach to the pineal gland in each approach.

**RESULTS**: The midline supracerebellar route is the shortest and provides direct exposure of the pineal gland, although the culmen and inferior and superior vermian tributaries of the vein of Galen frequently block this exposure. The off-midline routes provide a surgical exposure that, although slightly deeper, may reduce the need for venous sacrifice at both the level of the veins from the superior cerebellar surface entering the tentorial sinuses and at the level of the tributaries of the vein of Galen in the quadrigeminal cistern, and require less cerebellar retraction. Shifting from midline to off-midline exposure also provides a better view of the cerebellomesencephalic fissure, collicular plate, and trochlear nerve than the midline approaches. Endoscopic assistance may aid exposure of the pineal gland while preserving the bridging veins.

**CONCLUSIONS**: Understanding the characteristics of different

infratentorial routes to the pineal gland will aid in gaining a better view of the pineal gland and cerebellomesencephalic fissure and may reduce the need for venous sacrifice at the level of the tentorial sinuses draining the upper cerebellar surface and the tributaries of the vein of Galen.

## INTRODUCTION

Supracerebellar infratentorial approaches are commonly used for lesions involving the pineal gland.[1,6, 10,13,32] Although the midline route is frequently selected, there is the potential for several off-midline routes between the torcula medially and the asterion at the junction of the transverse and sigmoid sinuses laterally. The midline and off-midline routes differ with respect to depth and angle of approach, area of exposure, and risk to vascular structures along the approach. This study examined the microsurgical and endoscopic anatomy of the various infratentorial routes to the pineal gland, including midline, paramedian, lateral, and far-lateral supracerebellar infratentorial approaches. In addition, this study also defined the depth of the pineal gland and angle of the tentorial surface of the cerebellum through each infratentorial route.

## METHODS

### Cadaveric Dissections

The posterior incisural spaces of 8 formalin-fixed adult cadaveric heads were examined in this study. The arteries and veins of 6 of the 8 formalin-perfused adult cadaveric heads were injected with red and blue colored silicone. All cadaveric heads were examined using 3–40× magnifications provided by an operating microscope and the straight endoscope. Bone dissection was done with a high-speed drill. The dissections followed the steps of the surgical procedures.

### Imaging Analyses

The distance to the pineal gland, slope of upper cerebellar surface, and angle of approach were measured on CT angiography (CTA) images obtained in 20 consecutive adult patients (6 men and 14 women) who underwent CTA for evaluation of unruptured intracranial aneurysms. The mean age of the patients was 62.7 years (range 40–82 years).

The CTA studies were obtained using a 64-slice Toshiba Aquilion 64 system (Toshiba Medical Systems) in 12 cases and a 320-slice Toshiba Aquilion One system in the remaining 8 cases. All imaging studies were performed at Kyushu University Hospital. None of the patients had mass effect due to an intracranial lesion.

The imaging data were analyzed with OsiriX imaging software version 5.9 (http://www.osirix-viewer.com) and observed using 2D multiplanar reconstruction with axial view; all axial planes were confirmed to be parallel to the orbitomeatal line.

In examining the different supracerebellar infratentorial approaches (routes), the distance between the inion and junction of the transverse and sigmoid sinuses was divided into thirds as previously reported.[11] The midline route was directed along the midline below the torcula, the paramedian route along the junction of the medial and intermediate (middle) thirds, the lateral route along the junction of the intermediate and lateral thirds, and the far-lateral above the cerebellum adjacent to the junction of the transverse and sigmoid sinuses (Fig. 1A and B). An axial plane was adjusted to intersect the junction of the transverse and sigmoid sinuses (Fig. 1A). Before measurement, the approach point for each route, the point just below the transverse sinus and on the inner surface of the occipital bone was determined (Fig. 1C–F). For each route, a sagittal plane, perpendicular to the axial plane, that intersected the pineal gland and approach point was used to measure the depth of the pineal gland, slope of the surface of the cerebellum, and angle of approach to the pineal gland (Fig. 1C–F). The distance between the pineal gland and each approach point was measured to establish the depth of the pineal gland for each route. The steepest angle between the orbitomeatal line and the line through the approach point and highest point in the tentorial surface was measured to define the slope of the tentorial surface of the cerebellum (Fig. 1C–F). The angle between the orbitomeatal line and the line through the approach point and the pineal gland was measured to define the approach angle (Fig. 1C–F).

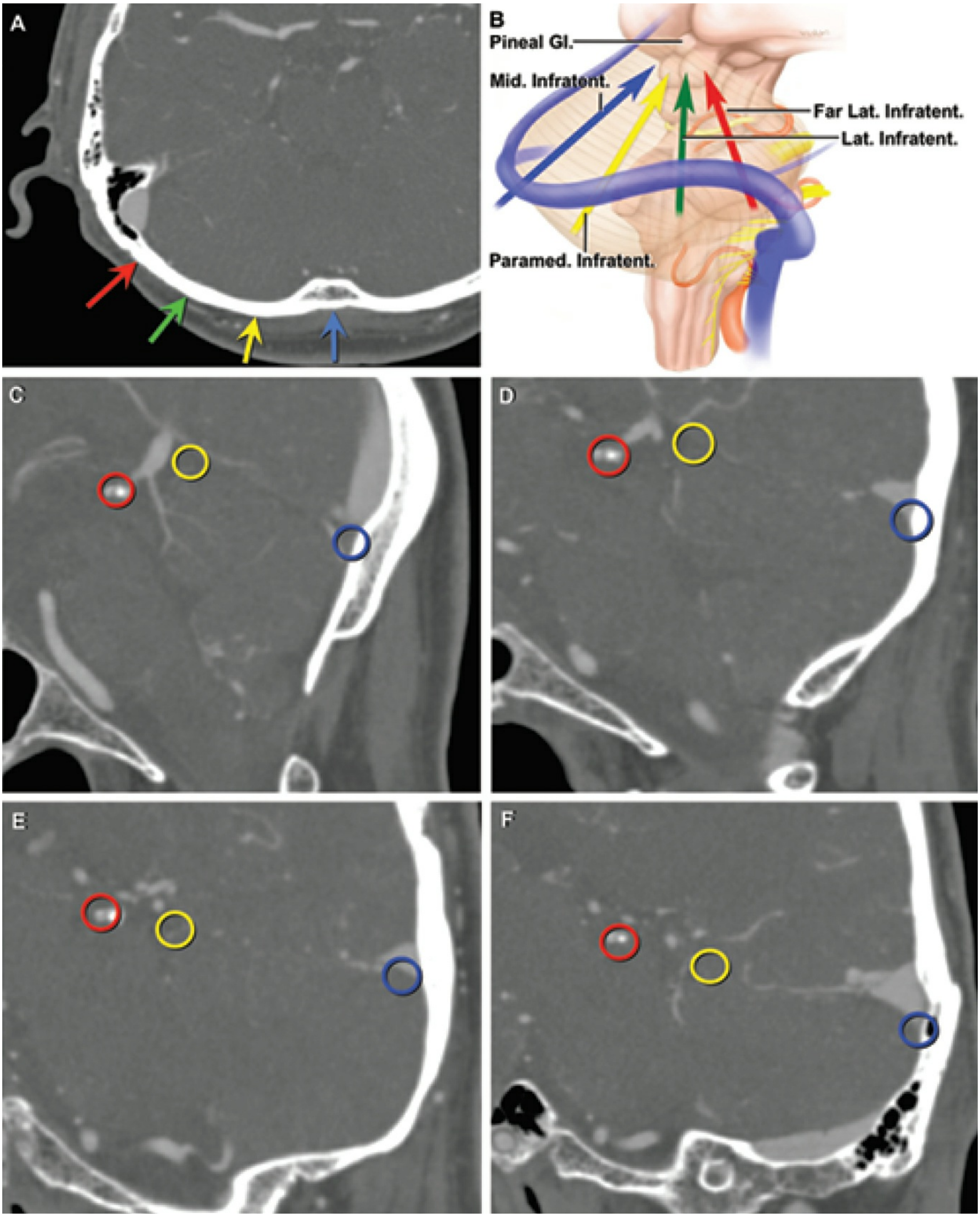


Figure. 1. Measurements of the depth of the pineal gland and angle of the tentorial surface of the cerebellum through the midline, paramedian, lateral, and far-lateral supracerebellar infratentorial routes. A: Axial CT image at the level of the corner of the transverse and sigmoid sinuses (Plane A, the axial plane passing through the junction of the transverse and sigmoid sinuses). In examining the different supracerebellar infratentorial approaches, the distance between the inion and sigmoid

**sinus was divided into thirds. A midline route was directed along the midline (blue arrow), the paramedian route was directed along the junction of the medial and middle thirds (yellow arrow), the lateral route was directed along the junction of the middle and lateral thirds (green arrow), and the far-lateral route was directed above the cerebellum adjacent to the junction of the transverse and sigmoid sinuses (red arrow). B: Right posterolateral view of the supracerebellar infratentorial surgical approach to the pineal gland. Midline (blue arrow), paramedian (yellow arrow), lateral (green arrow), and far-lateral routes (red arrow) are shown. Copyright Satoshi Matsuo. Published with permission. C: Reconstructed sagittal CT image perpendicular to the plane shown in Panel A (Plane A) and intersecting the pineal gland (red circle) and the approach point (blue circle) of the midline route. The approach point was defined as the point just below the sigmoid sinus on the inner surface of the occipital bone. The distance between the pineal gland (red circle) and the approach point (blue circle) was defined as the depth of the pineal gland. The angle of the tentorial surface of the cerebellum was defined as the angle between the orbitomeatal plane and the line through the approach point (blue circle) and the highest point of the tentorial surface of the cerebellum (yellow circle). D: Reconstructed sagittal CT image perpendicular to Plane A and intersecting the pineal gland (red circle) and the approach point (blue circle) of the paramedian route. E: Reconstructed sagittal CT image perpendicular to Plane A and intersecting the pineal gland (red circle) and the approach point (blue circle) of the lateral route. F: Reconstructed sagittal CT image perpendicular to Plane A and intersecting the pineal gland (red circle) and the approach point (blue circle) of the far-lateral route. Gl. = gland; Infratent. = infratentorial; Lat. = lateral; Mid. = midline; Paramed. = paramedian. (Images courtesy of AL Rhoton, Jr.)**

## RESULTS

### Basic Anatomy of the Pineal Region

The pineal gland is positioned inferior to the anterior part of the splenium, posterior to the third ventricle, above the collicular plate, anterior to the vein of Galen, and between the pulvinars. This deep region, also referred to as the posterior incisural space, is located posterior to the midbrain and corresponds to the region of the pineal gland and vein of Galen (Figs. 2 and 3).

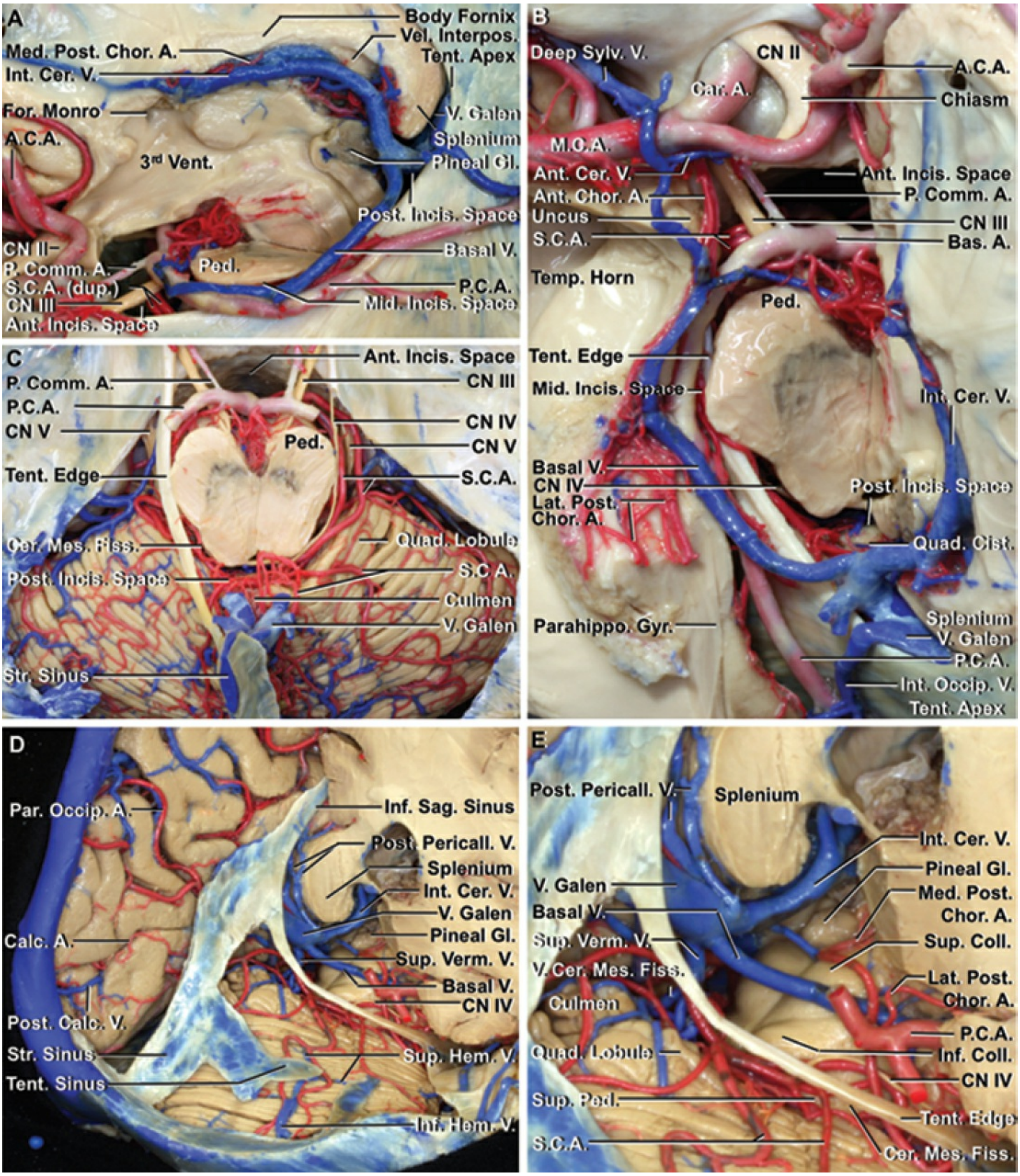


**Figure. 2. Neurovascular relationships of the posterior incisural space. A: Lateral view of the left tentorial incisura. The left cerebral hemisphere has been removed. The tentorial incisura is located between the tentorial edges. The tentorial incisura is divided into anterior, middle, and posterior spaces in relation to the brainstem. The posterior incisural**

space, the site of the pineal gland, is located between the posterior midbrain and the tentorial apex. The posterior cerebral and superior cerebellar arteries arise in the anterior incisural space, and pass around the brainstem to reach the posterior incisural spaces. The internal cerebral vein, which courses through the velum interpositum, and the basal vein, which arises in the anterior incisural space, course around the midbrain, join at the posterior incisural space, and empty into the vein of Galen. The pineal gland is located posterior to the third ventricle, anterior to the vein of Galen, inferior to the anterior part of the splenium, and superior to the collicular plate. B: Superior view of the left tentorial incisura after removal of all of the left cerebral hemisphere except the temporal lobe. The roof of the temporal horn and part of the parahippocampal gyrus have been removed. The basal vein, which originates in the anterior incisural space at the union of the anterior cerebral and deep middle cerebral veins, and internal cerebral vein join in the posterior incisural space and empty into the vein of Galen. C: Superior view of the tentorial incisura and cerebellum. The cerebral hemispheres and tentorium have been removed to expose the tentorial surface of the cerebellum. The distal part of the posterior cerebral artery has been removed to expose the course of the superior cerebellar artery. The superior cerebellar artery, which usually arises below the oculomotor nerve as a single trunk from the basilar artery, arises on the right side as a duplicated trunk. The superior cerebellar artery courses below the trochlear nerve and above the trigeminal nerve, to reach the cerebellomesencephalic fissure, which extends downward between the midbrain and the cerebellum. The superficial part of the posterior lip of the fissure is formed by the culmen in the midline and the quadrangular lobule laterally. After leaving the fissure, the superior cerebellar artery gives rise to the branches to the tentorial surface of the cerebellum. D: Posterolateral view of the left posterior incisural space and tentorial surface of the cerebellum. The right occipital, parietal, and temporal lobes have been removed at the level of the body of the lateral ventricle. The right tentorium has been removed to expose the tentorial surface of the cerebellum. The superior and inferior hemispheric veins drain the tentorial surface of the cerebellum and join before emptying into the tentorial sinuses. The posterior pericallosal vein, which drains the posterior part of the cingulate gyrus, empties around the splenium into the vein of Galen in the quadrigeminal cistern. E: Enlarged view. The internal cerebral, posterior pericallosal, basal, and superior vermian veins empty into the vein of Galen. The superior and inferior colliculi are located posterior and inferior to the pineal gland. The medial posterior choroidal artery courses beside the pineal gland and enters the velum interpositum in the roof of the third ventricle. The lateral posterior choroidal artery, which arises from the posterior cerebral artery, enters into the lateral ventricle through the choroidal fissure. A. = artery; A.C.A. = anterior cerebral artery; Ant. = anterior; Bas. = basilar; Calc. = calcarine; Car. = carotid; Cent. = central; Cer. = cerebral, cerebellar; Cer. Mes. = cerebellomesencephalic; Chor. = choroidal; Cing. = cingulate; Cist. = cistern; CN = cranial nerve; Coll. = colliculus; dup. = duplicate; Fiss. = fissure; For. = foramen (of); Gyr. = gyrus; Hem. = hemispheric; Incis. = incisural; Inf. = inferior; Int. = internal; Interpos. = interpositum; M.C.A. = middle cerebral artery; Med. = medial, medullary; Mid. = middle; Occip. = occipital; P.C.A. = posterior cerebral artery; P. Comm. = posterior communicating; Par. = parietal; Parahippo. = parahippocampal; Ped. = peduncle; Pericall. = pericallosal; Post. = posterior; Quad. = quadrigeminal, quadrangular; S.C.A. = superior cerebellar artery; Sag.= sagittal; Str. = straight; Sulc. = sulcus; Sup. = superior; Sylv. = sylvian; Temp. = temporal; Tent. = tentorium, tentorial; V. = vein (of); Vel. = velum; Vent. = ventricle; Verm. = vermian. (Images courtesy of AL Rhoton, Jr.)

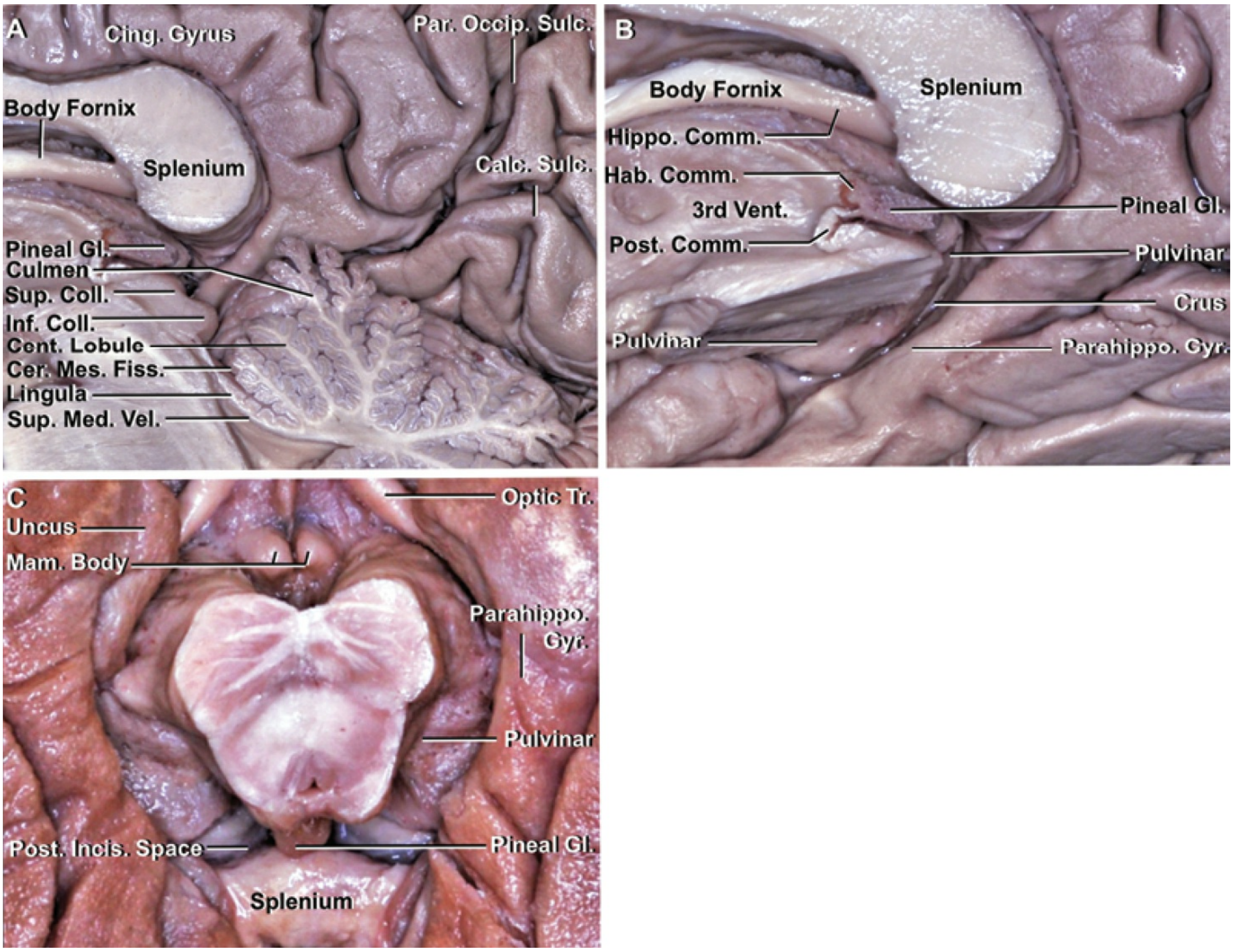


Figure. 3. Neural relationships of the posterior incisural space. A: Sagittal view of the posterior incisura space after removal of the left cerebral hemisphere, cerebellum, and brainstem. The anterior wall of the posterior incisural space is formed by the pineal gland, the superior and inferior colliculi, and the lingula of the vermis. The roof of the posterior incisural space is formed by the lower surface of the splenium and posterior part of the body of the fornix. The floor of the posterior incisural space is formed by the culmen of the vermis and central lobule. The posterior incisural space extends inferiorly into the cerebellomesencephalic fissure. B: Right posterosuperior view after removal of the right half of the brainstem at the level of the superior colliculus. The habenular and posterior commissures form the attachment of the gland to the posterior part of the third ventricle. The pulvinar, crus of the fornix, and parahippocampal gyrus form the lateral wall of the posterior incisural space. C: Inferior view of the medial temporal lobe and lateral wall of the posterior incisural space. The brainstem and cerebellum have been removed. The pulvinar, located just lateral to the pineal body, and the crus of the fornix, located posterior to the pulvinar, form the lateral wall

**of the posterior incisura space. Cer. Mes. = cerebellomesencephalic; Coll. = colliculus; Comm. = commissure; Hab. = habenular; Hippo. = hippocampal; Mam. = mammillary; Tr. = tract. (Images courtesy of AL Rhoton, Jr.)**

## Neural Relationships

The posterior incisural space is surrounded by neural tissue in all directions except posteriorly. The anterior wall is formed by the pineal gland, superior and inferior colliculi, lingula of the vermis, and superior cerebellar peduncle in order from rostral to caudal (Figs. 2A, 2D, 2E, and 3). The habenular commissure forms the upper and the posterior commissure the lower attachment of the gland to the posterior part of the third ventricle (Fig. 3B). The median part of the anterior wall inferior to the collicular plate is formed by the lingula of the vermis, the uppermost division of the vermis, and the lateral part by the superior cerebellar peduncle (Figs. 2E and 3A). The roof of the posterior incisural space consists of the inferior surface of the splenium, the terminal part of the crura of the fornices, and the hippocampal commissure, which courses between the crura (Figs. 2A, 2D, 2E, 3A, and 3B). The floor of the posterior incisural space is formed by the culmen of the vermis and central lobule medially and by the quadrangular lobules of the hemispheres laterally (Figs. 2D, 2E, and 3A). The posterior incisural space extends inferiorly into the cerebellomesencephalic fissure (Fig. 1F). The lateral wall is formed by the pulvinar, crus of the fornix, and the medial surface of the cerebral hemisphere below the splenium (Fig. 3B). The pulvinars are located just lateral to the pineal body (Fig. 3C). The crura of the fornix forms the lateral walls posterior to the pulvinars (Fig. 3B and C). The posterior part of the lateral wall is formed by the parahippocampal and dentate gyri (Fig. 3B and C).[24]

## Arterial Relationships

Both the posterior cerebral artery and superior cerebellar artery and their branches course through the posterior incisural space. The posterior cerebral artery arises at the basilar bifurcation and encircles the midbrain, passing through the crural and ambient cisterns to reach the posterior incisural space, and usually bifurcates into its terminal branches, the calcarine and parieto-occipital arteries, near where it crosses above the free edge of the tentorium (Fig. 2D).[24,34] The superior cerebellar artery arises from the basilar artery near its apex, passes below the oculomotor nerve, and encircles the brainstem (Fig. 2A–C). The artery courses below the trochlear nerve and above the trigeminal nerve to enter the cerebellomesencephalic fissure (Fig. 2C). After leaving the fissure, the artery gives rise to the branches that supply the tentorial surface of the cerebellum (Fig. 2D and E). The superior cerebellar artery usually arises as a single trunk but may also arise as a duplicate trunk (Fig. 2A–C).[21] The posterior cerebral arteries supply the structures above the level of the lower margin of the superior colliculus, and the superior cerebellar arteries supply the structures below the upper margin of the inferior colliculus.[24]

## Venous Relationships

The internal cerebral and basal veins and the vein of Galen and their tributaries pass through the posterior incisural space (Fig. 2A, B, D, and E). The internal cerebral vein originates from just behind the foramen of Monro and passes through the velum interpositum to enter the posterior incisural space where the vein joins its contralateral partner to form the vein of Galen (Fig. 2A, B, D, and E). The basal vein originates from the union of the anterior cerebral and deep Sylvian veins (Fig. 2B). The basal vein courses posteriorly between the midbrain and temporal lobe and reaches the posterior incisural space to empty into the internal cerebral vein or vein of Galen (Fig. 2A, B, D, and E).[22] The anterior calcarine vein, also known as the internal occipital vein, drains the anterior part of the cuneus and lingula, and empties into the vein of Galen.[22] The posterior pericallosal vein, which drains the posterior part of the cingulate gyrus, and passes around the splenium to empty into the vein of Galen or internal cerebral vein in the quadrigeminal cistern (Fig. 2D and E).[22] The collicular veins drain the collicular plate and course backward to empty into the vein of the cerebellomesencephalic fissure, vein of Galen, or superior vermian vein (Figs. 4C, 4D, and 5).2 The pineal veins originate near the habenular trigone, and course backward superior or inferolateral to the pineal gland to empty into the internal cerebral vein or vein of Galen (Figs. 4C, 4D, and 5).[2] The vein of Galen courses below the splenium to empty into the straight sinus at the tentorial apex (Figs. 2A, 2B, 2D, and 2E). The junction of the vein of Galen with the straight sinus varies from being nearly flat if the tentorial apex is located below the splenium to forming a sharp angle if this apex is located above the level of the splenium, so that the vein of Galen must turn sharply upward to reach the straight sinus at the tentorial apex.[22]

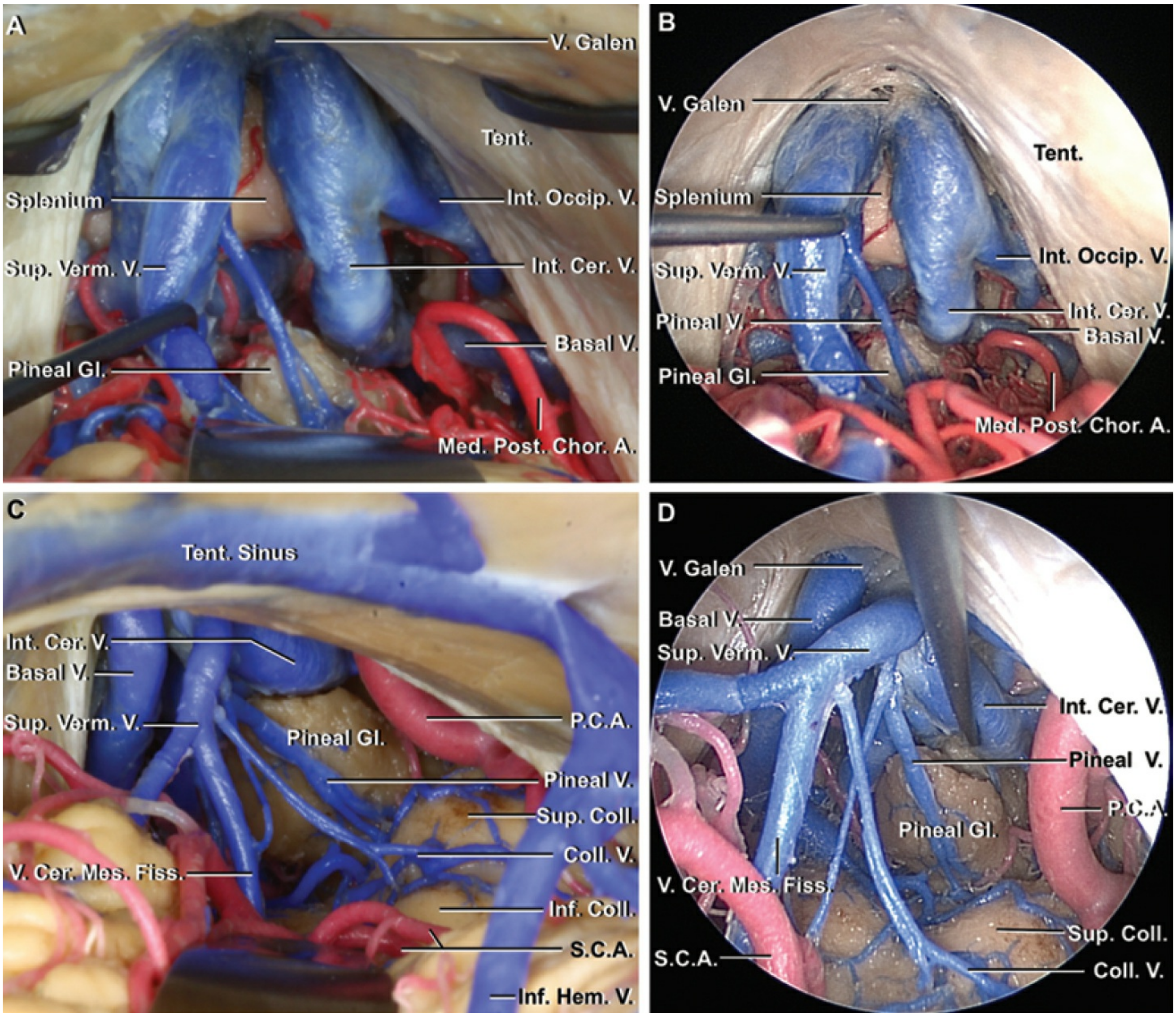


**Figure. 4. Midline (A and B) and right paramedian (C and D) infratentorial supracerebellar microsurgical and endoscopic approaches to the pineal gland. A: Microsurgical midline approach to the pineal gland. Opening the quadrigeminal cistern exposes the superior vermian, internal occipital, basal, and internal cerebral veins and the vein of Galen. The superior vermian vein may need to be retracted or sacrificed to expose the pineal region in a midline approach. B: Endoscopic midline approach. C:**

Microsurgical right paramedian approach to the pineal gland. The pineal gland and the superior and inferior colliculi can be exposed between the superior vermian and the internal cerebral veins without venous sacrifice. The off-midline views of the gland open the viewing angle between the large veins around the gland. D: Endoscopic paramedian approach. The pineal gland can be exposed between the galenic tributaries. Retracting the cerebellum can provide access to the superior and inferior colliculi. Coll. = collicular, colliculus; Med. = medial; Tent. = tentorial, tentorium. (Images courtesy of AL Rhoton, Jr.)

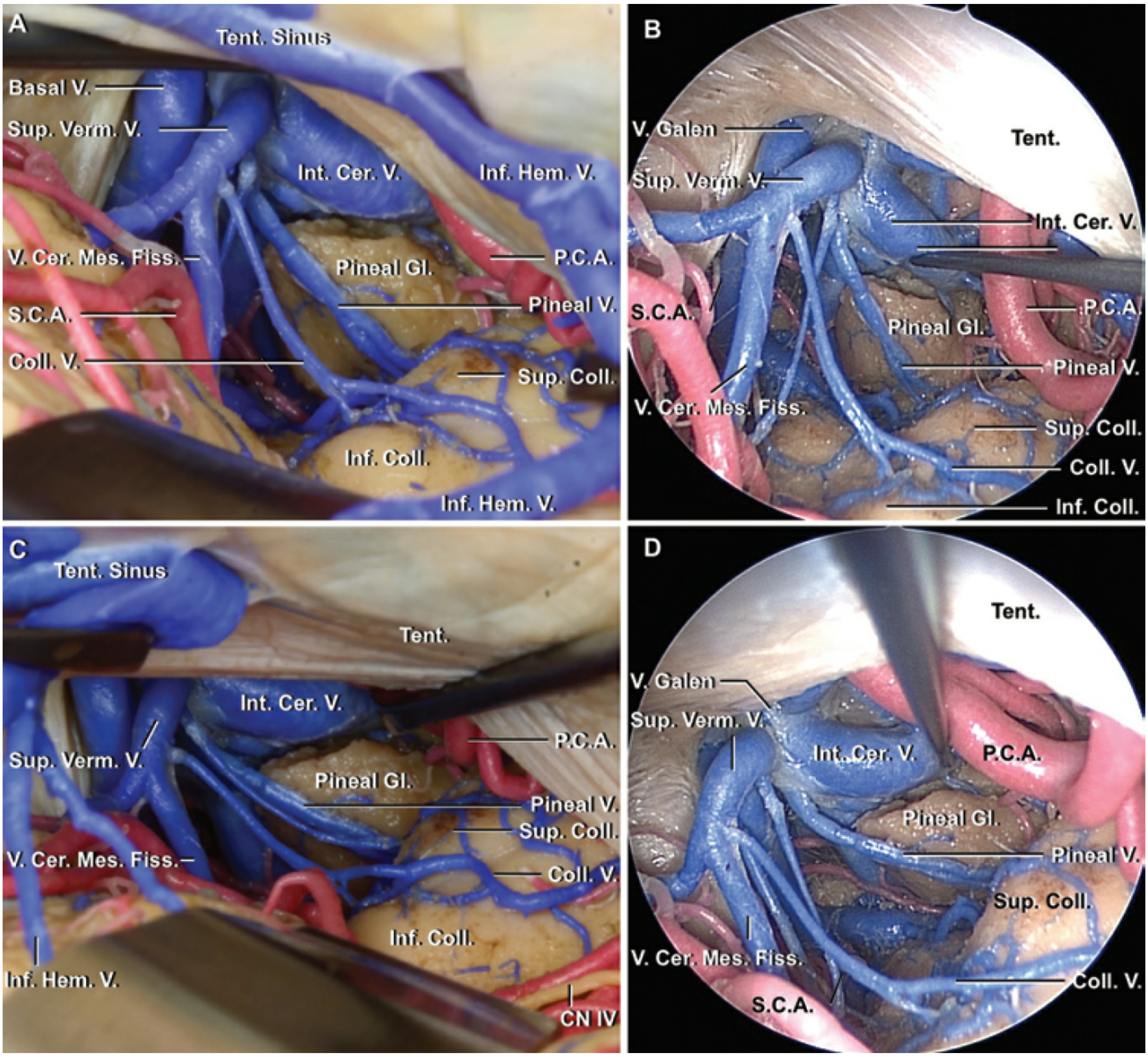


Figure. 5. Right lateral (A and B), and far-lateral (C and D) infratentorial supracerebellar microsurgical and endoscopic approaches to the pineal gland. A: Microsurgical right lateral approach to the pineal gland. Note that the off-midline approaches permit exposure between the hemispheric veins emptying into the tentorial sinuses at a superficial

**level and anterior to the superior vermian vein at the level of the vein of Galen. B: Endoscopic lateral approach. C: Microsurgical right far-lateral approach to the pineal gland. The farther laterally the approach moves, the wider the approach between the superior vermian and internal cerebral veins becomes. D: Endoscopic far-lateral approach. Cer. = cerebral; Cer. Mes. = cerebellomesencephalic; Coll. = collicular, colliculus; Tent. = tentorial, tentorium. (Images courtesy of AL Rhoton, Jr.)**

## Infratentorial Approaches

### Depth and Angle of Approach

The depth of the pineal gland at the midline below the torcula was the shortest among the 4 routes (mean [± SD] 5.9 ± 0.4 cm, range 4.7–6.5 cm; Table 1). The depths of the 3 off-midline routes are almost identical, and all are more than 5 mm deeper than the approach along the midline (Table 1). The mean value of the slope of the tentorial surface in the midline approach was 35.2° ± 6.9° (range 21.0°–46.8°), the steepest of the mean slope values obtained for the 4 approaches. The angle decreased as the approach shifted laterally (Table 2). The mean value of the approach angle in the midline approach was 20.3° ± 5.8° (range 7.6°–30.1°), which is almost identical to that of the paramedian and lateral approaches, whereas the mean approach angle of the far-lateral approach was largest among of the 4 approaches (24.0° ± 3.3°, range 17.1°–29.6°; Table 3).

**TABLE 1. Depth of the pineal gland in the supracerebellar infratentorial approaches**

| Approach | Mean (Range) | SD |
|---|---|---|
| Midline (n = 20) | 5.9 cm (4.7–6.5 cm) | 0.4 cm |
| Paramedian (n = 40) | 6.5 cm (5.4–7.1 cm) | 0.5 cm |
| Lateral (n = 40) | 6.7 cm (5.8–7.3 cm) | 0.4 cm |
| Far lateral (n = 40) | 6.7 cm (6.0–7.2 cm) | 0.3 cm |

**TABLE 2. Angle between the tentorial surface of the cerebellum and orbitomeatal line in the supracerebellar approaches**

| Approach | Mean (Range) | SD |
|---|---|---|
| Midline (n = 20) | 35.2° (21.0°–46.8°) | 6.9° |
| Paramedian (n = 40) | 24.7° (9.9°–34.9°) | 5.7° |
| Lateral (n = 40) | 17.1° (6.4°–24.3°) | 4.8° |
| Far lateral (n = 40) | 17.5° (11.3°–26.2°) | 4.0° |

**TABLE 3. Angle between the pineal gland and orbitomeatal line in the supracerebellar approaches**

| Approach | Mean (Range) | SD |
|---|---|---|
| Midline (n = 20) | 20.3° (7.6°–30.1°) | 5.8° |
| Paramedian (n = 40) | 19.1° (8.7°–28.2°) | 5.1° |
| Lateral (n = 40) | 19.3° (11.3°–28.2°) | 4.1° |
| Far lateral (n = 40) | 24.0° (17.1°–29.6°) | 3.3° |

## Arterial Considerations

The infratentorial approach is directed between the posterior cerebral artery trunks above and the superior cerebellar artery trunks below (Figs. 4 and 5). The posterior cerebral artery trunks are largely supratentorial but overlap the incisural space from above, and the superior cerebellar artery trunk courses largely below the pineal gland in the cerebellomesencephalic fissure and on the tentorial surface. These vessels do not cross posterior to the pineal gland unless they are tortuous or elongated. The small neural branches of the posterior cerebral, superior cerebellar, and choroid arteries supplying the walls of the posterior incisural space, including the colliculi, thalamus, and pineal gland are at greater risk than the major arterial trunks during removal of pineal lesions.

## Venous Considerations

Significant venous trunks are encountered at 2 levels in the infratentorial approach. The first is at the level of the veins draining the cerebellum that cross the infratentorial space to empty into the tentorial sinuses draining into the torcula and straight and transverse sinuses. The second is at the level of the quadrigeminal cistern where multiple large tributaries of the vein of Galen surround the gland (Figs. 4, 5, and 6).

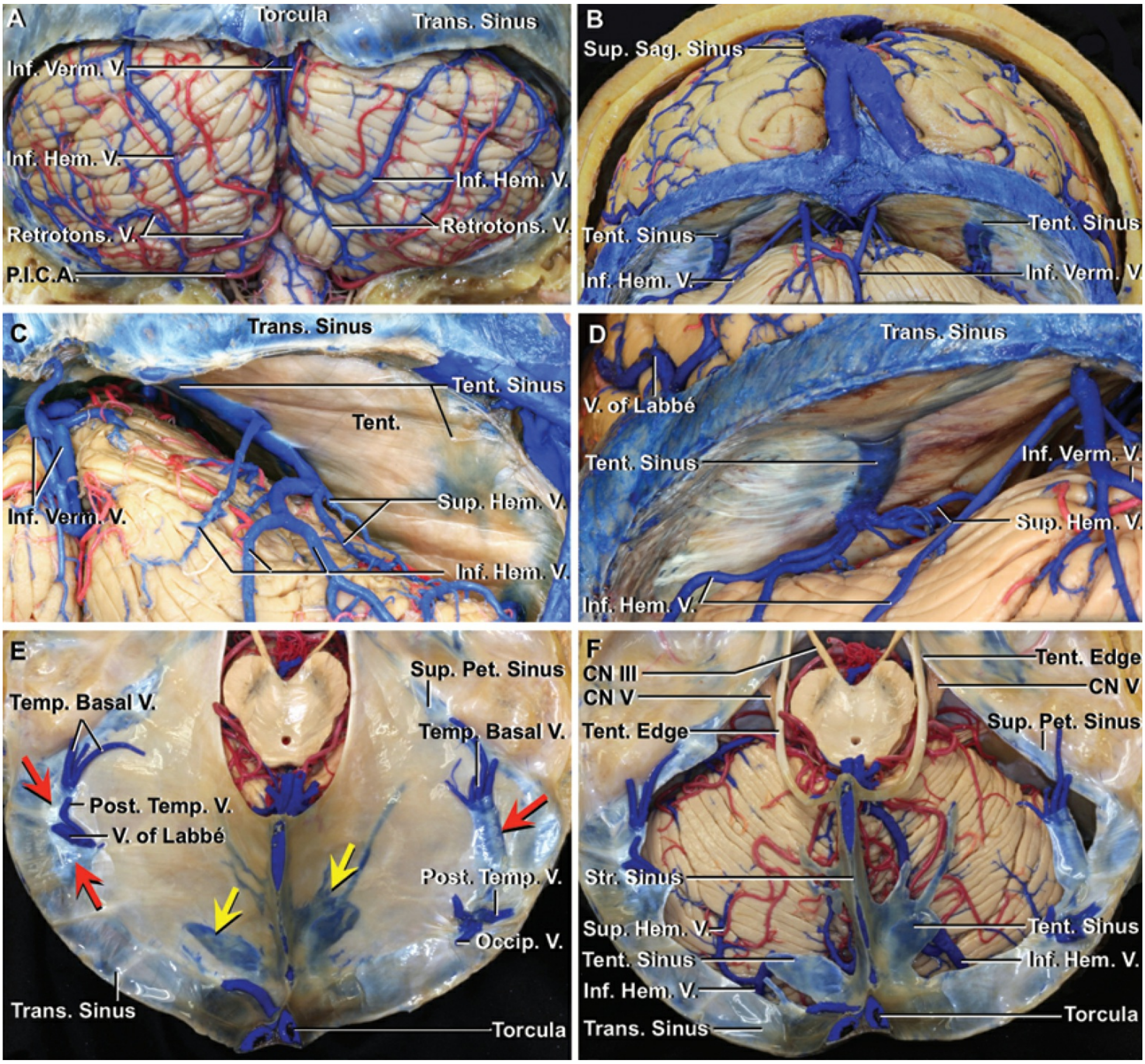


**Figure. 6. Supracerebellar infratentorial microsurgical approaches to the pineal gland. A: Suboccipital surface of the cerebellum. The retrotonsilar veins ascend to join the inferior vermian veins, which ascend along the vermohemispheric fissures and empty into the transverse sinus near the torcula and midline. The inferior hemispheric veins ascend to empty into venous sinuses in the tentorium. The right inferior hemispheric veins anastomose with the retrotonsilar veins. B: Posterior view beneath the tentorium. The inferior vermian vein drains the tonsil and inferior vermis and adjacent part of the hemisphere and empties into the transverse**

**sinus near the midline. The superior and inferior hemispheric veins drain the suboccipital and tentorial cerebellar surfaces and empty into the tentorial sinus, which may empty into either the straight (C) or transverse sinus (D). The off-midline infratentorial approaches directed between the 2 groups of hemispheric bridging veins can often access the pineal gland without sacrificing any of these bridging veins, while the midline approach will often require significant retraction or obliteration of some of these bridging veins. C: Posterior view beneath the right half of the tentorium. The superior and inferior hemispheric veins drain the suboccipital and tentorial cerebellar surfaces and empty into a tentorial sinus, which empties into the straight sinus in the posterior fossa. D: Posterior view beneath the left half of the tentorium. The superior and inferior hemispheric veins drain the suboccipital and tentorial cerebellar surfaces and empty into a tentorial sinus that empties into the transverse sinus. E: Superior view of the tentorium. The cerebral hemispheres have been removed while preserving the tentorium. Each half of the tentorium has 2 tentorial sinuses. The medial tentorial sinuses (yellow arrows) course medially to empty into the straight sinus near the junction of the straight and transverse sinuses. The lateral tentorial sinuses (red arrows), formed by the union of veins from the basal and lateral surfaces of the temporal and occipital lobes, including the vein of Labbé and temporobasal and occipital veins, course laterally to empty into the terminal portion of the transverse sinus. F: Superior view of the tentorial cerebellar surface. The tentorium has been removed while preserving the tentorial edges and the tentorial, superior petrosal, straight, and transverse sinuses. The medial tentorial sinuses formed by the union of the superior and inferior hemispheric veins course medially to empty into the torcula or straight sinus. P.I.C.A. = posterior inferior cerebellar artery; Pet. = petrosal; Retrotons. = retrotonsilar; Tent. = tentorial, tentorium; Trans. = transverse.**

After the dura mater is opened, the bridging veins crossing the infratentorial space between the tentorial surface of the cerebellum and the tentorial sinuses usually come into view (Fig. 6).[26] Dividing even a limited number of these veins may cause serious cerebellar swelling and complications such as hemorrhagic infarction because of the large areas drained.[1,7,19] In the midline approach, bridging veins directed to the torcula and straight sinus may need to be retracted or obliterated in order to reach the quadrigeminal cistern and gland. Upon reaching the quadrigeminal cistern, the tributaries of the vein of Galen from the superior vermis and cerebellomesencephalic fissure are encountered directly below the pineal gland and may block the exposure of the gland along the midline (Fig. 4A and B).[18,23,26] In the off-midline approaches, the superior hemispheric veins, which drain the anterior part of the tentorial cerebellar surface, and the inferior hemispheric veins from the suboccipital surface, which ascend and cross the margin of the occipital and tentorial cerebellar surfaces, frequently join to form bridging veins that drain a large part of the cerebellum. These large bridging veins commonly drain into the tentorial sinus in the intermediate third of the tentorium along the lateral off-midline infratentorial route (Fig. 6B–F).[15,26] These bridging veins would be less likely to be encountered in the paramedian and far-lateral off-midline approaches than in the lateral route. However, there is considerable variability in the site of these bridging veins, and the off-midline routes are most likely to allow their preservation.[17,26,29] Selecting from among the off-midline routes may avoid or reduce the need for venous sacrifice.[17,29]

Dissecting the arachnoid mater surrounding the quadrigeminal cistern exposes the second tier of veins formed by the tributaries of the vein of Galen, which block access to the pineal region. These tributaries of the vein of Galen, including the superior vermian and vein of the cerebellomesencephalic fissure, approach the vein of Galen from the inferior direction in the midline, and others like the internal cerebral and basal vein reach the vein of Galen from near the midline superiorly (Figs. 2A, 2B, 2D, 2E, 4, and 5). In the midline approach, the superior vermian and cerebellomesencephalic veins are aligned one above the other below the pineal gland and may need to be retracted or sacrificed if the approach is directed strictly along the midline (Figs. 4 and 5). Shifting the approach slightly laterally off the midline may avoid the need for sacrifice of these veins. An advantage of the off-midline approaches, as they move farther laterally, is that they open the angle between the galenic tributaries exiting the cerebellomesencephalic fissure below and the internal cerebral veins from above and provide access to the gland, often without venous sacrifice except for possibly the small tributaries, such as the pineal vein, draining directly from the pineal gland and adjacent neural structures (Figs. 4 and 5).

## DISCUSSION

### Depth and Slope

It is well established that in the midline approaches the prominence of the cerebellar culmen and quadrangular lobules limits the working angle available for instruments and interferes with adequate illumination at the pineal gland's depth and that the depth and slope of the upper surface of the cerebellum through each route can affect surgical maneuverability. However, these differing depths and slopes have not been previously established. We found that the differences in depth among off-midline routes are only a few millimeters, although the off-midline routes are more than 5 mm deeper than the midline approach, which provides the shortest approach. On the other hand, the slope of the upper cerebellar (tentorial) surface of each route changed dramatically as the approaches shifted from medial to lateral. Among infratentorial approaches, the midline route is approximately twice as steep as the lateral and far-lateral routes. We also found that the slope of the cerebellar (tentorial) surface in the midline and paramedian routes is larger than the angles of these approaches. In contrast, the slope of the cerebellar (tentorial) surface in the lateral and far-lateral routes is smaller than the angles of these approaches. Thus, midline and paramedian routes require greater retraction of the cerebellum to approach the pineal gland than do the lateral and far-lateral routes. The off-midline routes, especially through the intermediate or lateral third of the tentorium, require less retraction of the cerebellum to reach the pineal gland. However, based on our previous studies, the routes through the intermediate third carry a higher risk of needing to sacrifice bridging veins from the upper cerebellar surface to the tentorial sinuses.[15,26]

Supracerebellar infratentorial approaches are commonly selected for lesions of the pineal gland.[6,10,13,32] The traditional infratentorial approach to the pineal gland is along the midline below the torcula,[25] but it requires greater cerebellar retraction than off-midline approaches due to the height of the culmen of the vermis. The off-midline infratentorial supracerebellar approaches, namely the paramedian, lateral, and far-lateral routes, have been developed to minimize the need for cerebellar retraction and facilitate exposure of different parts of the posterior incisural space.[8,12,14,17,19,20,28,30,31] The paramedian and lateral routes have been selected for pineal lesions, and the far-lateral route has been selected for lesions in posterolateral mesencephalon rather than the pineal gland.[14,30] Komune et al.[11] reported the far-lateral supracerebellar infratentorial approach to the inferior colliculus, which included a lateral suboccipital craniotomy without tentorial incision. In that study, we found that the pineal gland could also be accessed through a far-lateral approach directed adjacent to the transverse and sigmoid sinuses. The off-midline approaches also have the advantage of providing a more direct view of the structures along the anterior wall of the cerebellomesencephalic fissure, such as the collicular plate and the fourth cranial nerve. A disadvantage of the more lateral approaches is that the pulvinar may hide part of the pineal region and prevent access to lesions extending forward in the midline from the pineal gland between the 2 halves of the thalamus in the roof of the third ventricle.

## Arteries

The trunks of the superior cerebellar and posterior cerebral arteries supplying the pineal region are usually not at as great a risk in an approach to the pineal region as the veins because these arteries do not cross posterior to the pineal gland as do the veins that are at greater risk in approaches to the pineal region. The main arterial risk is to the small perforating branches of the posterior cerebral, superior cerebellar, and choroidal arteries that enter the borders of the quadrigeminal cistern.

## Veins

Sacrificing the superior vermian, hemispheric, or vermian bridging veins has been considered relatively safe.[5,6,10,20] Kodera et al.[10] reported that these veins can be sacrificed if the collateral circulation of each vein is preserved. However, Page et al.[18] reported a case of severe cerebellar swelling after sacrifice of the hemispheric and vermian bridging veins through the midline approach. Jakola et al.[7] reported that sacrificing even a limited number of tentorial bridging veins may cause venous infarction or hemorrhage in the cerebellum.[14] Although the anatomical relationship of the venous system of the cerebellum and tentorium has been well investigated, it is impossible to determine which veins can be sacrificed before or during an operation.[15,16,23,26] Even preoperative venography identifies only half the number of these veins seen in a cadaveric study.[4] To avoid hazardous complications, the goal of limiting sacrifice of bridging veins to the smallest number and to veins of the smallest size should be one consideration in directing the approach. Commonly, these smaller veins join to form bridging veins entering the tentorial sinuses, and if occluded may sacrifice large areas of cerebellar drainage. Brain retraction combined with venous sacrifice entails a higher risk of brain damage than either alone.[9] To avoid hazardous complications, reducing the need for brain retraction should be one consideration in directing the approach. Endoscopic supracerebellar infratentorial approaches require less cerebellar retraction and may aid in accessing pineal lesions without sacrificing bridging veins.

## Surgical Exposure

A common surgical exposure for a pineal lesion is through a vertical suboccipital midline incision. With this incision, the bony exposure below the transverse sinus and adjacent to the midline can be extended laterally to access the paramedian and adjacent lateral approach on either side. Another common approach for accessing the far-lateral part of the upper surface of the cerebellum is the retrosigmoid approach, through which the bone exposure can be extended medially to take advantage of a lateral approach, depending on the venous architecture related to the veins entering the tentorial sinuses. In addition, the retrosigmoid incision can be shifted medially away from its usual position centered below the asterion for the para median and lateral approaches. Another approach taking advantage of the paramedian, lateral, and far-lateral approaches on one side is a horseshoe-type flap that extends from the mastoid area upward along the superior nuchal line to the torcula and then downward in the midline. Most pineal tumors are accessed through a midline incision. There are, however, distinct advantages to having access to the off-midline approaches, which reduce the possible need for sacrifice of veins at the level of the tentorial bridging veins and the quadrigeminal cistern.

### Endoscopic Infratentorial Approaches

The endoscopic infratentorial supracerebellar approach has been applied for lesions such as pineal cysts, epidermoids, and astrocytomas,[3,27] and it is considered an alternative to the microscopic approaches to the pineal gland.[33] Recently, Hasan et al.[33] investigated the endoscopic and microsurgical supracerebellar infratentorial approaches quantitatively by measuring surgical freedom. They reported that their lateral route, which we call far-lateral in the present study, provides the largest surgical exposure and the most vertical attack angle, and the midline route provides the largest horizontal angle when approaching the pineal gland through the endoscopic supracerebellar infratentorial approaches.[33] Endoscopic supracerebellar infratentorial approaches require less cerebellar retraction and may aid in accessing pineal lesions without sacrificing bridging veins (Figs. 4B, 4D, 5B, and 5D).

## CONCLUSIONS

The supracerebellar infratentorial approaches, including the median, paramedian, lateral, and far-lateral routes, provide access for the removal of most tumors involving the pineal gland. Understanding the difference among supracerebellar infratentorial routes, including the differences in depth and angle of the approach, and selecting the route that requires division of the least number of bridging veins at the level of both the infratentorial space above the cerebellum and at the quadrigeminal cistern may reduce postoperative complications. Endoscopic supracerebellar infratentorial approaches may also be helpful in approaching the pineal gland, especially in defining a route that minimizes venous sacrifice.

Contributors: Satoshi Matsuo, MD, Serhat Baydin, MD, Abuzer Güngör, MD, Koichi Miki, MD, Noritaka Komune, MD, PhD, Ryota Kurogi, MD, Koji Iihara, MD, PhD, and Albert L. Rhoton, Jr, MD

Content from Matsuo S, Baydin S, Güngör A, Miki K, Komune N, Kurogi R, Iihara K, Rhoton AL, Jr. Midline and off-midline infratentorial supracerebellar approaches to the pineal gland. *J Neurosurg* 2017;126:1984–1994. doi.org/10.3171/2016.7.JNS16277.

*The Neurosurgical Atlas* is honored to maintain the legacy of Albert L. Rhoton, Jr, MD.

## REFERENCES


1. Azab WA, Nasim K, Salaheddin W: An overview of the current surgical options for pineal region tumors. Surg Neurol Int 5:39, 2014
2. Chaynes P: Microsurgical anatomy of the great cerebral vein of Galen and its tributaries. J Neurosurg 99:1028–1038, 2003
3. Gore PA, Gonzalez LF, Rekate HL, Nakaji P: Endoscopic supracerebellar infratentorial approach for pineal cyst resection: technical case report. Neurosurgery 62 (3 Suppl 1):108–109, 2008
4. Han H, Yao Z, Wang H, Deng X, Yu Fong AH, Zhang M: Dural entrance of the bridging vein into the transverse sinus provides a reliable measure for preoperative planning: an anatomic comparison between cadavers and neuroimages. Neurosurgery 62 (5 Suppl 2):ONS289–ONS296, 2008
5. Hart MG, Santarius T, Kirollos RW: How I do it—pineal surgery: supracerebellar infratentorial versus occipital transtentorial. Acta Neurochir (Wien) 155:463–467, 2013
6. Hernesniemi J, Romani R, Albayrak BS, Lehto H, Dashti R, Ramsey C III, et al: Microsurgical management of pineal region lesions: personal experience with 119 patients. Surg Neurol 70:576–583,

2008

7. Jakola AS, Bartek J Jr, Mathiesen T: Venous complications in supracerebellar infratentorial approach. Acta Neurochir (Wien) 155:477–478, 2013
8. Kaku Y, Yonekawa Y, Taub E: Transcollicular approach to intrinsic tectal lesions. Neurosurgery 44:338–343, 1999
9. Kasama A, Kanno T: A pitfall in the interhemispheric translamina terminalis approach for the removal of a craniopharyngioma. Significance of preserving draining veins. Part II. Experimental study. Surg Neurol 32:116–120, 1989
10. Kodera T, Bozinov O, Sürücü O, Ulrich NH, Burkhardt JK, Bertalanffy H: Neurosurgical venous considerations for tumors of the pineal region resected using the infratentorial supracerebellar approach. J Clin Neurosci 18:1481–1485, 2011
11. Komune N, Yagmurlu K, Matsuo S, Miki K, Abe H, Rhoton AL Jr: Auditory brainstem implantation: anatomy and approaches. Neurosurgery 11 (Suppl 2):306–321, 2015
12. Laborde G, Gilsbach JM, Harders A, Seeger W: Experience with the infratentorial supracerebellar approach in lesions of the quadrigeminal region, posterior third ventricle, culmen cerebelli, and cerebellar peduncle. Acta Neurochir (Wien) 114:135–138, 1992
13. Little KM, Friedman AH, Fukushima T: Surgical approaches to pineal region tumors. J Neurooncol 54:287–299, 2001
14. Matsushima T, Fukui M, Suzuki S, Rhoton AL Jr: The microsurgical anatomy of the infratentorial lateral supracerebellar approach to the trigeminal nerve for tic douloureux. Neurosurgery 24:890–895, 1989
15. Matsushima T, Suzuki SO, Fukui M, Rhoton AL Jr, de Oliveira E, Ono M: Microsurgical anatomy of the tentorial sinuses. J Neurosurg 71:923–928, 1989
16. Muthukumar N, Palaniappan P: Tentorial venous sinuses: an anatomic study. Neurosurgery 42:363–371, 1998

17. Ogata N, Yonekawa Y: Paramedian supracerebellar approach to the upper brain stem and peduncular lesions. Neurosurgery 40:101–105, 1997
18. Page LK: The infratentorial-supracerebellar exposure of tumors in the pineal area. Neurosurgery 1:36–40, 1977
19. Piatt JH, Kellogg JX: A hazard of combining the infratentorial supracerebellar and the cerebellomedullary fissure approaches: cerebellar venous insufficiency. Pediatr Neurosurg 33:243–248, 2000
20. Rey-Dios R, Cohen-Gadol AA: A surgical technique to expand the operative corridor for supracerebellar infratentorial approaches: technical note. Acta Neurochir (Wien) 155:1895–1900, 2013
21. Rhoton AL Jr: The cerebellar arteries. Neurosurgery 47 (3 Suppl):S29–S68, 2000
22. Rhoton AL Jr: The cerebral veins. Neurosurgery 51 (4 Suppl):S159–S205, 2002
23. Rhoton AL Jr: The posterior fossa veins. Neurosurgery 47 (3 Suppl):S69–S92, 2000
24. Rhoton AL Jr: Tentorial incisura. Neurosurgery 47 (3 Suppl):S131–S153, 2000
25. Stein BM: The infratentorial supracerebellar approach to pineal lesions. J Neurosurg 35:197–202, 1971
26. Ueyama T, Al-Mefty O, Tamaki N: Bridging veins on the tentorial surface of the cerebellum: a microsurgical anatomic 1145, 1998
27. Uschold T, Abla AA, Fusco D, Bristol RE, Nakaji P: Supracerebellar infratentorial endoscopically controlled resection of pineal lesions: case series and operative technique. J Neurosurg Pediatr 8:554–564, 2011
28. Van den Bergh R: Lateral-paramedian infratentorial approach in lateral decubitus for pineal tumours. Clin Neurol Neurosurg 92:311–316, 1990

29. Vince GH, Herbold C, Coburger J, Westermaier T, Drenckhahn D, Schuetz A, et al: An anatomical assessment of the supracerebellar midline and paramedian approaches to the inferior colliculus for auditory midbrain implants using a neuronavigation model on cadaveric specimens. J Clin Neurosci 17:107–112, 2010

30. Vishteh AG, David CA, Marciano FF, Coscarella E, Spetzler RF: Extreme lateral supracerebellar infratentorial approach to the posterolateral mesencephalon: technique and clinical experience. Neurosurgery 46:384–389, 2000

31. Vougioukas VI, Omran H, Gläsker S, Van Velthoven V: Far lateral supracerebellar infratentorial approach for the treatment of upper brainstem gliomas: clinical experience with pediatric patients. Childs Nerv Syst 21:1037–1041, 2005

32. Yamamoto I: Pineal region tumor: surgical anatomy and approach. J Neurooncol 54:263–275, 2001

33. Zaidi HA, Elhadi AM, Lei T, Preul MC, Little AS, Nakaji P: Minimally invasive endoscopic supracerebellar-infratentorial surgery of the pineal region: anatomical comparison of four variant approaches. World Neurosurg 84:257–266, 2015

34. Zeal AA, Rhoton AL Jr: Microsurgical anatomy of the posterior cerebral artery. J Neurosurg 48:534–559, 1978