The Anterolateral Limit of the Occipital Lobe: An Anatomical and Imaging Study

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Abstract

Objectives The boundaries of the temporal lobe, the parietal lobe, and the anterior portion of the occipital lobe (OL) are poorly defined. Lesions in these areas can be difficult to localize. Therefore, we studied the anterolateral limit of the OL to identify reliable anatomical landmarks.

Design In 10 formalin-fixed cadaveric heads, the boundaries of the OL and relative anatomical landmarks were studied.

Main Outcome Measures Distances between the following structures were measured: (1) preoccipital tentorial plica (POTP) to the junction between lambdoid suture and superior border of the transverse sinus (POTP-SL), (2) POTP to the sinodural angle of Citelli (POTP-PP), (3) lambda to parietooccipital sulcus (L-POS), and (4) preoccipital notch to termination of the vein of Labbé (PON-VL). Landmarks in 559 computed tomography and magnetic resonance images were also studied.

Results The POTP was found on the tentorium of all anatomical specimens, located at the same coronal level as the PON and its attachment to the bony protuberance (BP) at the lateral cranial wall. The mean distances were POTP-SL, 6.5 ± 6.4 mm; POTP-PP, 18.1 ± 7.8 mm; L-POS, 10.8 ± 5.0 mm; and PON-VL, 8.8 ± 10.1 mm.

Conclusion Osseous (asterion, lambda, and BP), dural (POTP), and vascular (VL) landmarks can be used as reference structures to identify the anterolateral limit of the OL.

Keywords

- anatomy
- CT
- MRI
- occipital lobe
- vein of Labbé

Background

Precise localization of any intracranial lesion is the first step in brain surgery. This information is needed to plan a surgical approach, to manipulate and preserve neurovascular structures, and to predict possible postoperative deficits. On computed tomography (CT) images or magnetic resonance images (MRIs), most lesions are easily identified relative to the cerebral lobes. Based on sulcal morphology,

however, the posterior portion of the temporal and parietal lobes as well as the anterior portion of the occipital lobe can be difficult to identify on the superolateral surface of the cerebrum. In this region, the occipital lobe is separated from the posterior portions of the parietal and temporal lobes by an imaginary line that connects the most superior portion of the parietooccipital sulcus (POS) with the preoccipital notch (PON) at the inferolateral margin of the cerebral hemisphere.

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Contemporary imaging techniques and image-guided surgery systems can easily localize lesions within this region; however, lesion definition and localization can be limited by soft tissue shift that can occur in space-occupying lesions or after opening cisterns and draining cerebral spinal fluid.^{1,2} Thus, anatomical knowledge is essential for the surgeon to understand the anatomical correlations with the surrounding structures. Such understanding can also help in intraoperative decision making when wide resection is warranted. However, assigning lesions to the correct lobe based on cortical surface features remains elusive. In the current study, we performed cadaveric dissections to define anatomical references for the anterolateral limits of the occipital lobe, which serves as an example of difficult anatomic localization, may not be clearly demarcated, and is a region of the brain that may be infrequently accessed by neurosurgeons. These data were then compared with measurements on CT images and MRIs from normal patients.

Material and Methods

A total of 10 formalin-fixed human cadaveric heads (6 adult males and 4 adult females) with veins and arteries injected with colored silicone were studied.

Anatomical Dissections

Bilateral temporoparietooccipital craniotomy was performed to preserve the sagittal suture medially and the lambdoid suture posteriorly. The inferior limit of this craniotomy was the parietomastoid suture. The superior portion of the transverse sinus was exposed. Before the dura was opened, the posterolateral edge of the petrous portion of the temporal bone (sinodural angle of Citelli) and the bony protuberance at the junction of the lambdoid suture and superior portion of the transverse sinus were identified. The dura mater was opened and pediculated toward the middle cranial base. As the temporal lobe was lifted, the sinodural angle and PON were identified. This maneuver permitted observation of the relationship between the PON and the region where the dura attached to the cranium on the outer circumference of the tentorium as it coursed over the superior surface of the junction between the transverse and sigmoid sinuses. The dura of this region presented a fold that projected superiorly toward the PON and almost formed a septum between the walls of this notch. This fold was defined as the preoccipital tentorial plica (POTP).

Calipers were used to measure the distance between the following structures: (1) the POTP to the junction between the lambdoid suture and the superior portion of the transverse sinus sulcus (POTP-SL), (2) the POTP to the sinodural angle of Citelli (POTP-PP), (3) lambda to the end of the POS on the superomedial surface of the cerebral cortex (L-POS), and (4) the PON to the termination of the vein of Labbé (VL) on the inferior margin of the temporal lobe (PON-VL).

Neuroimaging Studies

A total of 559 images (1,118 sides) from normal patients, without known intracranial space-occupying lesion or pathology, from our imaging department were evaluated. CT images were from

355 patients (710 sides; 156 males, 199 females; mean age, 55.1 years; age range, 3–93 years). The MRIs were from 204 patients (408 sides; 108 men, 96 women; mean age, 44.2 years; age range, 3–91 years). The patients from the CT and MRI groups did not overlap. Standard scan sequences and standard image reformatting were used to visualize the anatomical structures. Images from axial scans (CT and MRI) were used to identify the PON and bony attachment of the POTP. Images from sagittal scans (MRI) were used to determine the distance between lambda and the termination of the POS on the superomedial surface of the cerebrum.

Results

Anatomical Study

In all anatomical specimens, the dural-cranial fold or POTP (►Figs. 1 and 2) was present on the outer circumference of the tentorium, coursing medially over the superior surface of the junction between the transverse and sigmoid sinuses. The POTP was attached to a bony protuberance (BP) on the lateral inner surface of the cranium near the intersection of the lambdoid suture with the superior portion of the transverse sinus sulcus. In all specimens, the BP and POTP were situated at the same coronal level as the PON (►Fig. 3).

The mean distance from the POTP to the intersection between POTP-SL was 6.5 ± 6.4 mm. The mean distance between the POTP-PP was 18.1 ± 7.8 mm. The mean distance between L-POS was 10.8 ± 5.0 mm (►Table 1).

The VL was identified in all anatomical specimens. The mean distance from the PON and the termination of the VL was 8.8 ± 10.1 mm. In 40% of the cadaveric sides, the vein was directly beneath the PON, and in 15% the vein was less than 10 mm away from the PON. In another 40% of the specimens, the distance from the VL to the PON was 10 to 20 mm, and in only 5% of the specimens was the vein more than 20 mm away from the PON.

Neuroimaging Study

►Table 2 shows that in 60.3% of the 710 sides of CT images, the PON, the BP (attachment of the POTP), or both were identified and could be used as landmarks to determine the inferolateral limit of the occipital lobe (►Fig. 4A). On the CT images, the BP was the anatomical reference for localizing the PON (►Fig. 4B).

In 90.4% of the 408 sides of the MRIs, one or both of the above structures defining the anterolateral limit of the occipital lobe were identified (►Fig. 5A; ►Table 3). We also applied these findings to identify the exact place of a lesion on the occipital lobe. The VL was identified in juxtaposition to the BP, PON, or both, in 77.7% of the brain hemispheres studied on MRIs (►Fig. 5B).

The BP was more frequently identified on MRI than on CT (likely because the thickness of CT images was 5 mm, while MRI image thickness was 1–2 mm).

Lambda and the superior portion of the POS were identified on the medial or paramedial sagittal slices (5 mm thick) of all MRIs (►Fig. 6). The distance between these points averaged 8.7 ± 5.7 mm.

Fig. 1 Superior view of the middle and posterior fossae on the right side, POTP, POTP-PP, and POTP-SL landmarks are exposed. POTP, preoccipital tentorial plica; POTP-PP, distance from POTP to the sinodural angle of Citelli; POTP-SL, distance from the POTP to the intersection between the lambdoid suture and the superior portion of the transverse sinus sulcus. (Used with permission from Barrow Neurological Institute, Phoenix, Arizona, United States.)

Discussion

The occipital lobe is a pyramid-like structure with a posterior apex (formed by the occipital pole) and an anterior base. It also has three surfaces (medial, lateral, and basal) and three borders (superomedial, inferolateral, and inferomedial).³⁻⁷

During the 6th month of development in human fetuses and primates, the occipital lobe is limited anterolaterally by the external perpendicular sulcus, also known as the external

POS.^{5,7-9} The external perpendicular sulcus of the mature adult human brain becomes hidden and interrupted by the many anastomotic gyri that cross its course during the process of fetal growth. During development, the gyri of the anterior portion of the occipital lobe blend or intersect with the posterior parietal and temporal gyri.^{10,11} The lack of definition makes it difficult to identify the boundaries of each lobe; however, the external occipital fissure serves as a landmark of the POS extension into the cerebral convexity.¹²

Fig. 2 View of the tentorium shows the TS, POTP, confluence of the VL, and other veins on the basal surface of the occipital and temporal lobes. POTP, preoccipital tentorial plica; TS, transverse sinus; VL, vein of Labbé. (Used with permission from Barrow Neurological Institute, Phoenix, Arizona, United States.)

Fig. 3 A view of the lateral surface of the right cerebral hemisphere shows the POTP, the preoccipital notch, and the BP at the same coronal dissection level. BP, bony protuberance; POTP, preoccipital tentorial plica. (Used with permission from Barrow Neurological Institute, Phoenix, Arizona, United States.)

Thus, the anterolateral limit of the occipital lobe is an imaginary line joining the POS with the PON along the ancient external perpendicular sulcus.

Lying on the outer circumference of the tentorium, toward the superior aspect of the transverse sinus approximately 20 mm posterior to the lateral border of the petrous pyramid (sinodural angle of Citelli), the dura forms the POTP. This dural crest runs medially over the superior surface of the junction between the transverse and sigmoid sinuses. This dural structure was not described in classic anatomical textbooks,^{4,7} cited in *Anatomical Terminology*,¹³ or listed in the classic works of Klintworth^{14,15} and Bull¹⁶ on the anatomy,

phylogeny, and ontogenesis of the cerebellar tentorium. Seeger¹⁷ mentioned this fold on one of his anatomical diagrams and labeled it the plica innominata durae matris, but did not describe it (►Fig. 7).

On the skull, the POTP is attached to a BP near the intersection of the lambdoid suture with the superior portion of the transverse sinus before it reaches the asterion. The location of this protuberance and its attached tentorial plica correlates with the location of the PON and produces an impression on the inferolateral aspect of the cerebral cortex. This tentorial dural fold, which was present in all specimens, may play a role in the formation of the PON.

This ubiquitous structure deserves a specific name. We agree with the term POTP in contrast to Seeger's term, plica innominata durae matris.¹⁷ In anatomy, the Latin term plica is used as a synonym of fold or wrinkle. The name, initially used by Gusmão et al in 2002, offers the advantage of indicating the position of the dural fold as well as its relationship with the PON and anterolateral limit of the occipital lobe.¹⁸

The BP near the intersection of the lambdoid suture and superior part of the transverse sinus sulcus, together with the attached POTP, almost coincides with the position of the asterion. On neuroimaging, although counterintuitive, it may be easier to identify the BP on MR images than on CT images (►Fig. 4A). The asterion is a few millimeters superior to the BP. This craniometric point is the external reference for the PON and inferolateral limit of the occipital lobe. The anterolateral limit of the occipital lobe can be localized on the head by using simple measurements. It is represented by a line that connects a point 10 to 11 mm anterior to the lambda (POS) to the asterion (PON). The lambda and asterion are landmarks easily found on the cranium. The lambda is about 70 mm above the inion, and the asterion can be felt 50 mm superior to the mastoid process (►Fig. 8).⁷ This consistent

Table 1 Distances between landmarks on 10 anatomical specimens (20 sides)

Distance	Right side			Left side			Both sides		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
POTP-SL	0–21	7.4	6.9	0–17	5.7	6.1	0–21	6.5	6.4
POTP-PP	4–25	15.5	6.2	5–33	20.7	8.7	4–33	18.1	7.8
L-POS	0–21	10.5	6.3	5–18	11.2	3.7	0–21	10.8	5.0

Abbreviations: L-POS, lambda parietooccipital sulcus; PTPO-PP, preoccipital tentorial plica to sinodural angle; PTPO-SL, preoccipital tentorial plica to transverse sinus sulcus; SD, standard deviation.

Note: Range, mean, and SD in mm.

Table 2 Presence of landmarks on 710 CT images

Landmark	Right side n (%)	Left side n (%)	Both sides n (%)
Preoccipital notch	72 (20.2)	79 (22.2)	151 (21.3)
Bony protuberance	73 (20.6)	88 (24.8)	161 (22.7)
Preoccipital notch + bony protuberance	68 (19.2)	48 (13.5)	116 (16.3)
Absent	142 (40.0)	140 (39.5)	282 (39.7)

Abbreviation: CT, computed tomography.

Fig. 4 (A) Axial CT image showing the PON and its associated BP. (B) Three-dimensional reconstruction CT image of the lateral cranial wall with bone reconstruction showing the BP on the lateral cranial wall. Note the relationships between the BP and the transverse-sigmoid junction. BP, bony protuberance; CT, computed tomography; PON, preoccipital notch; SSS, sulcus of the sigmoid sinus. (Used with permission from Barrow Neurological Institute, Phoenix, Arizona, United States.)

finding is of utility during posterior-extended suprapetrous craniotomies, which require burr hole placement that is predominantly supratentorial.¹⁹

In our anatomical specimens, the superior extremity of the POS was 10.8 ± 5.0 mm anterior to the lambda (**Table 1**). This distance corresponded closely with the findings on the MRIs (mean distance, 9.7 ± 5.7 mm). Our measurements from the anatomical specimens and the two imaging modalities are similar to findings from previous studies. In anatomical specimens, Broca²⁰ reported that the distance between the lambda and the superior extremity of the POS was 10 mm.

The VL is the largest draining vein in the lateral superficial temporal lobe, and it connects the lateral sulcus veins to the

Fig. 5 (A) Axial MRI shows the PON and its associated BP. Although bony structures are better seen with CT, CT image thickness is usually more compared with the 1 to 2 mm thickness of MR images. The image shows that the bone cannot be seen, but the deformation it causes around the PON upon the brain is clear. (B) The VL can be used as an adjunct reference when it is associated with the PON and BP. BP, bony protuberance; CT, computed tomography; MRI, magnetic resonance imaging; PON, preoccipital notch; VL, vein of Labbé. (Used with permission from Barrow Neurological Institute, Phoenix, Arizona, United States.)

transverse sinus.²¹ It is estimated to be the single dominant draining vessel in 20 to 40% of individuals.^{22,23} In our dissections, the termination of the VL correlated closely with the location of the PON. In 40% of the hemispheres, the vein terminated inside the PON. In 95% of the specimens, the vein was located no more than 20 mm from the notch. This finding is consistent with a Rhoton⁶ report that the VL could terminate at any point between the PON and the anterior portion of the temporal lobe. According to Gusmão et al,²⁴ the distance between the sinodural angle and

Table 3 Presence of landmarks on 408 MR images

Landmark	Right side n (%)	Left side n (%)	Both sides n (%)
Preoccipital notch	33 (16.1)	36 (17.6)	69 (16.9)
Bony protuberance	23 (11.3)	30 (14.7)	53 (13.0)
Preoccipital notch + bony protuberance	125 (61.3)	122 (59.8)	247 (60.5)
Absent	23 (11.3)	16 (7.8)	39 (9.6)

Abbreviation: MR, magnetic resonance.

termination of the VL into the tentorium was 20 mm. In 71% of their specimens, the vein terminated into the junction of the sigmoid and transverse sinuses on the lateral cranial surface. This anastomotic segment of the VL that crosses the temporal lobe toward the transverse sinus is susceptible to avulsion during elevation of the temporal lobe.^{21,25} In 29% of their specimens, the vein terminated in a “vein star” formed by the confluence of the VL with one or more temporal lateral veins.^{24,26} Landeiro et al²⁷ found that the mean distance between the sinodural angle and termination of the VL was 15.5 mm on the right-cranial sides and 20.8 mm on the left-cranial sides. These findings suggest that the location of the VL is close to or correlates with the location of the POTP (i.e., 20 mm posterior to the angle of Citelli). On imaging studies (contrast-enhanced CT scans, MRIs, and phlebography), the VL appears as a round structure at the

Fig. 6 Paramedian sagittal MRI shows the distance between the LS and the POS. MRI, magnetic resonance imaging; LS, lambdoid suture; POS, parietooccipital sulcus. (Used with permission from Barrow Neurological Institute, Phoenix, Arizona, United States.)

base of the temporal lobe or its transition with the occipital lobe. In 77.7% of the brain hemispheres that we studied with MRI, this round image of the VL was associated with the BP or PON. The VL's clinical significance is therefore related to its potential damage during approaches to medial tentorial lesions via transpetrosal, subtemporal transtentorial, and transtemporal approaches.^{28–30} Because of the variability of the termination of the VL, the vessel should only be used as an adjunct landmark to distinguish the temporal lobe from the occipital lobe and only when its location corresponds with

Fig. 7 Illustration from Seeger.¹⁷ The author labeled the POTP as the plica innominata durae matris but did not describe it in his textbook. POTP, preoccipital tentorial plica. (Used with permission from Seeger W., Atlas of Topographical Anatomy of the Brain and Surrounding Structures. New York: Springer Verlag, Wien; 1978.)

Fig. 8 Occipital surface of the skull showing the bony references (L, LS, and A) that allow the anterolateral limit of the occipital lobe (POS=preoccipital notch) to be identified on the external surface of the skull. A, asterion; L, lambda; LS, lambdoid suture; POS, parieto-occipital sulcus. (Used with permission from Barrow Neurological Institute, Phoenix, Arizona, United States.)

that of the BP, PON, or both. When the intraoperative sacrifice of the VL is necessary, neurological deficit is not a guarantee; however, when the VL is the dominant superficial draining vessel for the temporoparietal cortex, injury may result in hemorrhage, edema, or venous infarction.³¹

Conclusion

The BP, the POTP, and the projection of the POS on the cranial vault are anatomical landmarks that can help in identifying the anterolateral limit of the occipital lobe. These anatomical structures are visualized well enough intraoperatively and can also be easily identified on CT or MRIs of the head; thus, they can act as topographical reference points. The VL is an adjunct anatomical landmark to the anterior limit of the occipital lobe when it contacts the BP, PON, or both. The BP near the intersection of the lambdoid suture and superior part of the transverse sinus sulcus closely estimates the location of the asterion. These data may serve to assist the neurosurgeon when operating or defining lesions in the anterior occipital cortex, a brain region that is relatively infrequently accessed, and that may not show clear demarcations.

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