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ORIGINAL ARTICLE

Temporal lobe anatomy: eight imaging signs to facilitate interpretation of MRI

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Abstract

Purpose The temporal lobe is anatomically and functionally complex. However, relatively few radiologic signs are described to facilitate recognition of temporal lobe sulci and gyri in clinical practice. We devised and tested 8 radiologic signs of temporal lobe anatomy.

Methods Images from volumetric magnetization-prepared rapid gradient-echo imaging were analyzed of 100 temporal lobes from 26 female and 24 male patients. Patient age ranged from 1 to 79 years (mean 19 years; standard deviation 16 years). Standardized axial, coronal, and sagittal planes were evaluated and cross-referenced. Eight signs to delineate the superior temporal gyrus, Heschl gyrus (HG), parahippocampal gyrus, rhinal sulcus, collateral sulcus proper, or the occipitotemporal sulcus, or a combination, were evaluated in the sagittal or axial plane. Two neuroradiologists independently evaluated each sign; the sign was considered present only with positive reader agreement.

Results All 8 signs were present in most patients. The most frequent signs were the posterior insular corner to identify HG in the axial plane (100 %), pointed STG to identify STG in the axial plane (98 %), and parahippocampal Y to identify the posterior parahippocampal gyrus in the sagittal plane (98 %). The frequencies were similar between the right and left cerebral hemispheres.

Conclusions Temporal lobe gyri and sulci can be reliably identified in multiple planes using anatomic signs.

Keywords Collateral sulcus · Fusiform gyrus · Heschl gyrus · Lateral occipitotemporal gyrus · Occipitotemporal sulcus · Parahippocampal gyrus

Abbreviations

BOLD	Blood oxygenation level–dependent
CS	Collateral sulcus
fMRI	Functional magnetic resonance imaging
HG	Heschl gyrus
ITG	Inferior temporal gyrus
LOTG	Lateral occipitotemporal gyrus
MPRAGE	Magnetization-prepared rapid gradient-echo imaging
MRI	Magnetic resonance imaging
MTG	Middle temporal gyrus
OTS	Occipitotemporal sulcus
PHG	Parahippocampal gyri
STG	Superior temporal gyrus

Introduction

The temporal lobe is anatomically complex, with diverse cortical function that includes primary auditory, receptive language, limbic, unimodal auditory association, and unimodal visual association areas. Although these functional regions cannot be delineated completely with anatomic imaging, many are sharply demarcated by sulci since subjacent gyri frequently have different functions, cytoarchitecture, and clinical relevance. This topic is particularly

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relevant with the increased use of functional magnetic resonance imaging (fMRI) and the need for anatomic correlation to functional regions.

In our experience, radiologists often understand the temporal lobe anatomy less well than many other areas of the brain, such as the central sulcus region, and this anatomy has been addressed less often in the radiology literature. During routine clinical evaluation, we formulated 8 signs to describe and facilitate recognition of temporal lobe anatomy. We have found that incorporation of these concepts into everyday clinical practice and formal didactic lectures has been useful for teaching this material to radiology residents and neuroradiology fellows. We believe these concepts have high practical utility in everyday radiology clinical practice. The purpose of the present investigation was to formally evaluate and portray these signs.

Methods

Imaging examination identification

Approval for this study, which is compliant with the Health Insurance Portability and Accountability Act, was obtained from the institutional review board at a large academic medical center. Fifty consecutive patients evaluated with a high-resolution volumetric magnetization-prepared rapid gradient-echo imaging (MPRAGE) series acquired in the coronal plane for the indication of evaluation of seizure or possible seizure on 2 of our institutional magnetic resonance units (Discovery MR750 3.0T; General Electric Co), running 23- or 24-level software. They were selected since they are commonly used to acquire images of high spatial resolution with consistent imaging parameters for the indication of seizure. A volumetric sequence was used to ensure accurate cross-referencing of anatomic structures between different planes for identification purposes.

Seizure protocol magnetic resonance imaging (MRI) examinations were selected because these routinely include a volumetric T1-weighted MPRAGE sequence in our institutional protocol. The specific parameters were slice thickness, 1.0 mm; matrix, 256 × 256; field of view, 240 × 240 mm^2; repetition time, 7.6/2300 ms; echo time, 3.1 ms; bandwidth, ±31.25 kHz; inversion time, 900 ms; and flip angle, 8°. In addition, the included patients had fast spin echocardiographic T2-weighted images and T2-weighted fluid attenuation inversion recovery images to facilitate evaluation of malformation of cortical development. Only examinations deemed normal or near-normal (e.g., minimal white matter changes of chronic small-vessel ischemia) were included.

Since the prominence of temporal lobe sulci varies with age [2], patients with a wide range of ages (0–79 years) were included. Since patients with an indication of seizure evaluation may ultimately receive a diagnosis of various conditions, primarily either a true seizure disorder or a seizure mimic such as “spells,” the ultimate diagnosis rendered by a neurology consult was recorded. All patients referred for imaging in this study were evaluated by a neurologist.

Exclusion criteria were the following:

- Evidence of malformation of cortical development
- Intracranial space-occupying mass or mass effect from any cause
- Hydrocephalus or ventriculomegaly
- MRI evidence of delayed myelination
- Abnormal intracranial signal beyond scattered punctate areas of T2 hyperintensity
- Encephalomalacia of the temporal lobe
- MRI evidence of mesial temporal sclerosis
- Excessive patient motion
- Artifact that limits visualization of evaluated structures
- Lacunar infarcts in the temporal lobe (patients with lacunar infarcts outside the temporal lobe were not disqualified)
- Generalized cerebral volume loss that is advanced for the patient’s age, assessed subjectively
- Prior surgery involving the temporal lobes
- Hippocampal malrotation, described elsewhere [1]

Definitions of evaluated sulci and gyri

Establishing the definitions of sulci and gyri used in this study is important because nomenclature and definitions of cerebral sulci and gyri vary in the literature. The surface anatomy of the temporal lobe gyri is illustrated in Figs. 1, 2, and 3. The temporal lobe gyri have been recognized on coronal images through the use of 5 gyri signs [11]. Beginning at the superolateral aspect of the temporal lobe, the gyri and sulci are, consecutively, superior temporal gyrus (STG), superior temporal sulcus, middle temporal gyrus (MTG), inferior temporal sulcus, inferior temporal gyrus (ITG), occipitotemporal sulcus (OTS), lateral occipitotemporal gyrus (LOTG), collateral sulcus (CS) proper, and parahippocampal gyrus (PHG) (Figs. 4, 5, 6). Hence, the identity of these structures on axial and sagittal images should be amenable to confirmation using cross-reference techniques to coronal images when a volumetric dataset is used. The anatomy of several structures, as defined in this study, is detailed below; in particular, the basal temporal sulci are described.

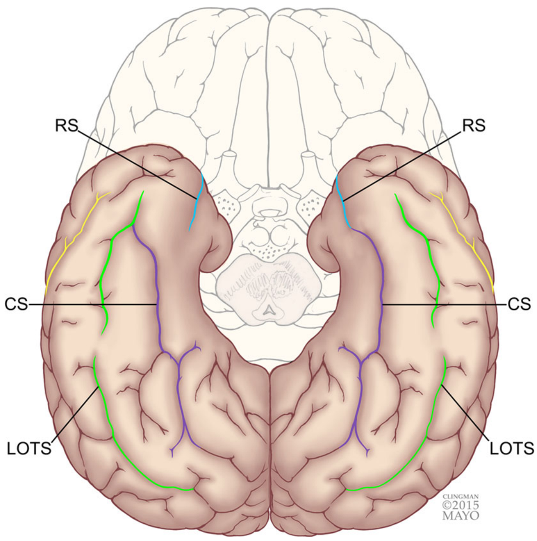

Fig. 1 Surface anatomy of the temporal lobe, inferior view. The rhinal sulcus (RS) (*light blue*), collateral sulcus (CS) (*purple*), and lateral occipitotemporal sulcus (LOTS) (*green*) are highlighted. The RS and LOTS are nearly parallel and oriented in an approximately anteroposterior direction in the anterior basal temporal lobe, immediately posterior to the temporal pole. The anterior termination of the CS proper is variable. The CS may join the LOTS (*left side of image*) or can continue anteriorly to join the RS (*right side of image*). The LOTS is typically discontinuous. Both CS and LOTS extend posteriorly into the occipital lobe. The anterior tip of the inferior temporal sulcus (ITS) (*yellow*) can sometimes be seen laterally. In this view, the parahippocampal gyrus is located medial to the RS and the CS; the lateral occipitotemporal gyrus is located lateral to these sulci (used with permission of Mayo Foundation for Medical Education and Research)

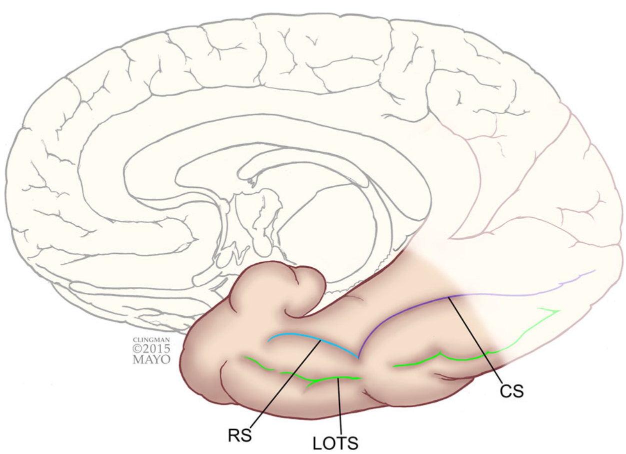

Fig. 2 Surface anatomy of the temporal lobe, inferior oblique medial view. The rhinal sulcus (RS) (*light blue*) and collateral sulcus (CS) proper (*purple*) have a back-to-back arc-like appearance orientation. The lateral occipitotransverse sulcus (LOTS) (*green*) is seen laterally. In this view, the parahippocampal gyrus is located superior to the RS and CS; the lateral occipitotemporal gyrus is located inferior to these sulci (used with permission of Mayo Foundation for Medical Education and Research)

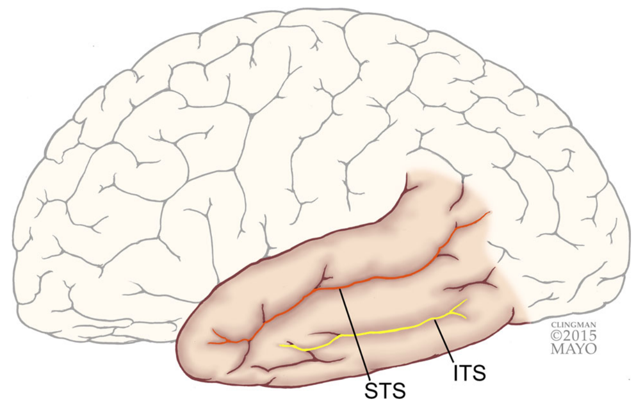

Fig. 3 Surface anatomy of the temporal lobe, lateral view. The superior temporal sulcus (STS) (*orange*) and inferior temporal sulcus (ITS) (*yellow*) divide the superior temporal gyrus, medial temporal gyrus, and inferior temporal gyrus. Of note, the Heschl gyrus, which projects superiorly from the superior temporal gyrus medially, is not a prominent feature of the anatomy on the far lateral surface and is not shown (used with permission of Mayo Foundation for Medical Education and Research)

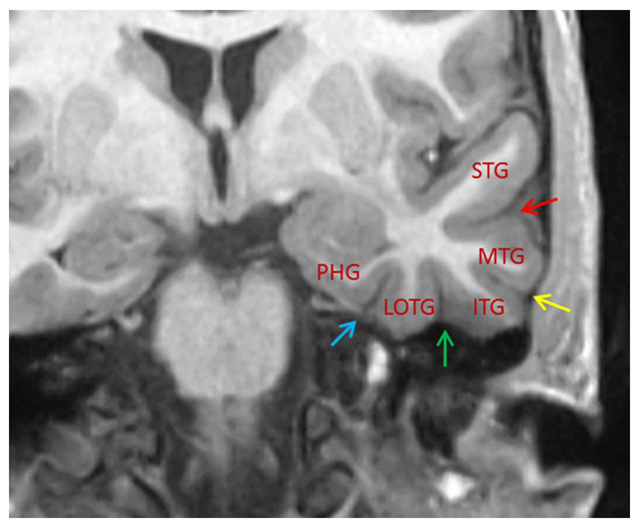

Fig. 4 Coned-in coronal image of the anterior temporal lobe. The *red arrow* shows the superior temporal sulcus; *yellow arrow* the inferior temporal sulcus; *green arrow* the occipitotemporal sulcus; and *light blue arrow* the rhinal sulcus. The temporal lobe gyri are labeled. *ITG* inferior temporal gyrus, *LOTG* lateral occipitotemporal gyrus, *MTG* medial temporal gyrus, *PHG* parahippocampal gyrus, *STG* superior temporal gyrus

Parahippocampal gyrus

The PHG is contiguous with the lingual gyrus of the medial inferior occipital lobe; together, these 2 contiguous gyri have been referred to as the medial occipitotemporal gyrus [5]. Superior to the lingual gyrus, the PHG is contiguous with the isthmus of the cingulate gyrus and contributes to the limbic lobe. Relative to the hippocampus (HC), the

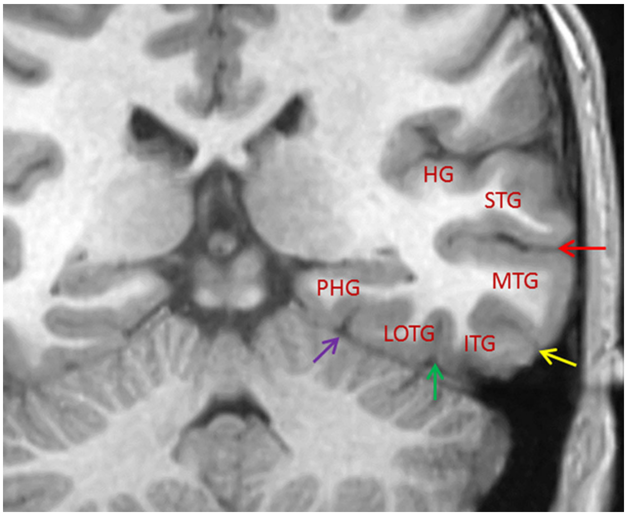

Fig. 5 Coned-in coronal image of the mid temporal lobe. The visualization shows the superior temporal sulcus (*red arrow*), the inferior temporal sulcus (*yellow arrow*), the occipitotemporal sulcus (*green arrow*), and the collateral sulcus (*purple arrow*). Heschl gyrus (HG) has a cap-like appearance atop the superior temporal gyrus (STG). *ITG* inferior temporal gyrus, *LOTG* lateral occipitotemporal gyrus, *MTG* medial temporal gyrus, *PHG* parahippocampal gyrus

PHG is centered immediately inferior on coronal and sagittal images and immediately posterior on axial images. The CS separates it from the LOTG.

Heschl gyri

The gyri temporales transversi, or Heschl gyri (HG), course along the superior surface of the STG, extending posteromedially to anterolaterally. In any single hemisphere, these gyri may be single, partially duplicated with a common white matter stem, or completely duplicated with 2 separate white matter stems. The HG blend into the lateral aspect of the STG. The nomenclature of the sulci defining the HG varies with the type of gyrus and is detailed elsewhere [4]. The gyri are seen clearly on coronal and sagittal images as superiorly directed, mushroom-like gyri separating the planum polare and the planum temporale.

Rhinal sulcus

Although the definition and recognition of the rhinal sulcus have been inconsistent, sometimes simply considered the anterior extension of the CS rather than a unique sulcus [8, 9], the rhinal sulcus is a separate sulcus and merits distinction. It is rostrocaudally directed in the anterior basal temporal lobe immediately lateral to the amygdala and the head of HC, extending posteriorly to the level of the mid hippocampal body [8]. This sulcus courses laterally and is parallel to the uncus [8].

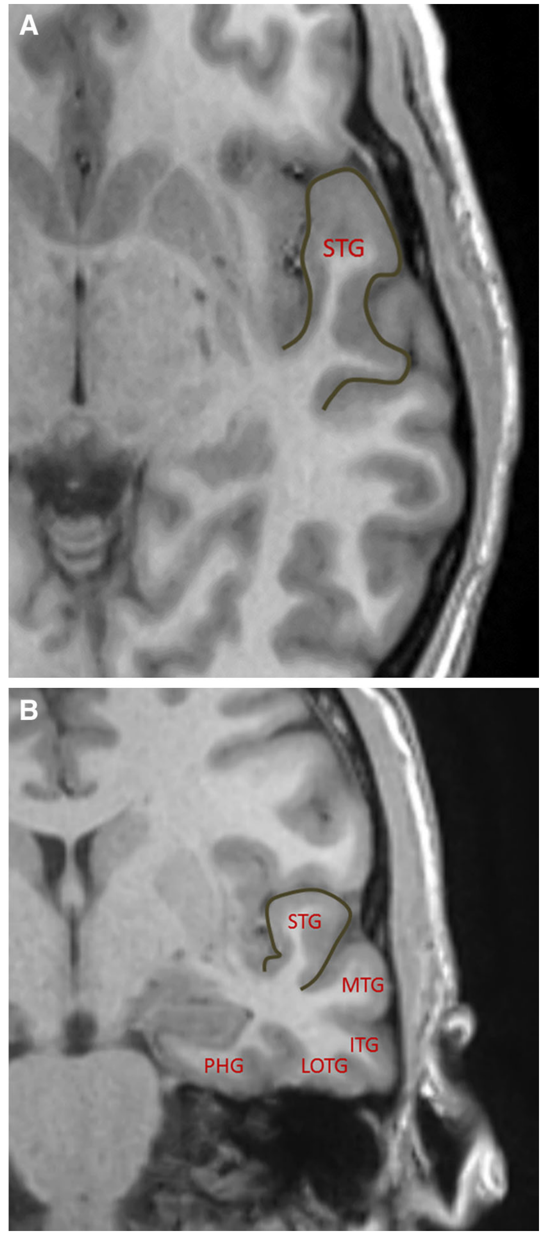

Fig. 6 Pointed superior temporal gyrus (STG) sign. **a** A coned-in axial image shows this sign outlined in *brown*. Heschl gyrus, represented by the posterior insular corner sign, and the frontoparietal operculum draped over the Sylvian fissure without a pointed appearance were immediately superior to this level (not shown). **b** A coned-in coronal image from the same patient shows the STG outlined in *brown*. The pointed STG sign in **a** cross references to the STG outlined in **b**. *ITG* inferior temporal gyrus, *LOTG* lateral occipitotemporal gyrus, *MTG* medial temporal gyrus, *PHG* parahippocampal gyrus

Collateral sulcus

The CS may be considered a complex of several individual sulci. Most anteriorly, the rhinal sulcus has been considered a portion of the CS by numerous authors [8, 9]. A posterior segment extends into the occipital lobe, separating the lingual gyrus from the occipital portion of the LOTG. The main segment, the CS proper, is positioned between the rhinal sulcus and the occipital extent. It separates the PHG from the temporal portion of the LOTG. Anteriorly, the CS proper may join the rhinal sulcus or OTS or it may terminate independently [8].

Occipitotemporal sulcus

The OTS is a discontinuous sulcus along the basal temporal lobe that separates the ITG from the LOTG [12].

Image analysis

Two board-certified radiologists (K.M.W. and D.F.B.) with certificates of added qualification in neuroradiology and with 15 and 3 years of experience scored all imaging studies independently. Each imaging examination was viewed on visualization software (version 4.4.11; TeraRecon, Inc). A reformatted axial image volume was generated by aligning the anterior and posterior commissures on a single image. After the axial plane was established, coronal and sagittal reformatted volumes were created in orthogonal planes.

Definition of anatomy and evaluation signs and methods

The 2 radiologists determined whether each of the 8 signs was present or absent.

Pointed STG sign

The pointed STG sign identifies the STG on axial images. The STG has an anteriorly pointed appearance with a broader base posteriorly and a narrower tip anteriorly on at least 1 axial image. The pointed designation indicates that the anterosuperior tip is separated from the adjacent frontal operculum by cerebrospinal fluid. The fluid borders the medial, anterior, and lateral sides on all images. The posterior medial base is contiguous with the posterior insula; however, it is broad and extends laterally, unlike HG. The lateral edge of the gyrus defines the lateral edge of the temporal lobe. In contradistinction, the subjacent frontoparietal operculum superficially draped over the insula lacks a pointed appearance. This sign is not defined to distinguish the STG from the MTG because the intervening superior temporal sulcus courses closest to the axial plane and may be difficult to identify confidently on axial images.

In the present study, each reader documented this sign as either present with all criteria met or absent on the axial images. For this sign to be present, the readers placed a cross-reference point on the most superior axial image, with confirmation of identity of the STG on coronal images. The STG was defined on coronal images as the temporal gyrus located superior to the superior temporal sulcus and inferior to the Sylvian fissure. In addition, the frontoparietal operculum draped over the Sylvian fissure was located on axial images and could not meet criteria for a pointed STG sign. Figure 6 shows the pointed STG sign.

Posterior insular corner sign

In the axial plane, the HG is a fingerlike gyrus that arises from the posterior insula and projects anterolaterally on at least 1 image. It contains the first white matter stem arising entirely from the posterior insula, encountered when the reader is scrolling from superior to inferior. The HG can consist of 1 or multiple gyri. The identity as HG was confirmed on coronal images. Figure 7 shows the posterior insular corner sign.

Fork prong sign

The anteriormost extent of anteroposteriorly directed basal temporal sulci (rhinal sulcus and OTS) was assessed. An anteriorly (±30°) projected sulcus extends inferior to the temporal horn of the lateral ventricle, forming the medial prong. Identification of the rhinal sulcus is confirmed on coronal images.

The lateral prong is formed by an anteriorly (±30°) projected sulcus located lateral to the temporal horn of the lateral ventricle. This sulcus is the most laterally positioned basilar temporal lobe sulcus on axial images at the level of the temporal horn of the lateral ventricle. It is confirmed on coronal images to represent the anterior segment of the OTS, separating the LOTG and ITG.

Both medial and lateral prongs are identified on at least 1 common axial image. The CS proper may extend to be continuous with the rhinal sulcus, merge with the OTS, or appear to end blindly as a third middle prong. If other criteria were fully met, the sign was considered present regardless of the CS termination. Each reader documented whether this sign was present with all criteria fulfilled or was absent, with the identity of the sulci confirmed on coronal images. Figure 8 shows the fork prong sign.

CS bracket sign

On axial images, the CS proper extends near the medial temporal lobe surface, bracketing the posterior border of the PHG. The lateral tip of this sulcus at the levels of the CS bracket sign is angled anteriorly or is straight laterally but not posteriorly. Inferior to the level of the junction of

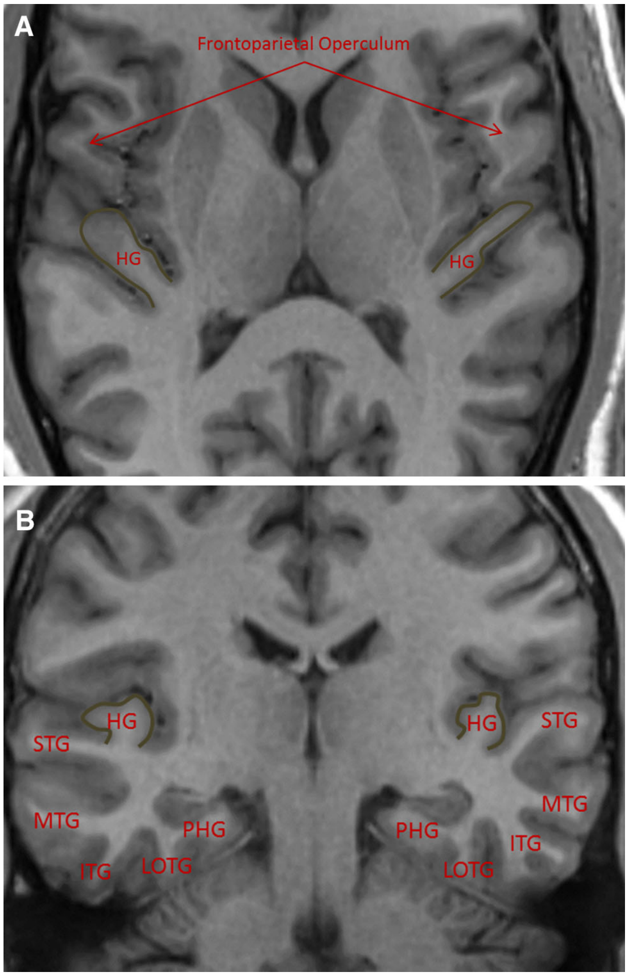

Fig. 7 Bilateral posterior insular corner signs. **a** A coned-in axial image shows the signs outlined in *brown*. The frontoparietal operculum is labeled with *red arrows*, superior to the level of the superior temporal gyrus (STG) (not shown). **b** A coned-in coronal image of the same patient confirmed that these signs correspond to a single Heschl gyrus (HG) bilaterally (outlined in *brown*), with a mushroom- or cap-like appearance atop the STG. *ITG* inferior temporal gyrus, *LOTG* lateral occipitotemporal gyrus, *MTG* medial temporal gyrus, *PHG* parahippocampal gyrus

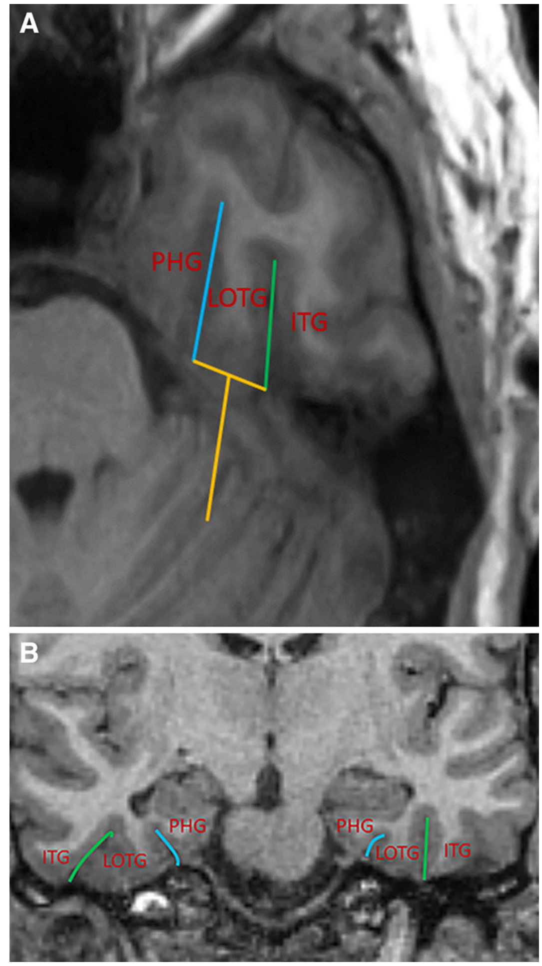

Fig. 8 Coned-in axial Image of the fork prong sign. **a** The medial prong is the rhinal sulcus (*light blue*); the lateral prong is the occipitotemporal sulcus (*green*). Of note, the fork handle (*gold*) posteriorly is illustrated for conceptual purposes and does not correspond to a sulcus. **b** A coned-in coronal image of the same patient at the level of the fork prongs in the anterior temporal lobe shows the rhinal sulcus (*light blue*) and occipitotemporal sulcus (*green*) separating the lateral occipitotemporal gyrus (LOTG) from the parahippocampal gyrus (PHG) medially and inferior temporal gyrus (ITG) laterally. The fork prongs on the axial image cross-referenced to these sulci on the left on this coronal image appropriately, although these are labeled bilaterally

the occipital extension of the CS and the CS proper, the HC is located immediately anterior to the PHG, and the LOTG is located posterior to the CS.

The identity of the CS proper was confirmed with cross-reference to the coronal plane. The CS proper has been defined elsewhere [8]. Briefly, it is a rostrocaudally directed sulcus that separates the PHG medially from the LOTG laterally. The CS bracket sign is shown in Fig. 9.

CS arc sign

The CS proper is seen as a temporal lobe sulcus on sagittal images, with a discrete, upward convex curved line (sulcus) that consists of an anterior slope, a single apex, and a posterior slope. Posterior to the apex, the sulcus continues as the occipital extension of the CS. An intralingual sulcus may join the arc and extend into the lingual gyrus, which was not factored into this sign. The arc apex is at the anteroposterior level of the atrium of the lateral ventricle. The PHG is located superior to the upward convex line anteriorly, and the LOTG is located inferior to it.

Each reader documented whether this sulcus was present or absent. The same methods used to confirm identification of the CS bracket sign were used to identify the CS proper on coronal images. The anterosuperior gyrus is the PHG, and the inferior gyrus is the LOTG—all were confirmed

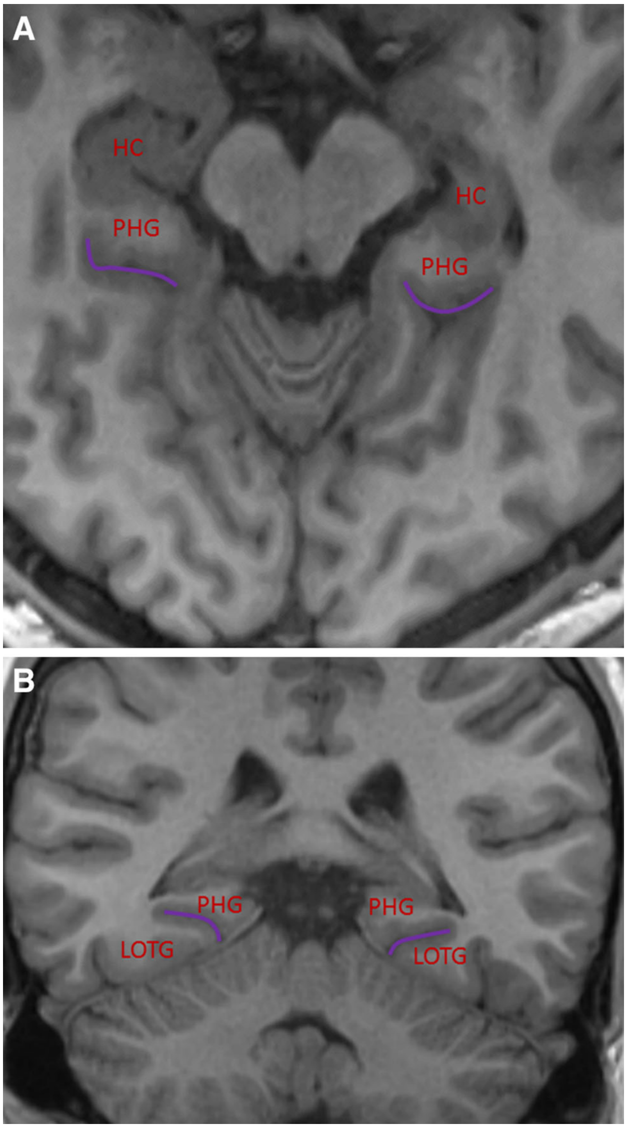

Fig. 9 Collateral sulcus (CS) bracket sign bilaterally. **a** A coned-in axial image shows the bracket sign bilaterally in *purple*. Parahippocampal gyri (PHG) are located immediately anterior to the parahippocampal brackets. **b** A coned-in coronal image of the same patient at the same level of the CS. The CS bracket sign on the axial images cross-referenced to the CS (*purple*) bilaterally on this image. *HC* hippocampus, *LOTG* lateral occipitotemporal gyrus

with cross-reference on coronal images. Figure 10 shows the CS arc sign.

OTS plateau sign

The upward convex plateau of gray matter within the temporal lobe has a broad base along the inferior temporal lobe located medial to the superior and inferior temporal sulci. Although the plateau may contain white matter, it is predominantly (>50 %) composed of gray matter. The length and height of plateaus were not factored since the

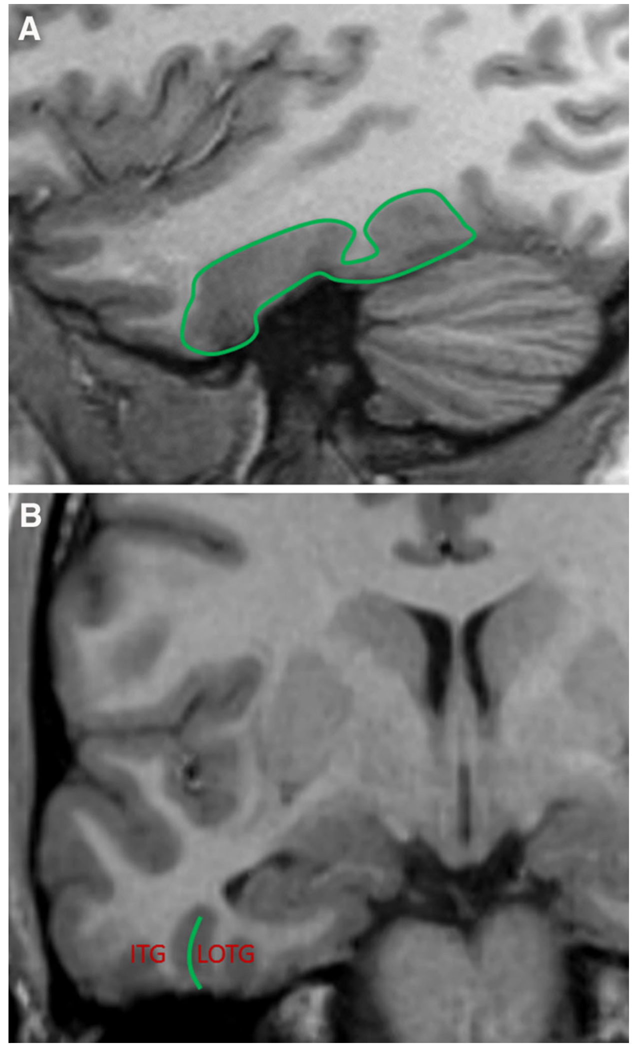

Fig. 10 Collateral sulcus arc sign. The arc sign is outlined in *purple*. Coned-in sagittal images demonstrate that the parahippocampal gyrus (PHG) is present immediately anterosuperior to the sulcus; the lateral occipitotemporal gyrus (LOTG) is located beneath it. *HC* hippocampus

posterior extent of this sulcus varies [12]. Because the OTS is often discontinuous with a variable number of segments, separate segments—or *plateaus*—could be present in the anteroposterior direction [12]. Identity as gray matter lining the OTS is confirmed with cross-reference on coronal images. Figure 11 shows the OTS plateau sign.

PHG Y sign

Posteriorly, the PHG is continuous with the isthmus of the cingulate gyrus superiorly and the lingual gyrus inferiorly on at least 1 sagittal image, with the anterior extent of the calcarine sulcus interposed. The white matter of these gyri creates a roughly horizontal Y appearance that opens up posteriorly. The Y sign of the PHG is illustrated in Fig. 12.

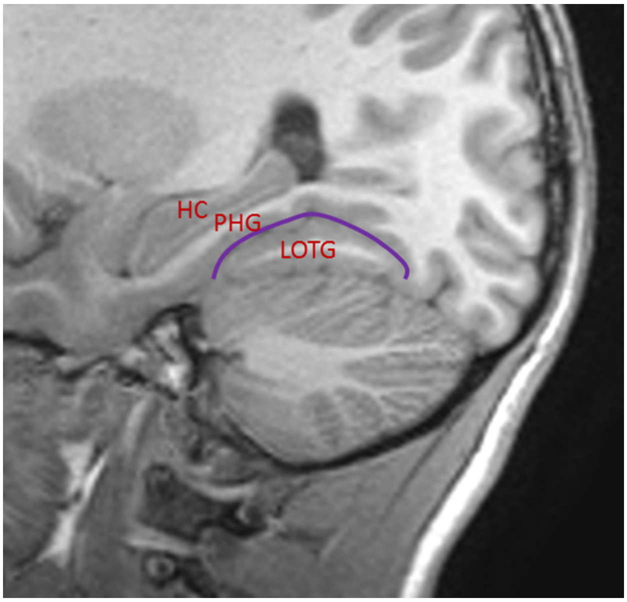

Fig. 11 Occipitotemporal sulcus plateau sign. **a** A coned-in sagittal image shows the plateau sign outlined in green. In this patient, 2 segments of the occipitotemporal sulcus create a double plateau appearance. **b** A coned-in coronal image at the level of the anterior segment of the plateau in the same patient confirmed that the occipitotemporal sulcus (*green*) corresponded to the plateau. *ITG* inferior temporal gyrus, *LOTG* lateral occipitotemporal gyrus

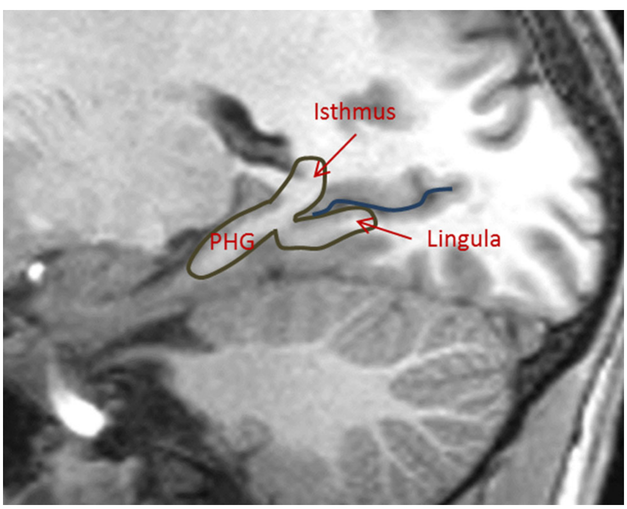

Fig. 12 Parahippocampal Y sign. A coned-in sagittal image shows the parahippocampal Y sign outlined in *brown*. The calcarine sulcus (*dark blue*) separates the isthmus from the lingula, which converge anteriorly to the parahippocampal gyrus (PHG)

Rabbit ear sign

The rhinal sulcus anteriorly and CS proper posteriorly arc upward from the inferior surface of the temporal lobe on at least 1 common sagittal image. Figure 13 shows the rabbit ear sign.

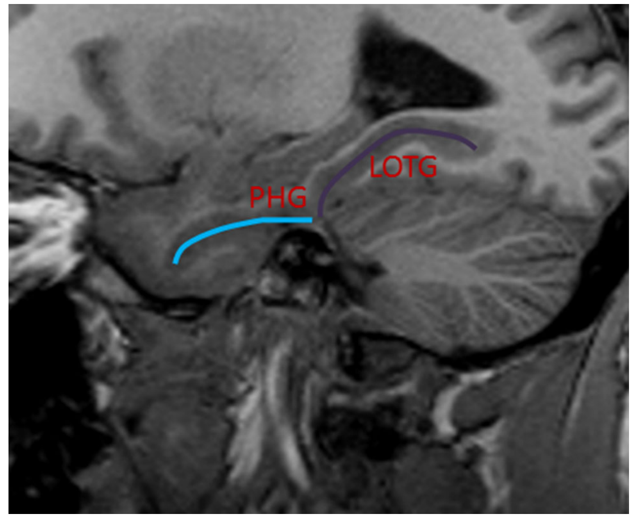

Fig. 13 Coned-in sagittal image showing the rabbit ear sign. The sign consists of the rhinal sulcus (*light blue*) and the collateral sulcus proper (*purple*). *LOTG* lateral occipitotemporal gyrus, *PHG* parahippocampal gyrus

Data analysis

When both readers independently determined that the criteria were fulfilled for each sign, it was considered present. If 1 or both readers did not believe that a sign was present, it was marked absent. The frequency of identification of each sign through this agreement was determined by hemisphere and for the 100 hemispheres overall. The frequency of each sign was determined in a subgroup of patients who were left-handed or ambidextrous, by age, and by sex.

Results

Initially, 69 examinations were reviewed, of which 19 were excluded because of malformation of cortical development ($n = 5$), mesial temporal sclerosis ($n = 4$), prior intracranial surgery ($n = 4$), hippocampal malrotation ($n = 2$), intracranial mass ($n = 2$), and extensive white matter signal change ($n = 2$). The other 50 examinations were analyzed. The persons examined included 24 male patients (48 %). The mean (range, SD) age of the included patients was 19 (1–79, 16) years. The age breakdown by decade was the following: less than 10 years ($n = 15$, 30 %), 10–20 years ($n = 16$, 32 %), 20–30 years ($n = 9$, 18 %), 30–40 years ($n = 7$, 14 %), 40–50 years ($n = 0$, 0 %), and greater than 50 years ($n = 3$, 6 %). Thirty-four patients (68 %) were right-handed, 4 patients (8 %) were left-handed, and 1 patient (2 %) was ambidextrous. Eleven patients (22 %) did not have documented hand dominance; 6 of

Table 1 Frequency of temporal lobe anatomic signs

Sign	Patients, no. (%)		
	Right ($n = 50$)	Left ($n = 50$)	Total ($N = 100$)
Pointed STG	49 (98)	49 (98)	98 (98)
Posterior insular corner	50 (100)	50 (100)	100 (100)
Fork prong	38 (76)	45 (90)	83 (83)
CS bracket	47 (94)	45 (90)	92 (92)
CS arc	45 (90)	42 (84)	87 (87)
OTS plateau	47 (94)	47 (94)	94 (94)
Rabbit ear	41 (82)	43 (86)	84 (84)
Parahippocampal Y	49 (98)	49 (98)	98 (98)

CS collateral sulcus, *OTS* occipitotemporal sulcus, *STG* superior temporal gyrus

these patients were younger than 3 years, thereby making determination of handedness difficult.

Thirty-five patients (70 %) ultimately received a diagnosis of definite seizures—17 (34 %) generalized, 17 (34 %) focal, and 1 (2 %) uncertain whether focal or generalized. Fifteen patients (30 %) ultimately received a diagnosis of (1) alternative conditions, predominantly "spell," present in 12 (24 %) or (2) other conditions, including catatonia in 1 (2 %), segmental dystonia in 1 (2 %), and autism in 1 (2 %).

All 8 signs were present in most patients (Table 1). The most frequent signs were the posterior insular corner (100 %), pointed STG (98 %), and parahippocampal Y (98 %). The frequencies were similar between the right and left cerebral hemispheres.

All 8 signs were also present in the majority of the 15 patients in the subgroup that was not ultimately diagnosed with seizures. Specifically, signs were present in these 30 cerebral hemispheres with the following frequencies: pointed STG (30, 100 %), posterior insular corner (30, 100 %), fork prong (27, 90 %), CS bracket (27, 90 %), CS arc (26, 87 %), OTS plateau (29, 97 %), rabbit ear (26, 87 %), and PHG Y (29, 97 %). Similar to the overall cohort, the pointed STG and posterior insular corner signs were always present, whereas the fork prong, CS bracket, CS arc, and rabbit ear signs were more commonly absent.

In addition, all the signs were present in the majority of patients across different age-groups. In the 15 patients younger than 10 years, the fork prong sign was present in 26 of the 30 cerebral hemispheres (87 %); CS bracket sign, 27 hemispheres (90 %); CS arc sign, 28 hemispheres (93 %); and rabbit ear sign, 25 hemispheres (83 %). The other signs were all present in the 30 hemispheres (100 %) of patients younger than 10 years. Examining the oldest cohort of 3 patients older than 50 years, all signs were present in 6 cerebral hemispheres, with the single exception of the OTS plateau sign, which was present in 4 hemispheres (66 %).

Results were generally similar among the 5 patients who were either left-handed or ambidextrous. Specifically, the CS arc sign was absent in 1 patient (20 %) on the right, the rabbit ear sign absent in 1 patient (20 %) on the right, and the parahippocampal Y sign absent in 1 patient (20 %) on the left. The signs were otherwise present. There were no instances of false-positive readings, in which a sign appeared to be present but was found to correlate to an unexpected anatomic structure on orthogonal confirmation images.

The average ages of the patients with absent signs were the following: pointed STG sign, 3.5 years; fork prong sign, 19.9 years; CS bracket sign, 12.5 years; CS arc sign, 20.7 years; OTS plateau sign, 31.9 years; rabbit ear sign, 17.9 years; and parahippocampal Y sign, 28.6 years.

Absent signs were noted in male and female patients. The percentages of male patients with absent signs, respectively, were pointed STG sign, 2/2 (100 %); fork prong sign, 9/17 (53 %); CS bracket sign, 2/8 (25 %); CS arc sign, 4/13 (31 %); OTS plateau sign 1/6 (17 %); rabbit ears sign 8/16 (50 %); and parahippocampal Y sign 1/2 (50 %).

In the majority of cases with an absent sign, only 1 of the 2 readers marked the sign as absent. The frequencies of agreement of absent signs (i.e., the ratio that both readers scored as absent over the total scored as absent by 1 or 2 readers) were pointed STG sign, 0/2 (0 %); fork prong sign, 1/17 (6 %); CS bracket, 0/8 (0 %); CS arc sign, 0/13 (0 %); OTS plateau, 1/6 (17 %); rabbit ear sign 1/16 (6 %); and parahippocampal Y sign, 0/2 (0 %).

Discussion

This study confirms that these 8 anatomic signs used to delineate temporal lobe anatomy in the axial and sagittal planes are present frequently. No instances of false-positive signs were found, indicating their reliability in identifying specific temporal lobe structures when present. Of importance, devising such means of anatomic localization on visual inspection could facilitate anatomic and functional imaging research, precise radiologic localization of lesions in clinical practice, and correlation of lesion location to functional neurologic deficits.

The anatomy of the superior portion of the temporal lobe, including the STG and HG, may be confusing on axial images. These data show that the pointed STG sign is present in most patients. Distinguishing the STG from frontoparietal operculum on axial images is important since the STG houses unimodal auditory association cortex whereas the pars opercularis of the inferior frontal gyrus contains a portion of the Broca language area in the language-dominant hemisphere [3].

The posterior insular corner sign identified HG in all cases. Identification of HG is important since they contain the cytoarchitecturally distinct primary auditory cortex [4]. Da Costa et al. [4] demonstrated that the primary auditory cortex spans both HG with partial or complete duplications, and in some cases, it extends beyond the posterior border into the planum temporale. Nevertheless, prior authors have stated that it resides only in the anteriormost HG [13].

In our experience, radiologists are often less familiar with the appearance of HG in the axial plane than with many other major cerebral gyri. Although we can only speculate, underrecognition may occur because (1) unilateral lesions often result in subtle deficits that radiologists may not be aware of or correlate anatomically, (2) focus on HG is relatively infrequent in the radiology literature, and (3) a simple, named sign has not been devised. Prior publications have shown the posterior insular corner sign on axial images with corresponding auditory blood oxygenation level-dependent (BOLD) signal [4, 6], although this sign has not been formally recognized. The HG also serves as a landmark of the superior border of the posterior temporal lobe, differentiating it from the inferior parietal lobe on axial images. The use of the posterior insular corner sign has potential to increase recognition of HG on axial images.

In addition, since the HG is positioned atop the STG, the pointed STG sign should be located immediately inferior to the posterior insular corner sign. Although not well defined on anatomic images, the Wernicke language area is centered largely in the posterior STG near the level of the planum temporale. Therefore, the Wernicke area should be centered in the region immediately posterior to the posterior insular corner sign, although further study is needed to confirm the utility of the sign for this purpose.

Together, rabbit ear, CS bracket, CS arc, OTS plateau, and fork prong signs can delineate the basal temporal sulci and gyri. Previously reported signs and methods are scant to facilitate recognition of the basal temporal anatomy with clinical imaging interpretation. The basal gyri have markedly different functions and should be distinguished on anatomic imaging. For example, the PHG has limbic function, whereas the LOTG has unimodal visual association function. Posteriorly along the level of the CS proper, the PHG indicates BOLD activity when a person is processing information pertaining to complex visual scenes [7, 8]. The CS arc and CS bracket signs may be useful for localizing such functional activity on axial and sagittal images, respectively. Anteriorly along the rhinal sulcus, the PHG likely processes information related to recognition of familiar objects [8]. In contradistinction, functions of the posterior LOTG include human form identification areas, such as a face recognition center and body recognition center [14].

Characterization of the temporal sulci also has potential to approximate cytoarchitectural subdivisions of the adjacent gyri. For example, subdivisions of the PHG are not technically distinguishable on anatomic imaging, but anteriorly, the subdivisions may be approximated by their relation to the rhinal sulcus [8, 9]. This relation includes the entorhinal cortex of the PHG and the perirhinal cortex adjacent to the rhinal sulcus, which both have distinct cytoarchitecture, specific function, and involvement in certain pathologic processes, such as early Alzheimer disease [14, 15]. Insausti et al. [9] correlated the MRI appearance and cytoarchitecture of these regions and described methods to determine the locations of each on the basis of relations to anatomic structures including the rhinal sulcus, although this rhinal sulcus was referred to as anterior collateral sulcus in the original description. As a first-order approximation, the majority of the entorhinal cortex is thought to be located along the anteroposterior level of the rhinal sulcus [8]. The present study showed that the fork prong and rabbit ear signs can facilitate identification of the rhinal sulcus and therefore may facilitate localization of the entorhinal and perirhinal cortices.

This investigation has several limitations. MPRAGE studies were selected from a population of patients being evaluated for possible seizures. Although patients with known anatomic alterations related to seizures were excluded, it is possible that subtle, unrecognized differences were present compared with a population without seizures. For example, the frequency of continuity of the CS with the rhinal sulcus vs the OTS in patients with temporal lobe epilepsy may differ from controls, according to 1 report [10]. However, results were similar in patients with and without seizures, and we believe such an impact is likely minor. Images were evaluated with a high spatial resolution dataset, and the frequency of these findings with lower spatial resolution and increased slice thickness may be lower than reported herein. Even with specific criteria, the readers disagreed in most cases of absent signs.

Although we can only speculate why, this disagreement may reflect some degree of subjectivity in evaluation and different interpretations of subtle anatomic variants. Finally, although we believe we included enough patients to show that these signs are frequently present in both sexes at a wide age range, it is possible that small differences in frequency based on age, sex, or handedness might be identified with analysis of a larger number of patients.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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