

## REVIEW

# A radiologic correlation with the basic functional neuroanatomy of the brain

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**Abstract:** Primary cortical areas for motor, sensory and sensitive functions are localized in certain areas of the brain cortex. In clinical practice, cross sectional imaging (computer tomography and magnetic resonance) is widely used for diagnostics purpose, treatment planning and follow up of the patients. Accurate orientation in brain structures is necessary for the evaluation of radiological images. There are numerable landmark signs, which can be used for precise identification of important brain structures. In this review article, the mostly used anatomical landmarks are described and shown on the cross sectional images (magnetic resonance imaging) (Fig. 14, Ref. 25). Text in PDF [www.elis.sk](http://www.elis.sk).

Key words: brain anatomy, anatomical landmarks, cross sectional imaging, primary cortical centres, functional somatotopy.

Knowledge of basic anatomic structures of the brain, localization of primary cortical areas for motor, sensory and sensitive functions and their connections allows us to better understand the relation of pathological process and clinical findings in neurological diseases and also improve the communication between a radiologist, neurologist and neurosurgeon.

## Recognition of anatomical structures

Primary cortical areas are localized preferentially in certain areas of the cortex, precisely in particular gyri of lobes. Primary sensorimotor cerebral cortex is localized in the pericentral gyri (rolandic region), primary visual cortex is localized in the occipital lobe, primary expressive speech area (Broca's area) is localized on the base of frontal lobe of dominant hemisphere, receptive speech area (Wernicke's area) along sulcus temporalis superior and posterior border of Sylvian fissure of dominant hemisphere and the primary and secondary auditory areas are on the upper surface of temporal lobe.

Accurate orientation in brain and knowledge of borders of hemispheres, lobes and specific gyri is necessary for the evaluation of anatomic or radiologic images.

Interhemispheric fissure is the simplest identifiable border that divides right and left hemisphere of the brain (Fig. 1). Out of lobar fissures, it is Sylvian fissure that divides temporal from frontal lobe and insular area of fronto-parietal lobe (Fig. 1). Frontal and

parietal lobe are divided by central sulcus. On medial surface of the brain is the border between parietal and frontal lobe formed by a notch of central sulcus, the border between parietal and occipital lobe is formed by parieto-occipital sulcus and between occipital and temporal lobe by preoccipital notch. The borders between parietal, occipital and temporal lobe on brain convexity are not exactly defined and there are different methods how to define them (1). The simplest way is to create imaginary lines that approximately divide the convexity of parietal, temporal and occipital lobe (Fig. 2).

With respect to cortical variability that may change the appearance of the brain convexity and also due to imaging methods (CT and MRI) that work mostly with basic transversal (axial) plane, there is a set of signs, that enable simpler identification of individual areas (2, 3, 4, 5). From radiologic point of view, it is important to add that to identify the structures properly we have to use also sagittal plane.

In the following text, we present most important landmarks for recognition of most important anatomical structures of brain.

## Pericentral region

There are few signs that help to identify the margins of the pericentral region and frontal lobe and some specific areas.

In axial plane images, there are the following landmarks:

- The precentral knob (Fig. 3), also called "hand knob" or "omega sign". It's a focal, posteriorly directed protrusion of the posterior surface of the precentral gyrus. The omega sign is present in 70 % of subjects, in 25 % it has an epsilon appearance and in 5 % it has a more complex structure (6, 7). There can be an asymmetry comparing the hemispheres.
- The pars bracket sign (Fig. 4), also familiarly called "the moustache" – it's the pars marginalis of the cingulate gyrus of both

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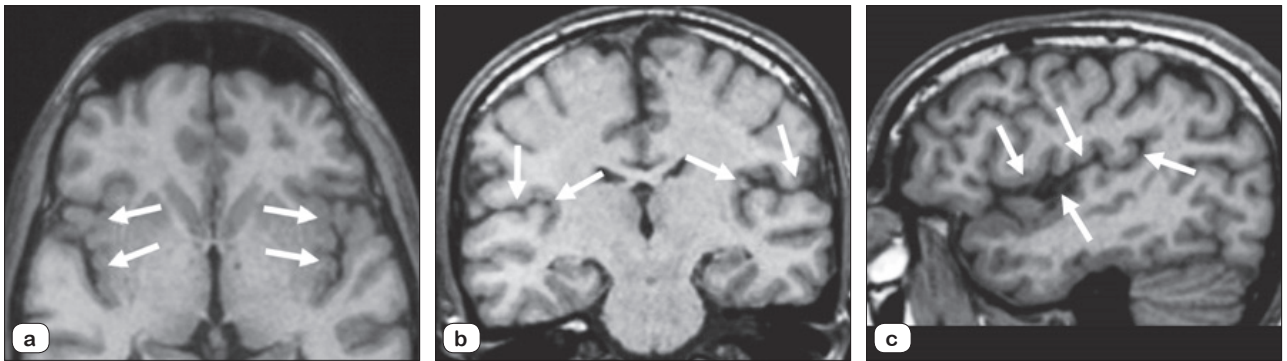


Fig. 1. Parts of the Sylvian fissure in a) axial plane, b) coronal plane and c) sagittal plane. Interhemispheric fissure is also shown (thick arrows in a) and b)).



Fig. 2. Borders of the parieto-occipito-temporal lobes. “Lateral parieto-temporal line” crosses the convexity from the lateral end of the parieto-occipital sulcus above to the preoccipital notch inferiorly. “Temporo-occipital line” as a variable line from the distal end of the Sylvian fissure to the midpoint of the anterior border of the occipital lobe. The central sulcus also depicted.

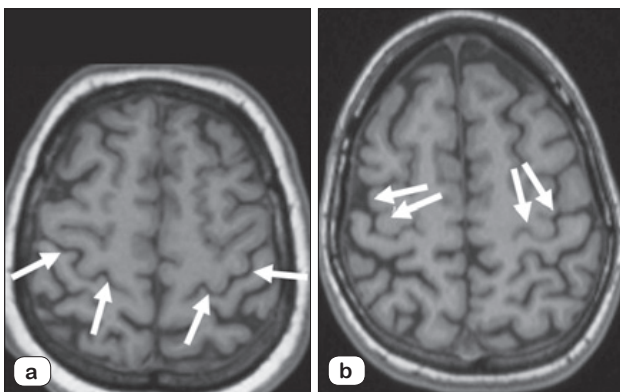


Fig. 3. The hand knob. a) Omega sign in the right hemisphere and epsilon sign in the left hemisphere. b) More complex appearance of the motor cortex in both hemispheres.

hemispheres that on axial plane appears as a horizontal bracket (1). The medial end of the central sulcus is the next ventral sulcus in about 94–96 %, whereas the postcentral sulcus enters the pars bracket in only 3 % (3).

- The junction of precentral sulcus with superior frontal sulcus (Fig. 5), can be seen in about 75 %, whereas in 25 % the superior frontal sulcus connects directly to the precentral gyrus (6, 7).
- Thickness of the pre- and postcentral gyri. The precentral gyrus is thicker than the postcentral gyrus, also the thickness of the precentral cortex is thicker than that of postcentral gyrus (4, 8).
- Oblique course of the precentral gyrus (Fig. 6). The precentral gyrus is not running vertically on the axial and sagittal plane, it has an oblique ventral course.
- The postcentral gyrus is bifid in 85 % and it encloses the lateral end of pars marginalis of cingulate gyrus in 88 %. This sign is called Bifid postcentral sulcus sign (Fig. 7) (4).
- Intraparietal sulcus intersects postcentral sulcus and it is easily recognizable on axial planes in 99 % (Fig. 8) (4).
- Central sulcus reaches the midline interhemispheric fissure and on axial planes it is the most prominent convexity sulcus. This sign is called the midline sulcus sign and is recognizable in 70 % (Fig. 9) (4).

On the sagittal plane images:

- The “M” shape of the inferior frontal gyrus (Fig. 6). It is a clear sign on the lateral sagittal plane, which can be used as a starting point for identification of the precentral sulcus, precentral gyrus, central sulcus and postcentral gyrus, which, in this order, lie posteriorly to the inferior frontal gyrus (8, 10, 11). The precentral “hook” (Fig. 10) or the precentral knob. On the middle sagittal plane at the level of insula, it’s the posteriorly directed protrusion of the precentral gyrus (“hand knob” on axial plane), which can be seen in 92 % (6).
- The pars marginalis of cingulate gyrus (Fig. 11). On the medial sagittal plane, the posterior margin of the cingulate gyrus curves upward to reach the cerebral surface. The central sulcus lies in front of and very close to the superficial part of the cingulate gyrus (4).

From our experience, the most prominent signs are the omega sign, pars bracket sign and the “M” shape of the inferior frontal gyrus. In some cases, e.g. by the mass effect of the tumour or large ischemia, there can be a problem of identifying the landmarks and than the failure of some signs is corrected by the concordance of localization given by the other signs (4).

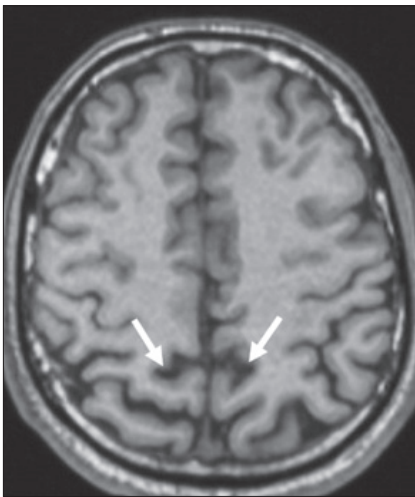


Fig. 4. Pars bracket sign.



Fig. 5. The junction of precentral sulcus with superior frontal sulcus or the “L” shape of the connection of the superior frontal gyrus with the precentral gyrus.

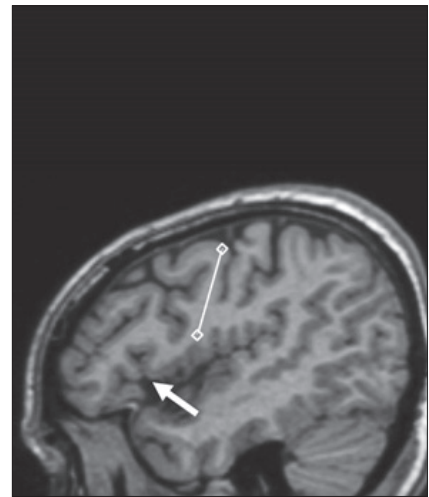


Fig. 6. Oblique course of the precentral gyrus (linear marker) and the “M” shape of the inferior frontal gyrus (arrow).

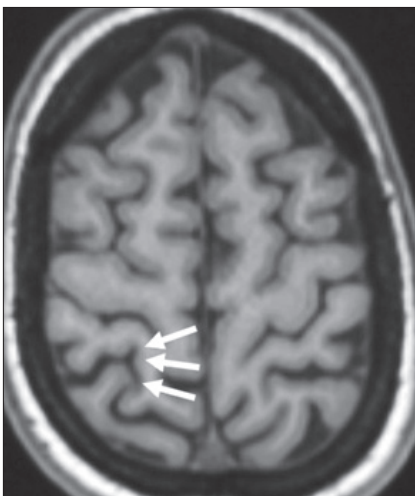


Fig. 7. Bifid poscentral sulcus sign.

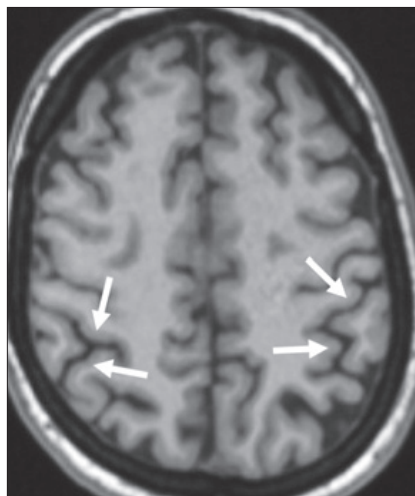


Fig. 8. Intraparietal sulcus intersects postcentral sulcus.

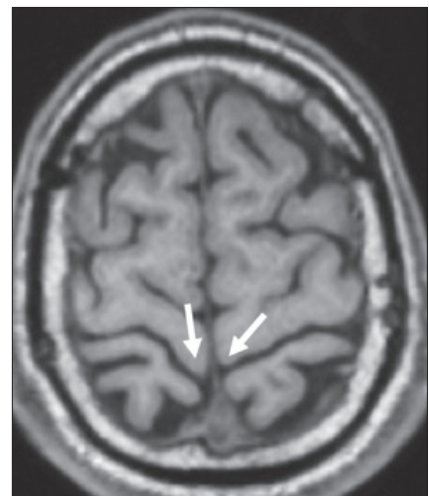


Fig. 9. Midline sulcus sign.

### Temporal lobe

Identification of the specific structures of the temporal lobe is much easier. Coronal plane can also be useful in identifying the correct structures.

The most prominent sign of the temporal lobe is the Heschl’s gyrus (transverse temporal gyrus). On the sagittal plane, the shape of Heschl’s gyrus is so characteristic that it can be easily identified directly on the supratemporal surface without need of additional landmarks – it’s the only emerging part from the flat horizontal surface of the superior temporal gyrus, with appearance of “omega”, mushroom or rabbit ear. Some variety can be seen – there can be one gyrus on the left side and two gyri on the right (48 %) but also two gyri on both sides (36 %) (9). The surface of the superior frontal gyrus anteriorly to Heschl’s

gyrus is planum polare and the part posteriorly to it is planum temporale (Fig. 12).

On the axial plane, the Heschl’s gyrus is characteristic by its anterolateral course (45° angle with the anteroposterior line), just beneath the insula. On the coronal plane, the Heschl’s gyrus has a characteristic “tent-like” shape.

### Occipital lobe

The important landmark of the occipital lobe is the calcarine sulcus. Calcarine sulcus is clearly seen as an obliquely running line in an anterosuperior direction from the occipital pole to its junction with parieto-occipital sulcus, with gradual posterior declination. It was found that the calcarine sulcus has a large variety of appearances and can be asymmetric in both hemispheres (12).



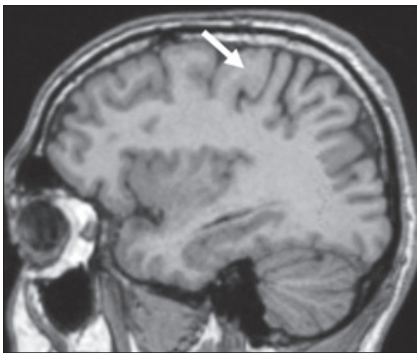


Fig. 10. The precentral “hook” (middle sagittal plane at the level of the insula).



Fig. 11. The cingulate sulcus and its ramus marginalis, middle sagittal plane. The central sulcus lies immediately anterior to the ramus marginalis.

#### Correlation between anatomical imaging and functional somatotopy.

The term somatotopy refers to the topographic organization of function along the cortex. In specific regions like the primary auditory cortex, the somatotopy may be described as tonotopy. For white matter, the preferred term is myelotopy. (1). Somatotopy in other words is a map of smaller or larger regions of cortex that form functional units or which correspond to different body parts. Somatotopy may be very fine, as in the primary hand movement

area, or very gross, as in the secondary functional areas (motor or sensory secondary areas).

#### Primary motor area

The primary motor cortex lies in the precentral gyrus, it extends from the anterior part of the paracentral lobule on the medial surface, over the cerebral margin, and down the convexity to the insular area. The somatotopy of the primary motor area is well known as the motor homunculus (Fig. 13). It represents the localization of the cortex involved in the execution of voluntary activity of the limbs, head, face and larynx. Contralaterally, this area excites all muscle groups of the extremity, ipsilaterally, most strongly those of the proximal musculature (1). There is a gross subdivision in the organization of foot, arm and face areas but also a fine-scale organization for intralimb representations (e.g. organization of different fingers), even if there is a considerable overlap of the activated volumes. It was found that there is no considerable difference between inter- and intraindividual organization of the primary motor cortex (13). That indicates that knowledge of the anatomical structures is the main relevant factor for correct recognition of the primary motor areas (in normal subjects). Different situation is in the secondary motor areas where a larger variability can be seen.

Damage in the “rolandic” or “central” area of the brain causes permanent movement and sensibility impairments (24). Neurological deficits resulting from injury to the secondary areas, however, are usually only temporary and can be fully compensated (25).

The interconnection of the primary motor area with the executive motor-neurons in the spinal cord is formed by the corticospinal tract. It can be easily seen in anatomical magnetic resonance imaging as a small area of different signal intensities extending from the precentral region through the posterior part of the internal capsule, down to the middle brain (Fig. 14).

#### Primary visual area

Most of the primary visual area (striate cortex) lies along the calcarine sulcus (12). As already mentioned, not only the configuration of calcarine sulcus varies but also the precise site of the striate cortex is variable. It can be localized on the medial surface of the occipital lobe, in the depth of the calcarine sulcus, in the parieto-occipital or anterior calcarine sulci, and also in the

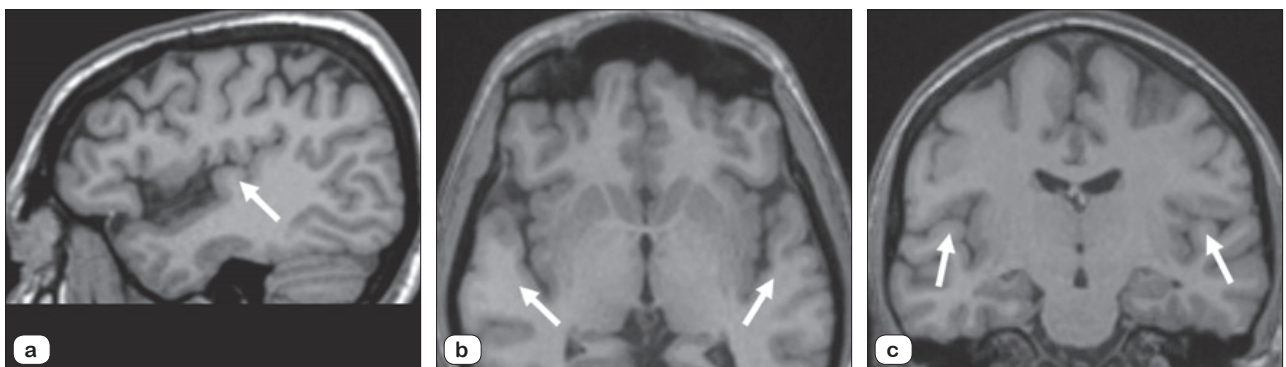
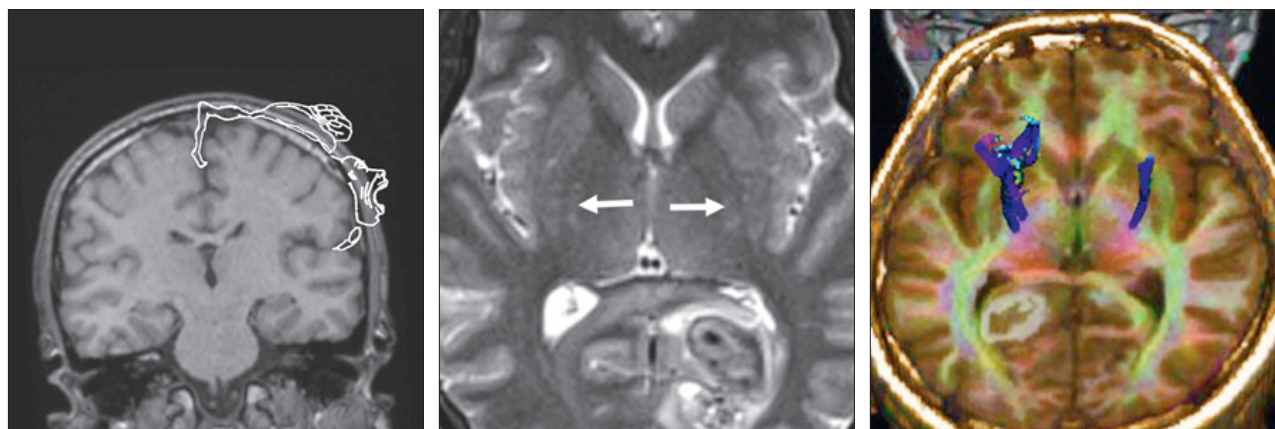


Fig. 12. Heschl's gyrus, a) sagittal plane, b) axial plane, c) coronal plane.



**Fig. 13. Motor homunculus depicted on MR image (coronal plane).** **Fig. 14. Corticospinal tract – anatomical imaging and DTI tractography imaging.**

tentorial surface of the occipital lobe (12). Therefore, recognition of the primary visual cortex can't be based only on anatomical knowledge. Other methods must be used to depict precisely the organization of the visual cortex (electrostimulation or functional magnetic resonance imaging).

#### *Primary auditory area*

The primary auditory cortex is localized in the posterior part of the supratemporal plane. Anatomically, it corresponds to the Heschl's gyrus (transverse temporal gyrus). Secondary auditory areas are in the surrounding cortex in the superior temporal gyrus and middle temporal gyrus (15). The primary auditory cortex is involved in classical tonotopic pathway, whereas the secondary auditory areas with collaboration of reticular activation system and limbic system are involved in non-classical ascending, diffuse descending and central processing of sound.

#### *Primary speech areas*

The classic model of language processing consists of a frontal expressive or motor language area (Broca's area), posterior receptive language area (Wernicke's area) and a white matter fibre tract (arcuate fasciculus) interconnecting them (16).

Broca's area is located in the inferior frontal gyrus (in the pars opercularis and posterior portion of the pars triangularis) in the dominant hemisphere (17). The dominant hemisphere is mainly the left hemisphere – in 95 % of right handed subject and in 70 % of left handed subject (23). Some data indicate that many women, but no men, have motor speech area in both hemispheres (20, 21).

Broca's area is involved in generating the signals for the musculature to produce meaningful sounds, in the initiation of speech, the organization of articulatory sequences and in the covert formation of speech (inner speech) (18, 19). Lesion in the Broca's area are related to effortful, nonfluent, monotonous, often agrammatic speech with phonemic paraphrasias and articulatory deficits (18).

The classic Wernicke's area is less well defined – it lies along the posterior margin of the Sylvian fissure, the bases of the superior and middle temporal gyrus and the planum temporale in the dominant hemisphere (17). Wernicke's area serves to recognize

speech related to it from the left Heschl's gyrus. Patients with lesion in Wernicke's area exhibit fluent, melodious speech, but empty of content, with neologisms, poor use of grammar, many errors in word usage (semantic paraphrasias). They show poor comprehension of language and poor ability to repeat language (1, 19).

The interconnection of speech areas is formed by arcuate fasciculus, a broad bundle of fibres that interconnects Wernicke's and Broca's areas. It courses from the posterior temporal lobe around the posterior edge of Sylvian fissure through the inferior parietal lobule forward deep to the insula to reach the inferior frontal gyrus (1). Lesions of the arcuate fasciculus break the connection between Broca's and Wernicke's areas, causing conduction aphasia. These patients have fluent speech (intact Broca's area), good comprehension of the spoken language (intact Wernicke's area), but have phonetic errors and poor ability to repeat language, particularly long words and sentences (1, 19, 22).

These are the classical models of neuroanatomic language systems. In condition of recent neuroimaging studies, it seems to be oversimplified and somewhat outdated, because it doesn't take into account all aspects of language processing (orthography, phonology, syntax and semantics) (22). Newly the speech and language disorders started to be classified according to the different levels of organization.

#### **Conclusion**

Understanding the structure and functions of the brain depends on understanding of the basic anatomic structures, functional somatotopy and the interconnections between them. This article has tried to present some of the relevant data and to provide a guide to better understanding of the brain function in correlation with the brain imaging.

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