

# ANATOMICAL GUIDE TO INTERPRET MR IMAGING OF THE BRAIN

**Bela Ajtai, MD, PhD**  
Dent Neurologic Institute

This presentation is to serve as an anatomical guide for general neurologists, to be able to properly review diagnostic MR images of the brain.

## Why is this skill necessary for a general neurologist?

- Although neurology is still a cognitive specialty and skills to properly perform a neurological examination and come up with a differential diagnosis remain crucial, neuroimaging is now an essential part of the diagnostic process in several disorders encountered in the everyday practice. In fact, neuroimaging is probably the most commonly/frequently utilized diagnostic modality.
- Contrary to other diagnostic tests (such as EEG, most of the EMG and sleep studies, etc.), imaging studies ordered by neurologists are very often interpreted by non-neurologists (radiologists, including general radiologists). This carries the inherent risk of missing/misinterpreting a finding that the treating neurologist would not have missed, given his/her knowledge and understanding of the patient's neurological status. A clinically oriented interpretation of an MRI is much more helpful than mere description of findings with an -oftentimes clinically irrelevant- lengthy differential diagnosis and a "clinical correlation is warranted" disclaimer at the end.
- If a clinician orders a diagnostic test, he/she is responsible for the findings and is expected to not miss any meaningful pathology. Should the interpreting radiologist miss something and harm come to the patient, the ordering neurologist is also legally responsible, in fact, there have been several cases when the medico-legal repercussions were more severe for the ordering/treating physician than for the radiologist.
- You will be learning a lot when you look at the MRI of your patient. You learn about imaging, but also about clinical neurology when you regularly correlate the imaging findings with your neurological examination and the history you obtained.
- There are some financial incentives too! Documenting that you have personally reviewed the images, as opposed to just reviewing the report, contributes to "points" for coding your visit potentially at a higher level.

## Important considerations before you start looking at an MRI...

- You ordered an "MRI of the brain". What you get however is an MRI of the HEAD... The study includes the scalp, the calvarium, the orbits, the paranasal sinuses, the pituitary gland, the skull base/posterior fossa, the arteries and venous sinuses, the nasal and oral cavities, the masticatory muscles, the pharynx, etc...even the upper cervical spine. Whatever structure is within the field of view, the interpreter is responsible for it and for all pathologies within, not just the "neuro". The brain itself is quite easy and quick to scroll through...more time is needed for the other regions.
- Develop your own, personal reading sequence! Make a list of all relevant structures that need to be looked at, decide which one you want to start with, which one you want to finish with and in what sequence you want to look at the others in between. You can start with the brain and finish with the scalp or the other way around, it doesn't matter. What matters is, once you have your personal reading sequence, stick with it and follow it each and every time! The worst thing a reader can do is to "jump around" in the study. If you do that, it is guaranteed that you will -at some point- forget to look at a structure and miss a subtle, or sometimes even a prominent, obvious pathology.
- Beware of "supernormal stimuli"-they can render you partially blind (or at least give you visual neglect). From time to time you will open an MRI study and see something shocking. A huge meningioma, a butterfly glioblastoma, a large stroke for instance. You have to be able to resist distraction by these and "forget about them" temporarily. Put this finding aside for now and just go on and follow your established reading sequence. Otherwise, you could miss an additional, maybe less obvious, but still important abnormality. An aneurysm for instance.

- Look at every pulse sequence. An MRI study typically includes T1 and T2 weighted, FLAIR (fluid attenuated inversion recovery), and diffusion weighted images, at a minimum. Different anatomical structures often need to be looked at with different techniques for best interpretation. In general, for anatomical/pathological review of structures outside the brain, the T2 weighted images are the most useful. When it comes to pathology, the pattern of appearance on different pulse sequences can often help to make the diagnosis.
- Go through the images in all available imaging planes. If you are uncertain about an anatomical situation for instance in the axial plane, the coronal and sagittal views can help out. Also, always go through ALL images in a series. An abnormality might be on the very last slice only!
- When looking at an MRI, your task is to find the pathology and other distortions of the normal anatomy. Before that, you have to know what normal is and what normal variants are. Find a normal study and look at it repeatedly, practice. Use imaging anatomy atlases, if needed. If you know what normal is and you look at the MRI study utilizing your reading sequence consistently, you will find the pathology also. You don't have to necessarily know what it is, just know it is there. Once you find it, you can consult with a colleague or another reference.

**Suggested brain MRI interpretation sequence** (feel free to change it to make your own, personal sequence...then keep using your sequence, consistently). The list may appear lengthy, however with practice and routine your MRI review time will shorten.

1. Scalp, calvaria, meninges (in axial T2 weighted images)
  - Review the layers: skin, scalp adipose tissue and the layers of the calvarium (two layers of cortical bone, bone marrow in between)
2. Orbits (in axial and coronal T2 weighted images)
  - Inspect the globe, the lens. Look at the extraocular muscles and the intra- and extraconal fat compartment. Subsequently look at the optic nerve and follow it all the way to the optic chiasm.
3. Paranasal sinuses (in axial and coronal T2 weighted images. Coronal images are important, as the floor of the maxillary sinuses is often not covered by the axial images).
  - Review the frontal, maxillary and sphenoid sinuses and the ethmoid air cells. Normal sinuses are dark (filled by air).
4. Oral cavity and masticatory muscles, parotid gland, nasopharynx, oropharynx (axial, coronal and sagittal T2 weighted images)
5. Pituitary gland (coronal and sagittal T2 images are the most useful)
  - Look at the gland, the stalk, and one more time the optic chiasm.
  - Inspect the parasellar structures, contents of the cavernous sinuses.
6. The posterior fossa (axial and coronal T2 weighted images)
  - Structures to look at: jugular foramen, the cerebellopontine angle, internal acoustic canal, 7-8<sup>th</sup> nerve complex, visualized structures of the inner ear, trigeminal nerves, Meckel's caves. Depending on the detail of the study, at times the oculomotor, abducens nerves and the hypoglossal canal are also seen
7. The craniocervical junction
  - Look for Chiari malformation! Also look at the visualized cervical spine segment (any sign of cord compromise?).
8. FLOW VOIDS
  - I spend most of my time with these, due to not wanting to miss an aneurysm. Start with the posterior circulation, continue with the vessels of the anterior circulation. Review the vessels in both axial as well as coronal T2 weighted images (these serve as "poor man's angiogram").
  - Review all visible major intracranial venous sinuses as well (sagittal, transverse, sigmoid, straight sinus, the confluence of sinuses), the major cortical draining veins and also the vein of Galen.
9. Evaluate the size of the brain
  - Axial T1 weighted images are useful (T2 weighted images may make one overcall the degree of atrophy).
  - Look at the third, fourth and lateral ventricles and the aqueduct (for the aqueduct, axial and sagittal T2 weighted images are useful). Always look at the anterior third ventricle, at the level of the foramen of Monro...never miss a colloid cyst here.
  - Look at the size of the sulcal spaces, the interhemispheric and the sylvian fissures and remember to look at the posterior fossa also when looking for atrophy

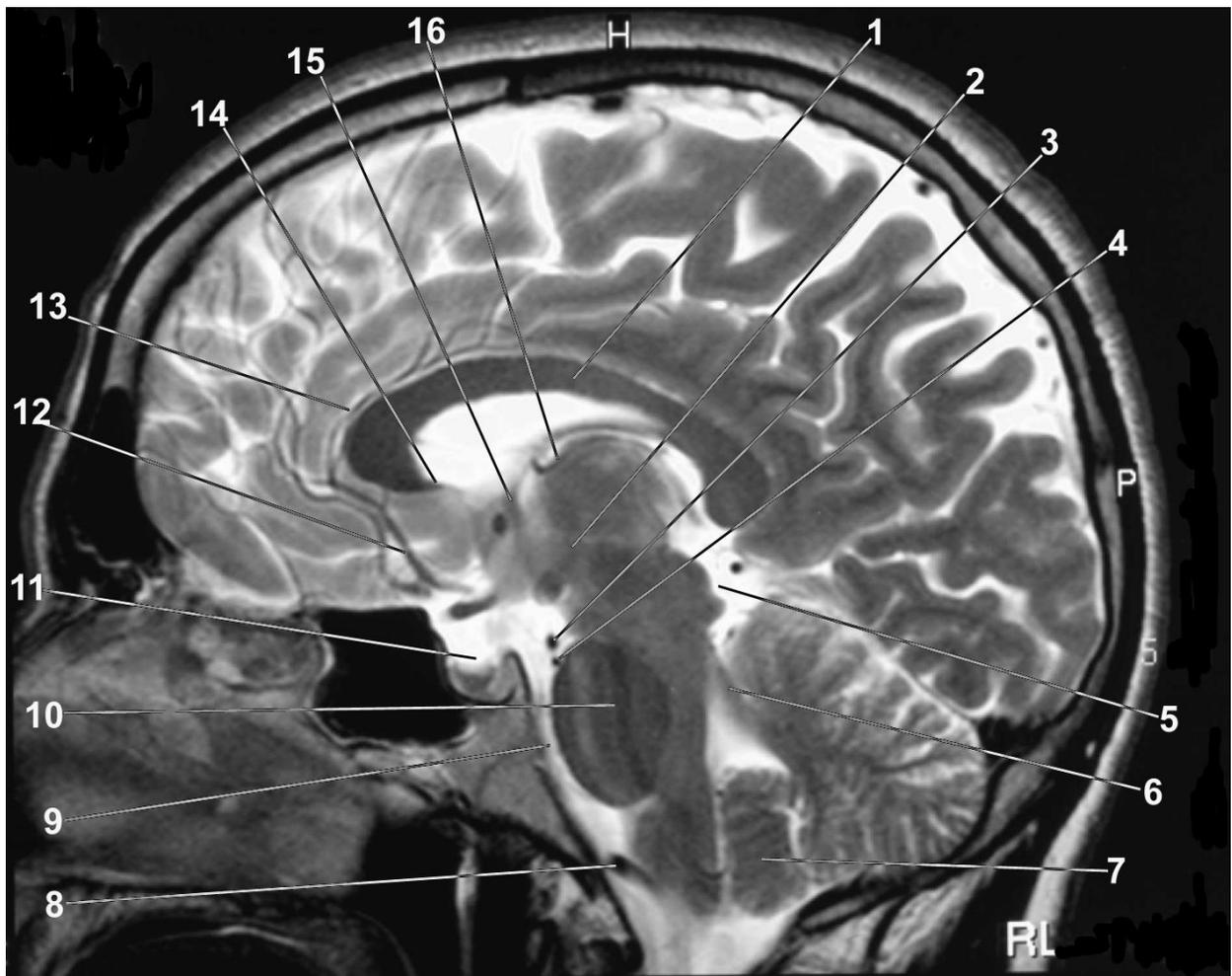
10. The central nervous system parenchyma

- Start at the medulla, move all the way up to the vertex.
- For the posterior fossa contents (brainstem and cerebellum) use T2 weighted and FLAIR sequences.
- For the supratentorial compartment FLAIR is usually utilized when looking for pathology. Review all slices, in at least two imaging planes.
- Take a moment to look at the tectal/pineal region as well as the corpus callosum (best on sagittal images).

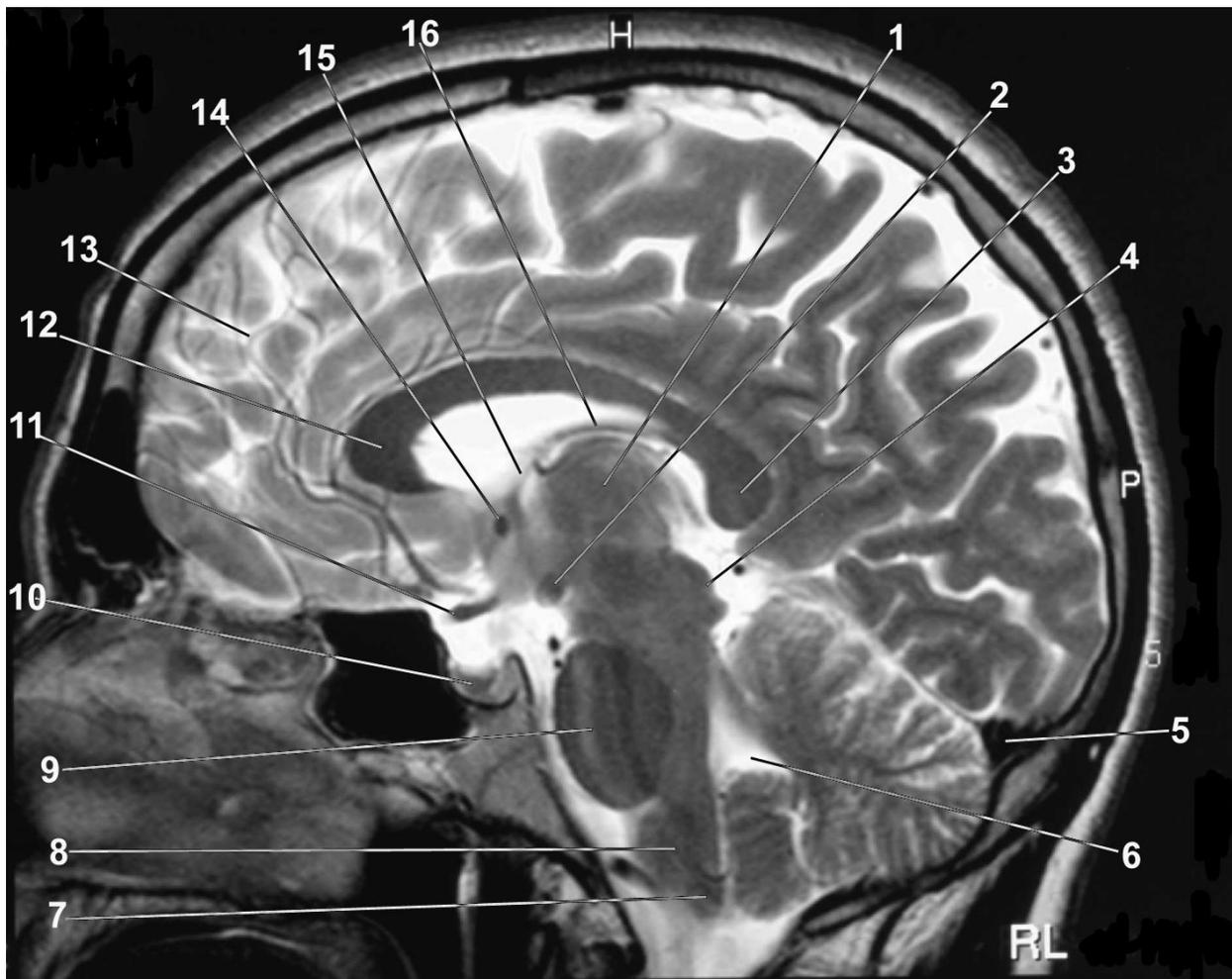
11. The last step of reading is the review of images with other special techniques

- Diffusion weighted images, for acute ischemia. As of note, in the hospital/emergency room setting, especially when the patient is evaluated for acute stroke, these are the images you may want to start with.
- Gradient echo or preferably susceptibility weighted images, for the intraparenchymal venous system and blood products.
- T1 postcontrast images in multiple planes, if available.
- Coronal FLAIR images to look at the hippocampal formation, look for hippocampal sclerosis.
- T1 inversion recovery sequences to see cortical maldevelopment, including heterotopia.

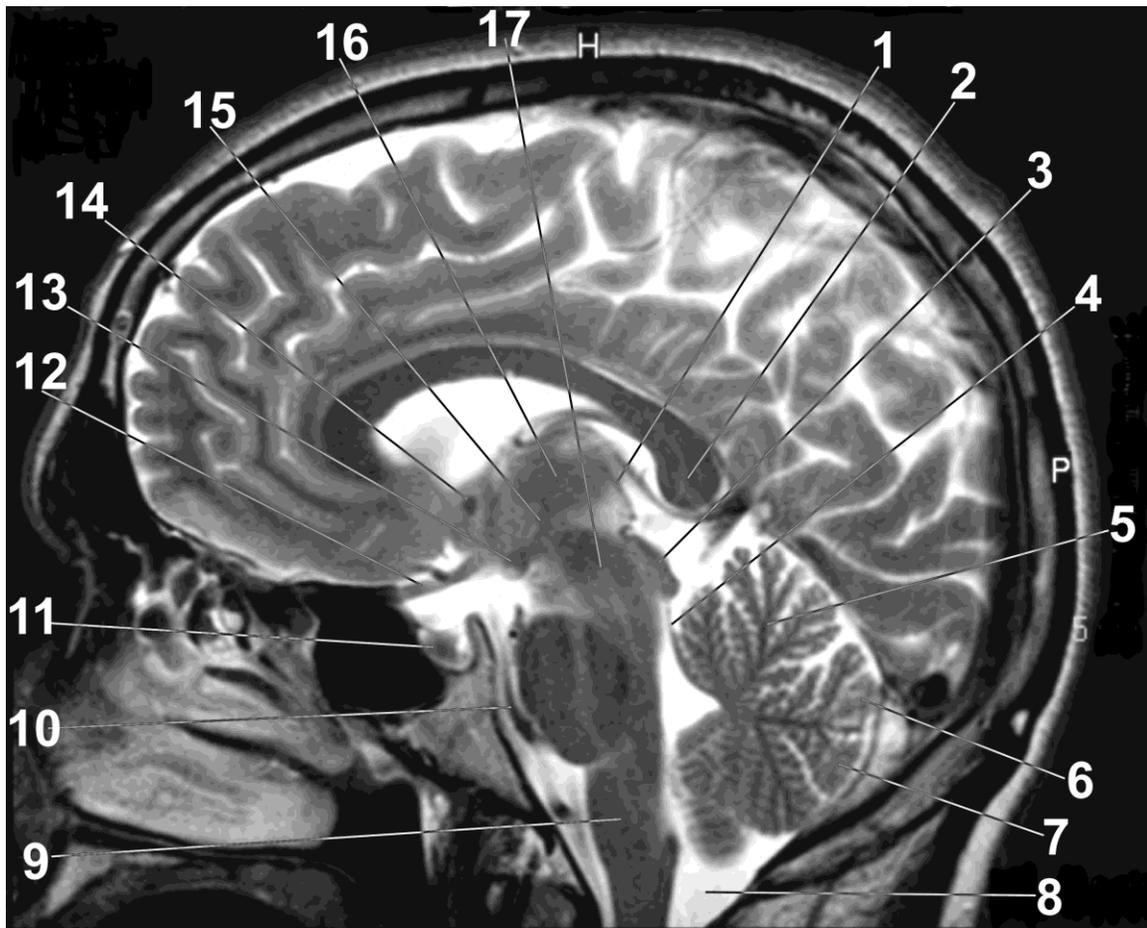
On the following pages a selection of annotated MR images are presented, depicting normal anatomy.



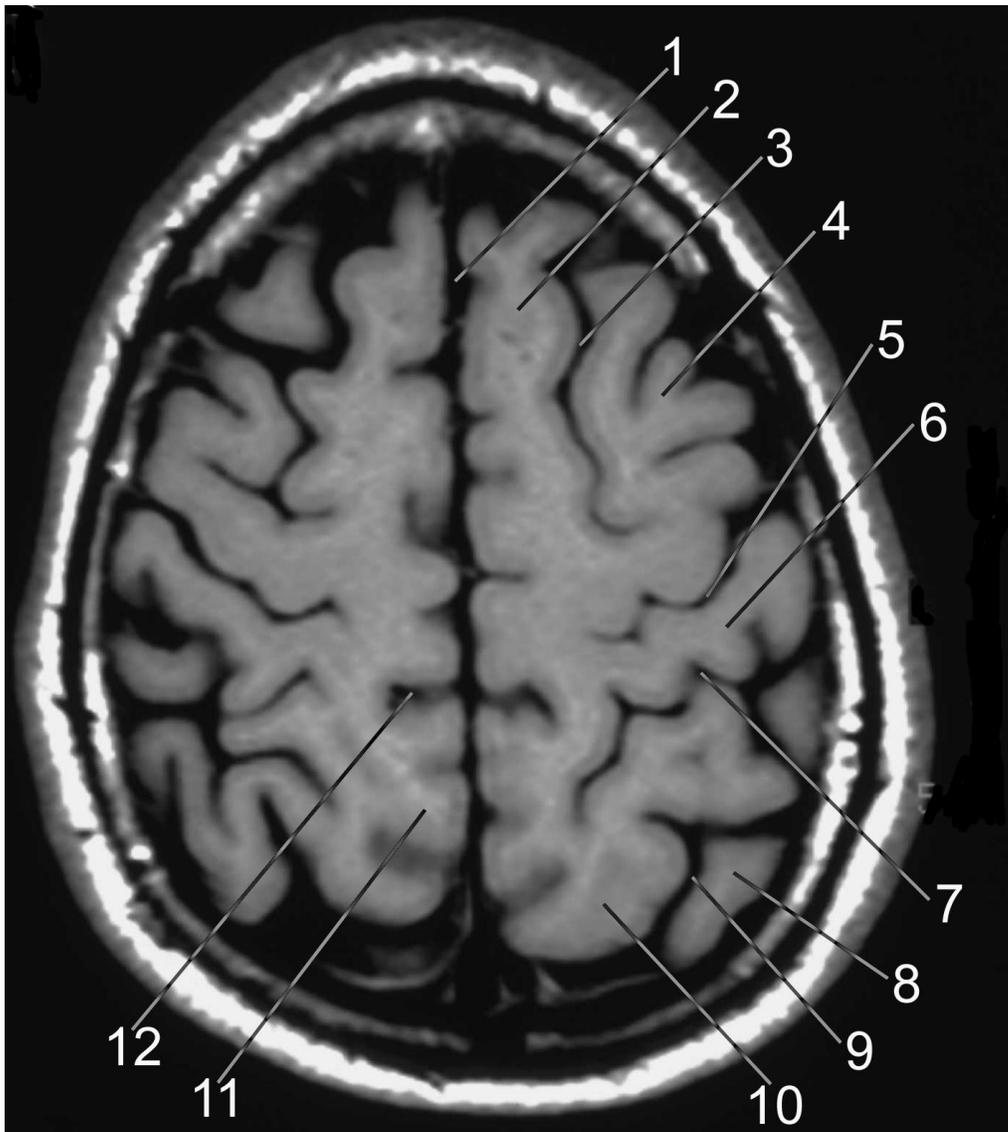
- 1-corpor callosum (body)
- 2-mamillothalamic tract
- 3-posterior cerebral artery
- 4-superior cerebellar artery
- 5-quadrigeminal cistern
- 6-superior cerebellar peduncle
- 7-cerebellar tonsil
- 8-vertebral artery
- 9-basal (prepontine) cistern
- 10-medial lemniscus
- 11-suprasellar cistern
- 12-anterior cerebral artery
- 13-pericallosal artery (from the anterior cerebral artery)
- 14-corpor callosum (rostrum)
- 15-fornix (column), approaching the mamillary body
- 16-internal cerebral vein



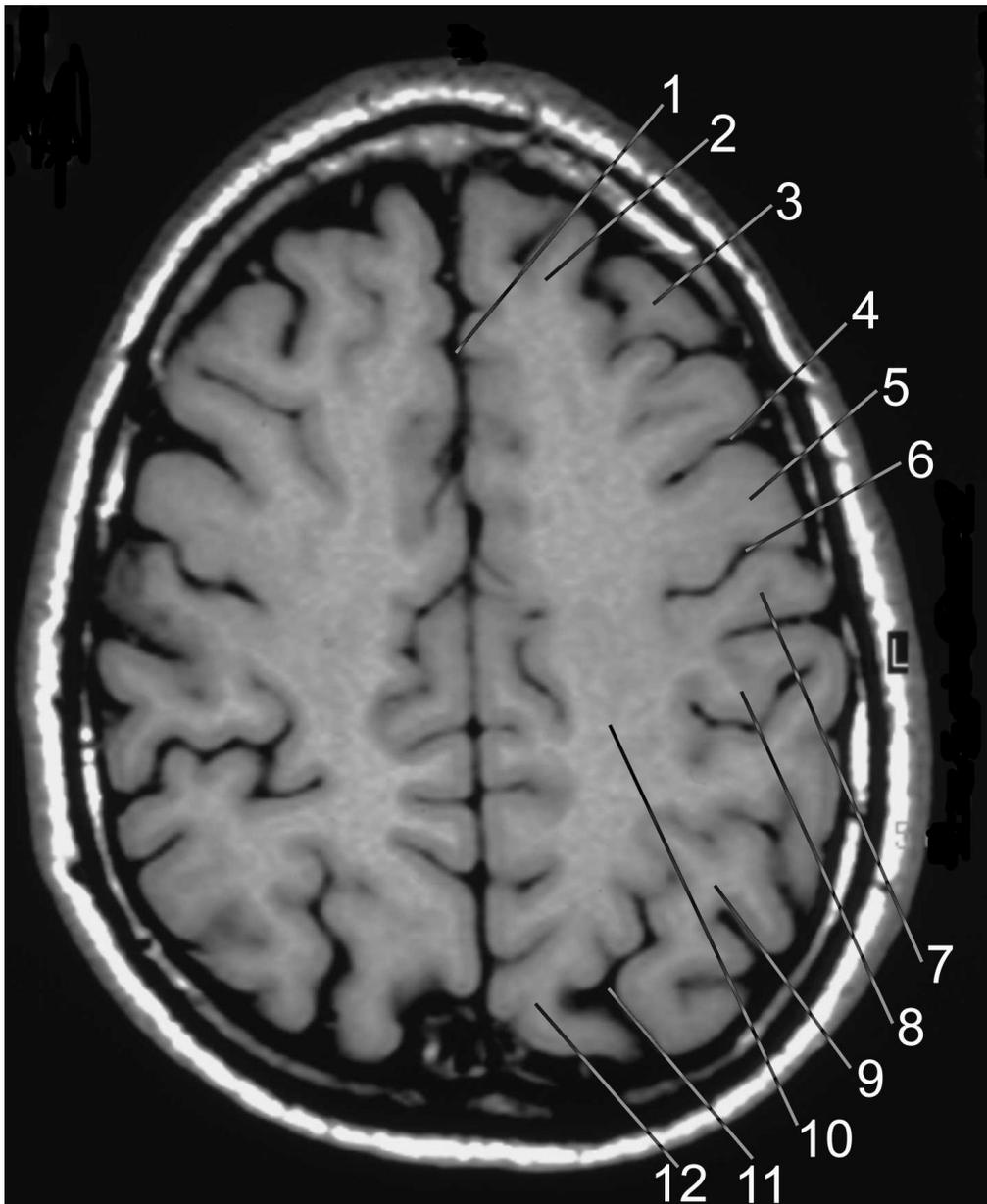
- 1-thalamus
- 2-mamillary body
- 3-corpor callosum (splenium)
- 4-tectum of the midbrain
- 5-transverse sinus
- 6-IVth ventricle
- 7-origin of the internal arcuate fibers of the medial lemniscus
- 8-medulla
- 9-corticospinal tract
- 10-pituitary gland
- 11-middle cerebral artery
- 12-corpor callosum (genu)
- 13-internal frontal branch (from the anterior cerebral artery)
- 14-anterior commissure
- 15-fornix (column)
- 16-fornix (body)



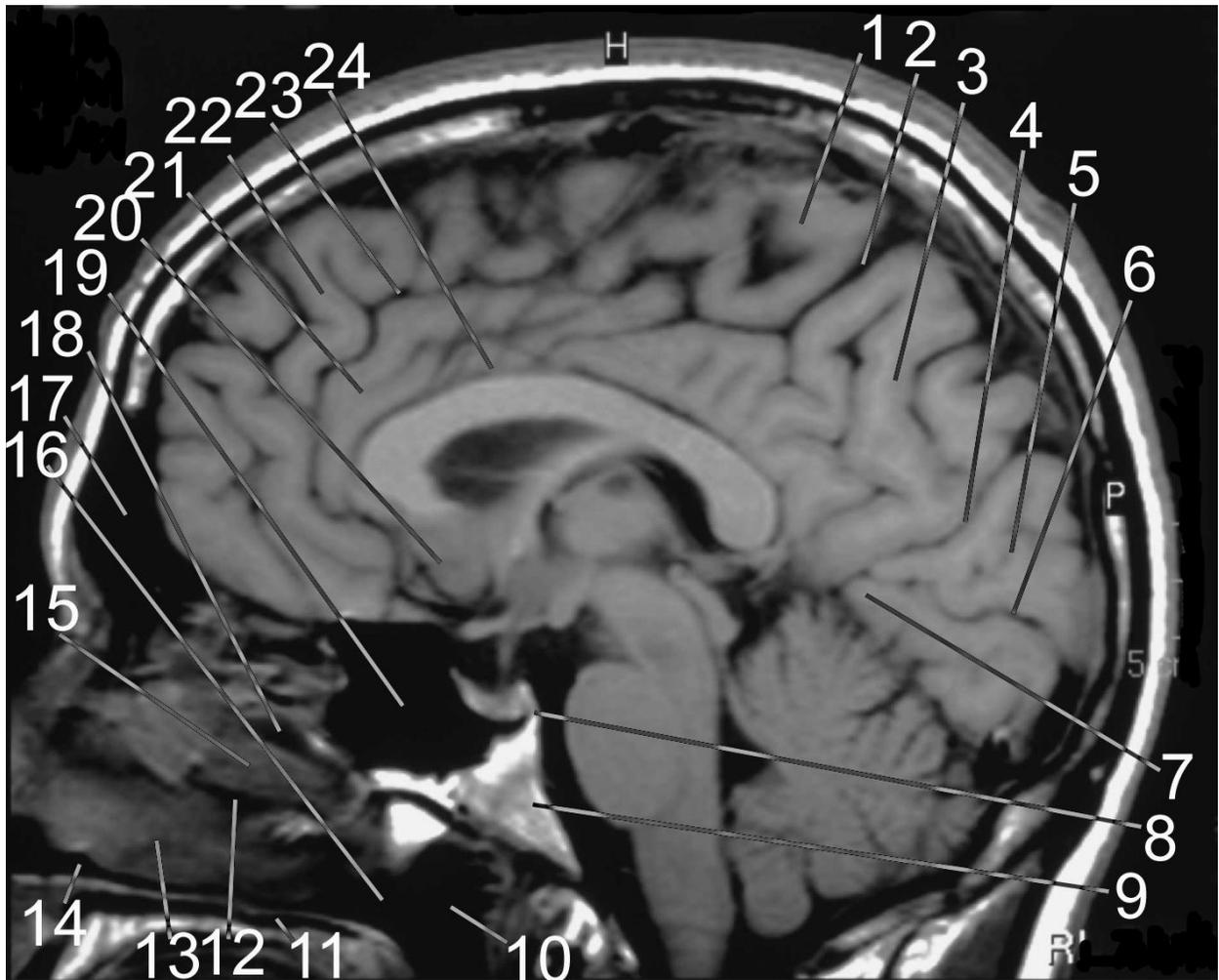
- 1-stria medullaris thalami
- 2-corpor callosum (splenium)
- 3-tectum of the midbrain
- 4-superior medullary velum
- 5-culmen
- 6-folium vermis
- 7-tuber vermis
- 8-cisterna magna
- 9-medulla
- 10-basilar artery
- 11-pituitary gland
- 12-optic nerve
- 13-mamillary body
- 14-anterior commissure
- 15-mamillothalamic tract
- 16-thalamus
- 17-midbrain tegmentum



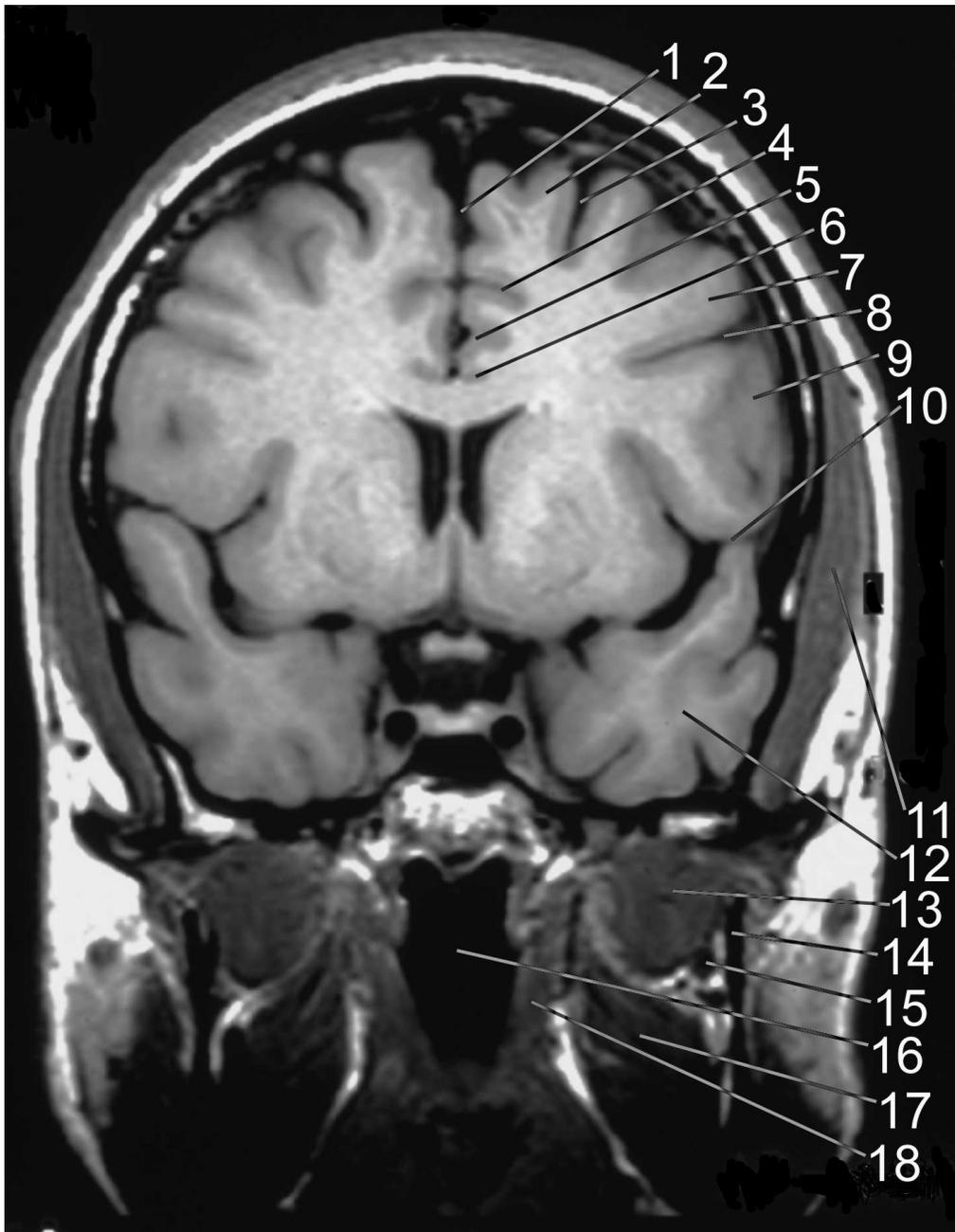
- 1-interhemispheric fissure
- 2-superior frontal gyrus
- 3-superior frontal sulcus
- 4-middle frontal gyrus
- 5-central sulcus
- 6-postcentral gyrus
- 7-postcentral sulcus
- 8-inferior parietal lobule
- 9-intraparietal sulcus
- 10-superior parietal lobule
- 11-medial parietal lobe (precuneus)
- 12-marginal branch of the cingulate gyrus



- 1-interhemispheric fissure
- 2-superior frontal gyrus
- 3-middle frontal gyrus
- 4-precentral sulcus
- 5-precentral gyrus
- 6-central sulcus
- 7-postcentral gyrus
- 8-supramarginal gyrus
- 9-inferior parietal lobule
- 10-centrum semiovale
- 11-intraparietal sulcus
- 12-superior parietal lobule

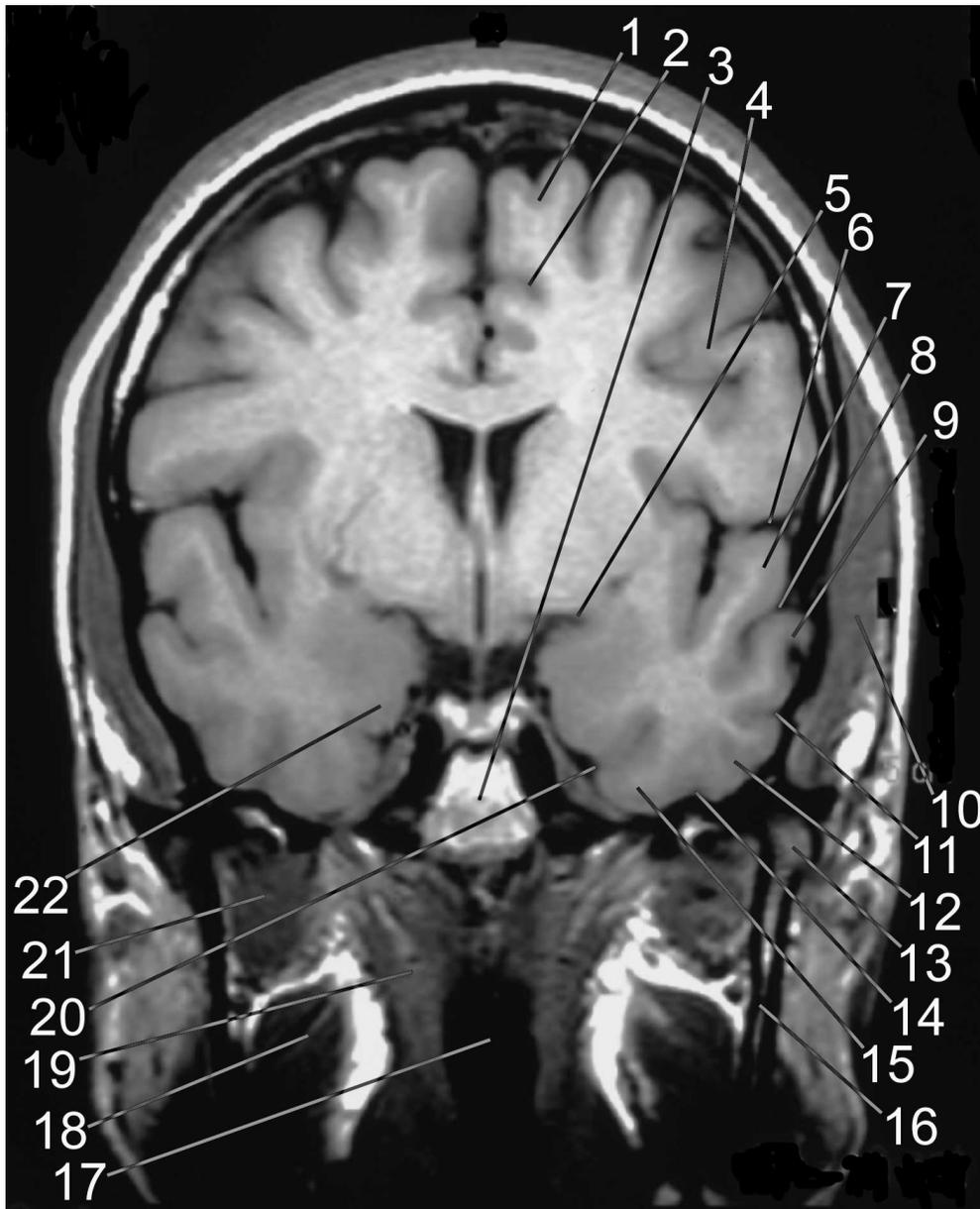


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|--|----------------------------------|
| 1-paracentral lobule                     | 13-inferior nasal concha         |
| 2-marginal ramus of the cingulate sulcus | 14-inferior nasal meatus         |
| 3-parietal lobe (precuneus)              | 15-middle nasal concha           |
| 4-parietooccipital fissure               | 16-choana                        |
| 5-occipital lobe (cuneus)                | 17-frontal sinus                 |
| 6-calcarine sulcus                       | 18-superior nasal meatus         |
| 7-lingual gyrus                          | 19-sphenoid sinus                |
| 8-dorsum sellae                          | 20-area subcallosa               |
| 9-clivus                                 | 21-cingulate gyrus               |
| 10-nasopharynx                           | 22-superior frontal gyrus        |
| 11-hard palate                           | 23-cingulate sulcus              |
| 12-middle nasal meatus                   | 24-sulcus of the corpus callosum |



- 1- interhemispheric fissure
- 2- superior frontal gyrus
- 3- superior frontal sulcus
- 4- cingulate sulcus
- 5- cingulate gyrus
- 6- sulcus of the corpus callosum
- 7- middle frontal gyrus
- 8- inferior frontal sulcus
- 9- inferior frontal gyrus

- 10- lateral sulcus
- 11- temporalis muscle
- 12- temporal lobe
- 13- lateral pterygoid muscle
- 14- ramus of the mandible
- 15- maxillary artery
- 16- pharynx
- 17- medial pterygoid muscle
- 18- superior pharyngeal constrictor muscle



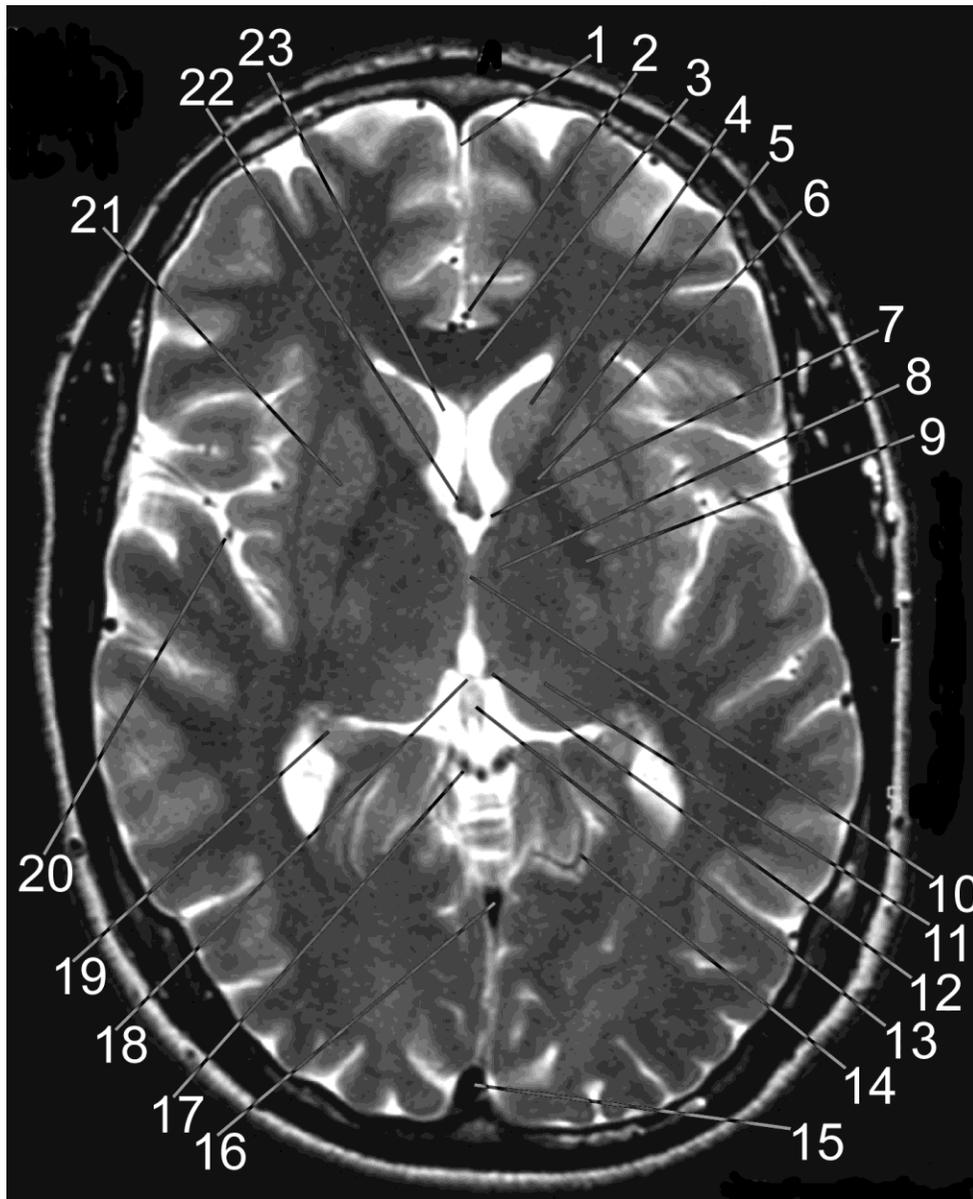
- 1-superior frontal gyrus
- 2-cingulate sulcus
- 3-clivus
- 4-inferior frontal sulcus
- 5-choroid fissure
- 6-lateral sulcus (Sylvian fissure)
- 7-superior temporal gyrus
- 8-superior temporal sulcus
- 9-middle temporal gyrus
- 10-temporalis muscle
- 11-middle temporal sulcus

- 12-inferior temporal gyrus
- 13-head of the mandible
- 14-inferior temporal sulcus
- 15-occipitotemporal (fusiform) gyrus
- 16-ramus of the mandible
- 17-pharynx
- 18-medial pterygoid muscle
- 19- superior pharyngeal constrictor muscle
- 20-collateral sulcus
- 21-lateral pterygoid muscle
- 22-(para)hippocampal gyrus

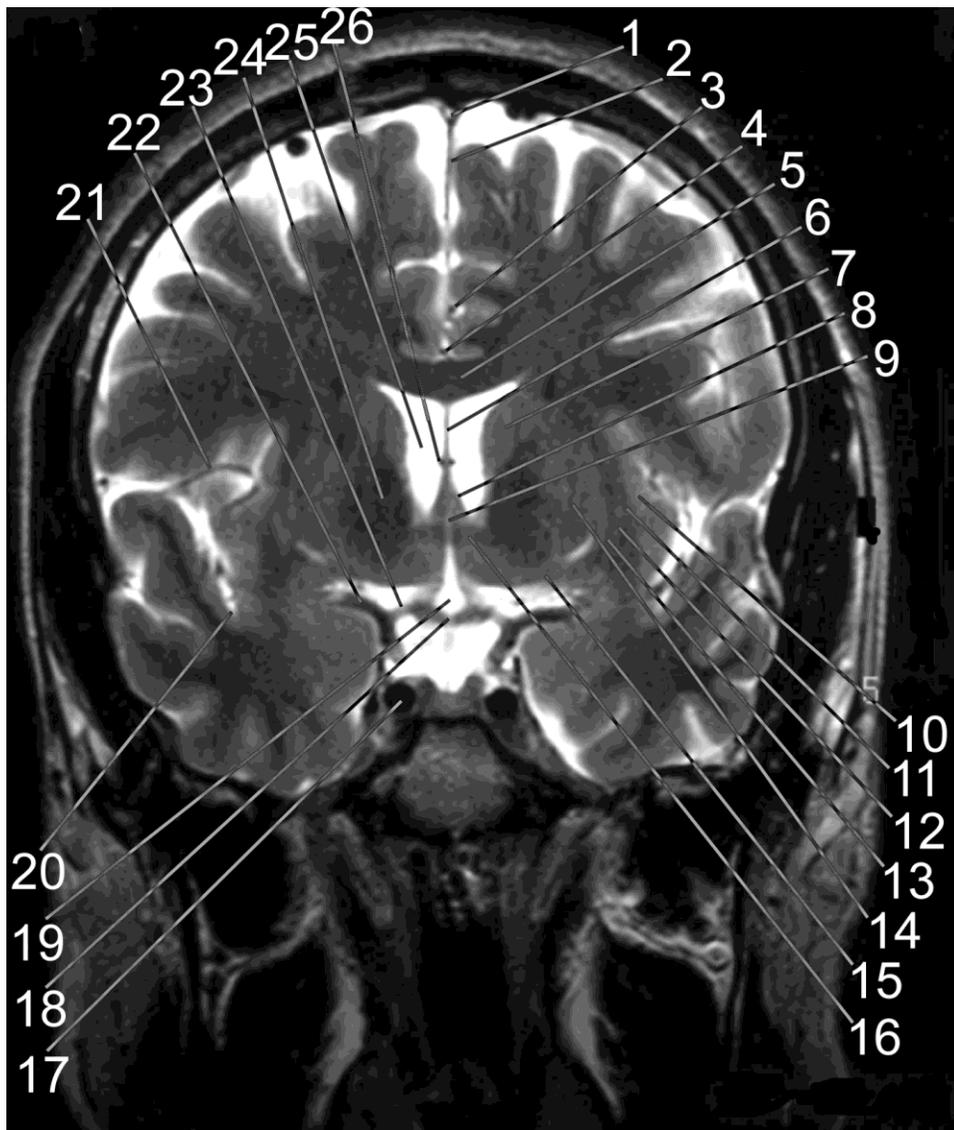


- 1-falx cerebri
- 2-pericallosal artery
- 3-septum pellucidum
- 4-head of the caudate nucleus
- 5-anterior limb of the internal capsule
- 6-foramen of Monro
- 7-genu of the internal capsule
- 8-posterior limb of the internal capsule
- 9-choroid plexus
- 10-fornix (crus)
- 11-corpora callosa (splenium)

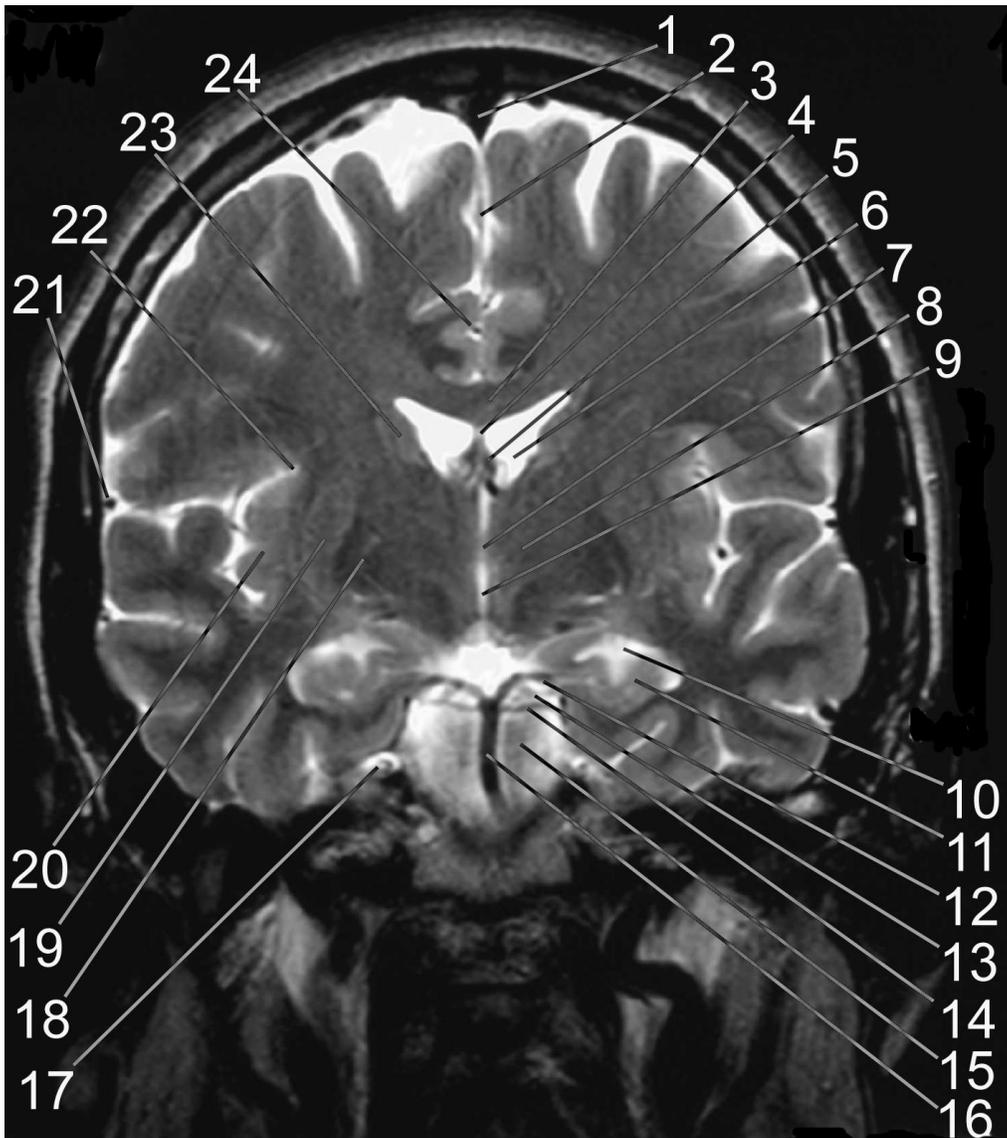
- 12-vein of Galen
- 13-straight sinus
- 14-superior sagittal sinus
- 15-internal cerebral vein
- 16-third ventricle
- 17-thalamus
- 18-branch of the middle cerebral artery
- 19-claustrum
- 20-external capsule
- 21-lentiform nucleus
- 22-thalamostriate vein



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|--|---|
| 1-falx cerebri                           | 12-habenula                             |
| 2-pericallosal artery                    | 13-pineal gland                         |
| 3-corpor callosum                        | 14-branch of posterior cerebral artery  |
| 4-head of the caudate nucleus            | 15-superior sagittal sinus              |
| 5-anterior limb of the internal capsule  | 16-straight sinus                       |
| 6-genu of the internal capsule           | 17-basal vein of Rosenthal              |
| 7-thalamostriate vein                    | 18-habenular commissure                 |
| 8-mamillothalamic tract                  | 19-hippocampus                          |
| 9-posterior limb of the internal capsule | 20-branch of the middle cerebral artery |
| 10-interthalamic adhesion                | 21-lentiform nucleus                    |
| 11-thalamus                              | 22-fornix (column)                      |
|  | 23-lateral ventricle (frontal horn)     |



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|--|--|
| 1-superior sagittal sinus                  | 14-putamen                               |
| 2-falx cerebri                             | 15-olfactory cortex (paleocortex)        |
| 3-callosomarginal artery                   | 16-anterior commissure                   |
| 4-pericallosal artery                      | 17-internal carotid artery               |
| 5-corpor callosum (body)                   | 18-optic chiasm                          |
| 6-septum pellucidum                        | 19-optic recess of the third ventricle   |
| 7-head of the caudate nucleus              | 20-circular sulcus of the insula         |
| 8-column of the fornix                     | 21-branch of the middle cerebral artery  |
| 9-triangular recess of the third ventricle | 22-middle cerebral artery (M1 segment)   |
| 10-insula                                  | 23-anterior cerebral artery (A1 segment) |
| 11-extreme capsule                         | 24-internal capsule                      |
| 12-claustrum                               | 25-lateral ventricle (frontal horn)      |
| 13-external capsule                        | 26-vein of the septum pellucidum         |



1- superior sagittal sinus

2-falx cerebri

3-corpor callosum

4-septum pellucidum

5-fornix

6-lateral ventricle (body)

7-interthalamic adhesion

8-thalamus

9-third ventricle

10-lateral ventricle (temporal horn)

11-hippocampus

12-posterior cerebral artery

13-oculomotor nerve

14-superior cerebellar artery

15-pons

16-basilar artery

17-Meckel's cave

18-globus pallidus

19-putamen

20-insula

21-branch of the middle cerebral artery

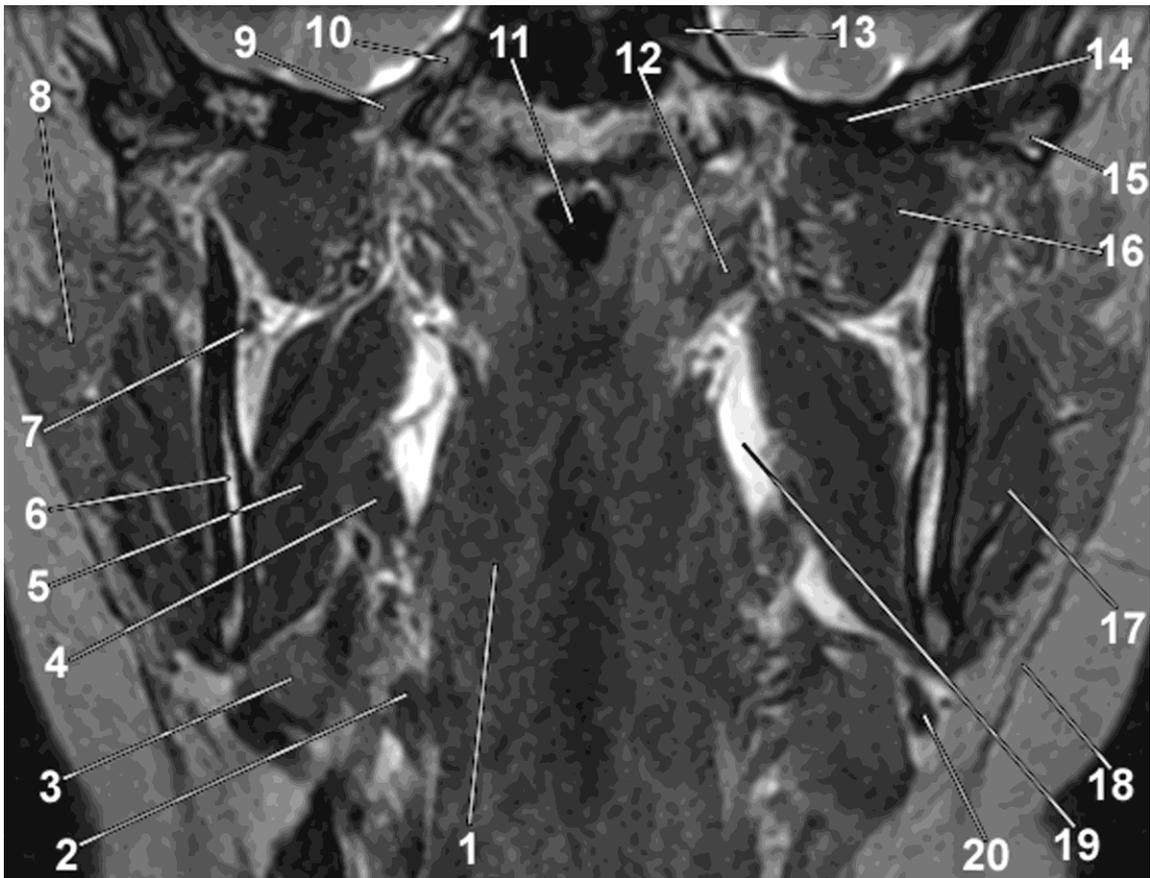
22-circular sulcus of the insula

23-caudate nucleus (body)

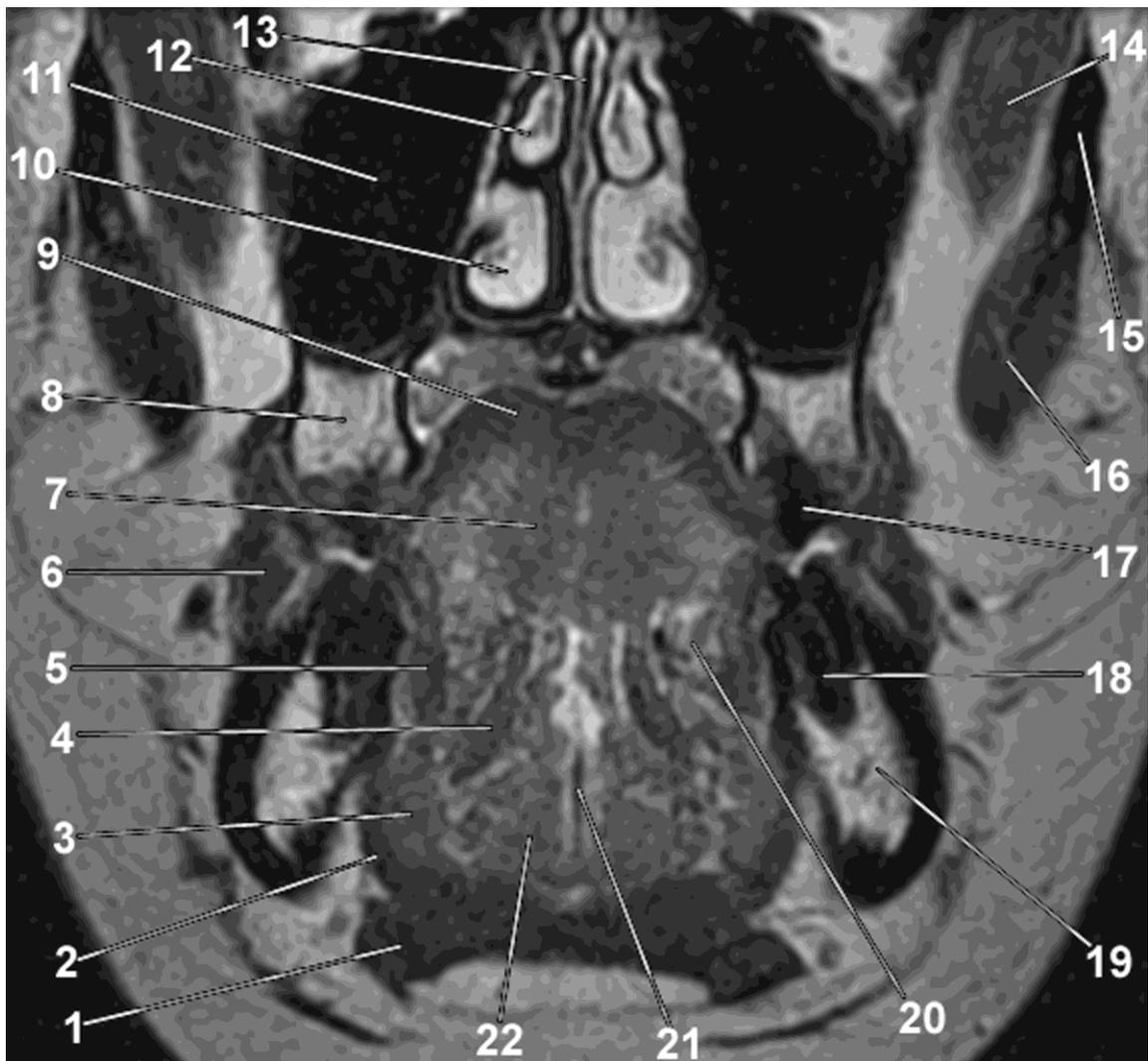
24-callosomarginal artery



- 1-pharynx
- 2-parapharyngeal space
- 3-medial pterygoid muscle
- 4-parotid gland
- 5-mandible
- 6-zygomaticus major muscle
- 7-levator anguli oris muscle
- 8-soft palate
- 9-hard palate
- 10-alveolar arch of the maxilla with root of tooth
- 11-deep portion of the temporalis muscle
- 12-masseter muscle
- 13-levator veli palatini muscle
- 14-longus capitis muscle
- 15-stylopharyngeus muscle
- 16-retromandibular vein
- 17-posterior belly of the digastric muscle
- 18-internal jugular vein
- 19-internal carotid artery

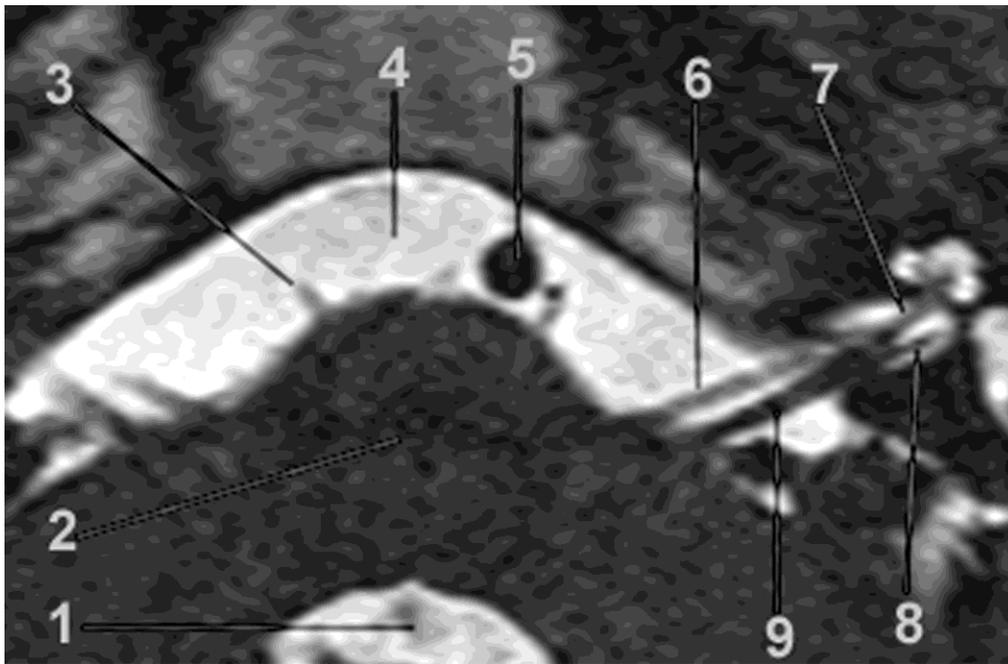


- 1-pharyngeal constrictor muscle
- 2-stylohyoid muscle
- 3-submandibular gland
- 4-styloglossus muscle
- 5-medial pterygoid muscle
- 6-ramus of the mandible
- 7-maxillary artery
- 8-parotid gland
- 9-maxillary nerve (2<sup>nd</sup> division of the trigeminal nerve)
- 10-ophthalmic nerve (1<sup>st</sup> division of the trigeminal nerve)
- 11-nasopharynx
- 12-levator veli palatini muscle
- 13-cavernous segment of the internal carotid artery
- 14-greater wing of the sphenoid bone
- 15-zygomatic process of the temporal bone
- 16-lateral pterygoid muscle
- 17-masseter muscle
- 18-fascia
- 19-parapharyngeal space
- 20-facial artery

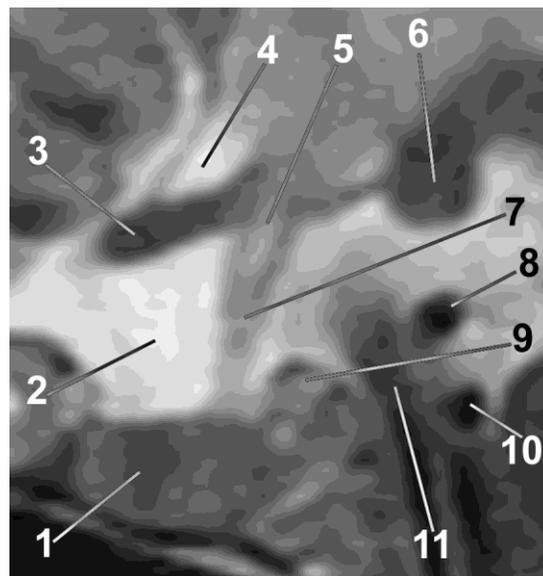


- 1-anterior belly of the digastric muscle
- 2-mylohyoid muscle
- 3-sublingual gland
- 4-genioglossus muscle
- 5-hyoglossus muscle
- 6-buccinator muscle
- 7-vertical muscle
- 8-alveolar process of the maxilla
- 9-superior longitudinal muscle
- 10-inferior nasal turbinate
- 11-maxillary sinus

- 12-middle nasal turbinate
- 13-nasal septum
- 14-temporalis muscle
- 15-zygomatic bone
- 16-masseter muscle
- 17-tooth in alveolar process of the maxilla
- 18-tooth in alveolar process of the mandible
- 19-mandible
- 20-inferior longitudinal muscle
- 21-frenulum of the tongue
- 22-geniohyoid muscle

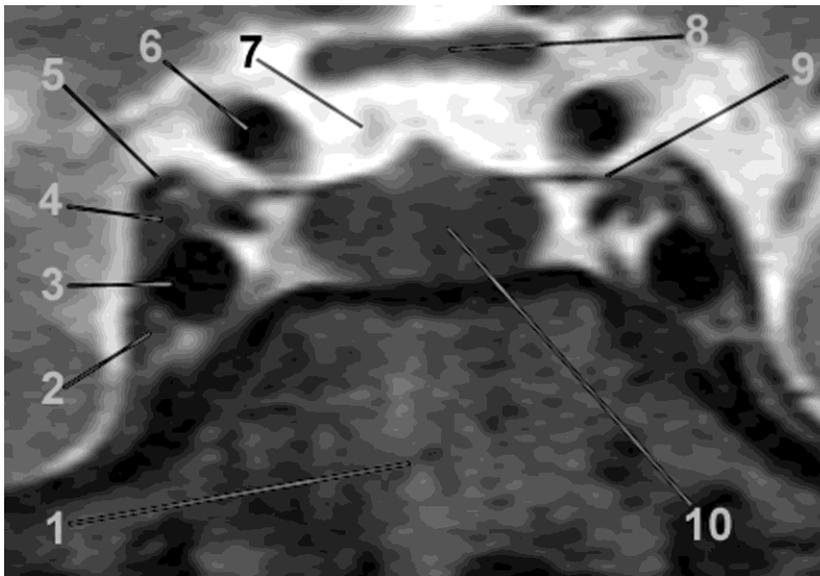


- 1-fourth ventricle
- 2-pons
- 3-abducens nerve
- 4-basal (prepontine) cistern
- 5-basilar artery
- 6-facial nerve
- 7-cochlear nerve
- 8-vestibular nerve
- 9-vestibulocochlear nerve



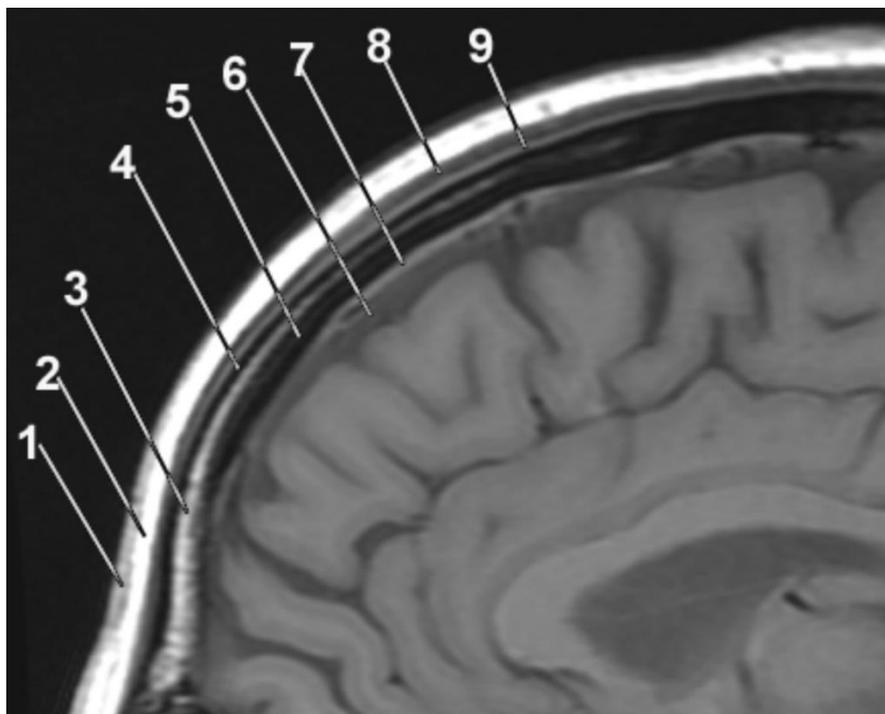
- 1-pituitary gland
- 2-suprasellar cistern
- 3-optic chiasm
- 4-chiasmatic recess of the third ventricle
- 5-infundibular recess of the third ventricle
- 6-mamillary body

- 7-pituitary stalk (infundibulum)
- 8-posterior cerebral artery
- 9-dorsum sellae
- 10-superior cerebellar artery
- 11-CSF pulsation artifact



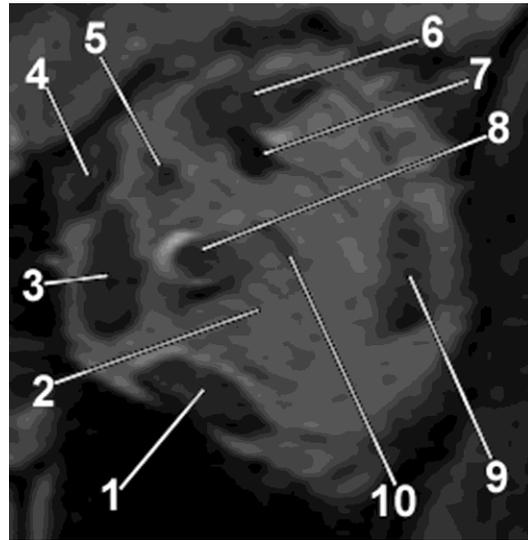
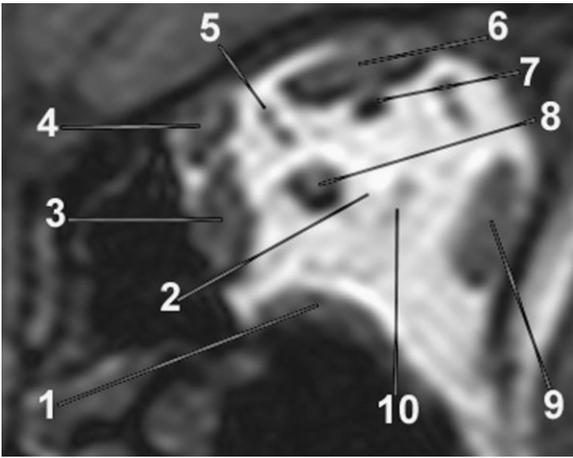
- 1-body of the sphenoid bone
- 2-1<sup>st</sup> division of the trigeminal nerve (ophthalmic nerve)
- 3-cavernous segment of the internal carotid artery
- 4-oculomotor nerve
- 5-anterior clinoid process

- 6-supraclinoid segment of the internal carotid artery
- 7-suprasellar cistern
- 8-optic chiasm
- 9-diaphragm of the sella
- 10-pituitary gland



- 1-skin
- 2-subcutaneous fat and connective tissue
- 3-bone marrow
- 4-outer table (compact outer cortical bone layer of calvarium)

- 5-inner table (compact inner cortical bone layer of calvarium)
- 6-subarachnoid space
- 7-dura
- 8-galea aponeurotica
- 9-loose connective tissue and periosteum



- 1-inferior rectus muscle
- 2-intraconal fat
- 3-medial rectus muscle
- 4-superior oblique muscle
- 5-ophthalmic artery
- 6-levator palpebrae superioris and rectus superior muscles
- 7-superior ophthalmic vein
- 8-optic nerve
- 9-lateral rectus muscle
- 10-lateral ophthalmic vein



1-medial rectus muscle  
2-sclera  
3-extraconal fat  
4-vitreous body  
5-lens

6-suspensory ligament/ciliary body complex  
7-intraconal fat  
8-lateral rectus muscle  
9-optic nerve (intraorbital segment)  
10-optic nerve (intracanalicular segment)