Structural Anatomy

7

Nivedita Agarwal and John D. Port

The images presented within this chapter are from the same single healthy 25-year-old female subject that was presented in Chap. 1. Voxel dimensions are 1 mm in all dimensions (isotropic), with reconstructions created in the true axial and true coronal planes. Selected images were chosen for labeling that best represented the local anatomy in a given region. Images were magnified to focus on the brainstem and cerebellum and were adjusted to accentuate difference between the gray and white matter so that labeling is more obvious.

Note that these images appear blurry; while 1 mm isotropic pixel dimensions are adequate for imaging the cerebral hemispheres, this resolution is insufficient to capture the detailed anatomy of the small brainstem and cerebellar structures. Such anatomy is better imaged with a 7 tesla MRI scanner (see Chap. 10). However, most MRI facilities have 1.5T and 3T scanners; thus we chose to label images as the radiologist would see them. Furthermore, we chose to reconstruct images in the planes most commonly viewed by radiologists; as such, our labels are more relevant to routine clinical MRI than the labels presented in traditional histological atlases, which are typically aligned perpendicular to the long axis of the brainstem [3–7].

Each page contains the labeled images on the left-hand side. In order to keep the labels small, label numbers are specific to each brain region (cerebellum, brainstem). A small image on the top right of the page documents the locations of the slices, and a key in the lower right-hand side of the page lists the individual structures.

N. Agarwal, M.D. (✉)
S. Maria del Carmine Hospital, Azienda Provinciale per i Servizi Sanitari, Rovereto (TN), Italy

Center for Mind/Brain Sciences (CIMeC), University of Trento, Rovereto (TN), Italy

Department of Radiology, Section of Neuroradiology, University of Utah, Salt Lake City (UT), USA
e-mail: Nivedita.agarwal@apss.tn.it

J.D. Port, M.D., Ph.D.
Department of Radiology, Mayo Clinic, Rochester, MN, USA

7.1 Cerebellum Overview

Embryologically, the cerebellum develops from the dorsal aspect of the rhombencephalon, specifically the dorsal metencephalon. Once formed, the cerebellum then develops into a midline portion known as the vermis and two more lateral cerebellar hemispheres. Three primary lobes develop: the primary fissure separates the more cranial anterior lobe from the caudal posterior lobe, and the pos-

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Table 7.1 General structure and function of the cerebellum

Cerebellar lobe	Vermis (archicerebellum, spinocerebellum)	Cerebellar hemispheres (neocerebellum)	Function
Anterior lobe	Lingula Central lobule Culmen	Wings of lingula Wings of central lobule Quadrangular lobule	Sensorimotor
Posterior lobe (cerebrocerebellum)	Declive Folium Tuber Pyramid Uvula	Simple lobule Superior semilunar lobule Interior semilunar lobule Biventral Tonsil	Cognition, language
Flocculonodular lobe (paleocerebellum, vestibulocerebellum)	Nodulus	Flocculus	Eye movements, balance

terolateral fissure separates the posterior lobe from the flocculonodular lobe. The posterior lobe has two fissures, a horizontal fissure that further divides the posterior lobe between the folium/superior semilunar and tuber/inferior semilunar lobules and a prepyramidal fissure that divides the posterior lobe between the tuber/inferior semilunar and pyramid/biventral lobules. The cerebellar tonsils consist of the uvula and flocculonodular lobe. These lobes contain a total of 18 smaller lobules, 9 in the vermis and 9 in the cerebellar hemispheres. The general structure and function of the cerebellum are detailed in Table 7.1.

The vermis receives input from the spinal cord. It is important in the control of the muscle tone and axial limb movement, maintaining posture of the antigravity muscles. The cerebellar hemispheres receive input from the brain through the pontine nuclei. These areas are responsible for the non-motor functions of the cerebellum such as cognition, language and emotion processing, and modulation. The flocculonodular lobe is heavily connected with the vestibular nuclei and brainstem nuclei for the important head and eye movement coordination.

Table 7.2 Comparison of Ito's and Larsell's nomenclature for the cerebellar vermis

Ito [1]	Larsell [2]
Lingula	I
Centralis	II, III
Culmen	IV, V
Declive	VI
Folium	Superior VII A
Tuber	Inferior VII B
Pyramis	VIIIA, VIIIB
Uvula	IX
Nodulus	X

The complex anatomy of the cerebellum has been categorized in many different ways. From the literature, two separate but similar naming systems have become more prominent than the others, specifically, those of Ito [1] and Larsell [2]. A comparison of these nomenclatures is presented in Tables 7.2, 7.3, and 7.4.

The nomenclature of Larsell [2] was used to label the cerebellar figures (Figs. 7.1–7.14) in this chapter. For the sake of brevity, only additional structures not found in Tables 7.2, 7.3, and 7.4 will be listed in the key for each cerebellar page.

Table 7.3 Comparison of Ito's and Larsell's nomenclature for the cerebellar hemispheres

Ito [1]	Larsell [2]
Vinculum	HI
Central lobule	HII, HIII
Quadrangular lobule, anterior portion	HIV, HV
Quadrangular lobule, posterior portion	HVI
Semilunar lobule, superior portion	HVIIA (Crus I)
Semilunar lobule, inferior portion	HVIIA (Crus II)
Gracile	HVIIB
Biventer	HVIII
Tonsil	HIX
Flocculus	HX

Table 7.4 Nomenclature of the cerebellar fissures

1′	Precentral fissure
2′	Preculminate fissure
3′	Primary fissure
4′	Superior posterior fissure
5′	Horizontal fissure
6′	Prepyramidal fissure
7′	Secondary fissure
8′	Posterolateral fissure
9′	Inferior posterior fissure

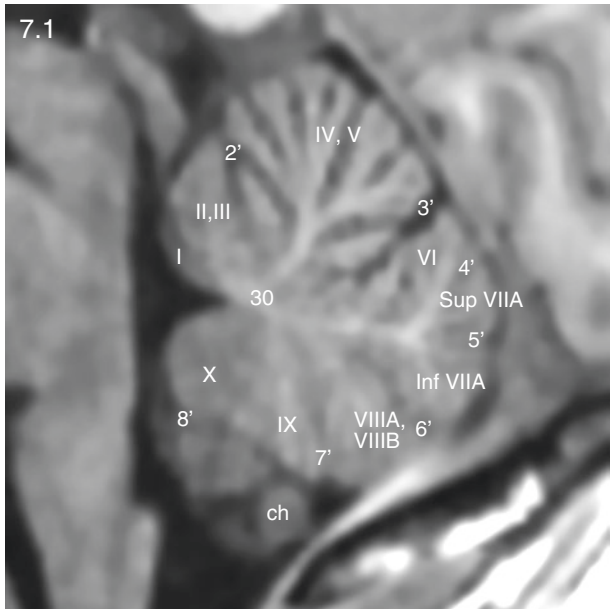
7.2 Brainstem Overview

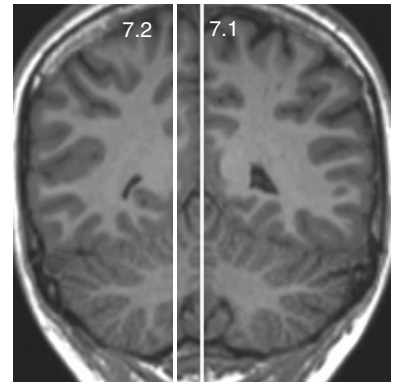
The brainstem develops from caudal two of the three embryological vesicles: the more rostral mesencephalon (a.k.a. midbrain) and the more caudal rhombencephalon. The rhombencephalon further subdivides into the metencephalon (a.k.a. pons) and the myelencephalon (a.k.a. medulla oblongata). All nuclei and tracts respect a columnar organization along the rostral-caudal axis of the brainstem. Thus, it is important to remember that some cranial nerve nuclei and most white matter tracts run through the entire length of the brainstem. It is a combination of symptoms that helps to localize pathology in one of the three parts of the brainstem.

In the developing central nervous system, a basal plate and an alar plate are formed delimited by the sulcus limitans. The alar plate is the dorsal part of the neural tube, whereas the basal plate is the ventral portion of it. The alar plate continues caudally into the sensory dorsal part of the spinal cord, and the basal plate continues to form the motor part of the spinal cord. In the brainstem the alar plates move out laterally and contain the general somatic, general and special visceral afferents of the cranial nerves. Also ascending sensory tracts are seen more laterally. The basal plate contains the motor axons and contain the general somatic and general and special visceral efferents. Also the motor descending fibers are mostly found in the medial part of the brainstem.

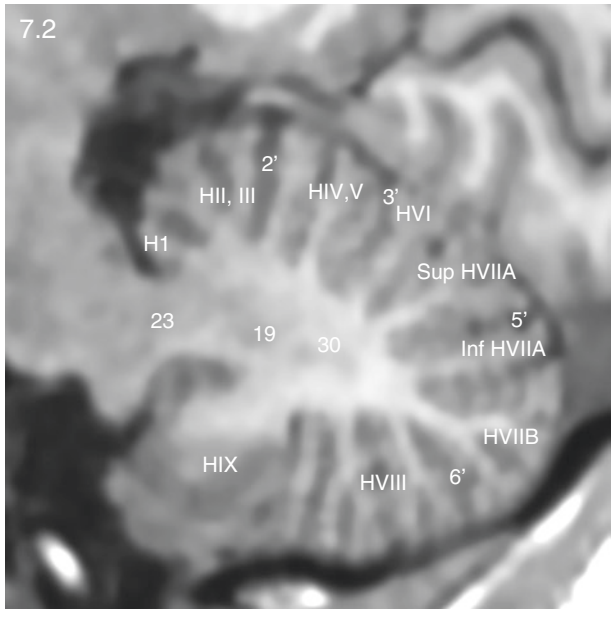
The brainstem contains most of the encephalic reticular centers. The brainstem reticular nuclei are divided into three longitudinal columns: median, central (or medial), and lateral. Median nuclei are the raphe nuclei and are cholinergic, locus coeruleus contain noradrenergic fibers, and the PAG and the reticular nuclei are mostly serotoninergic.

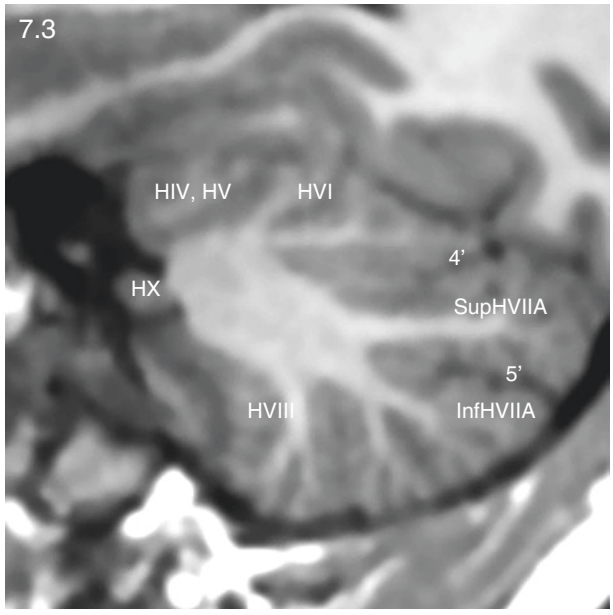
In this section, the gray matter contents of each brainstem region are reviewed. In Chap. 8, the white matter tracts in each brainstem region are discussed. The functions of the cranial nerves are separately detailed in Chaps. 12–23 and will not be referred to in this chapter. Finally, the functions of the gray matter structures and white matter tracts will be discussed in Chap. 11.

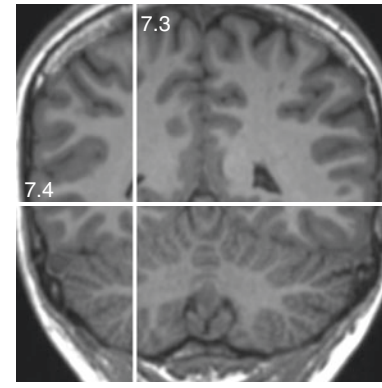




ch	Cerebellar hemisphere
19	Dentate nucleus
23	Middle cerebellar peduncle (brachium pontis)
30	Corpus medullare




7.3
HIV, HV
HVI
4’
HX
SupHVIIA
5’
HVIII
InfHVIIA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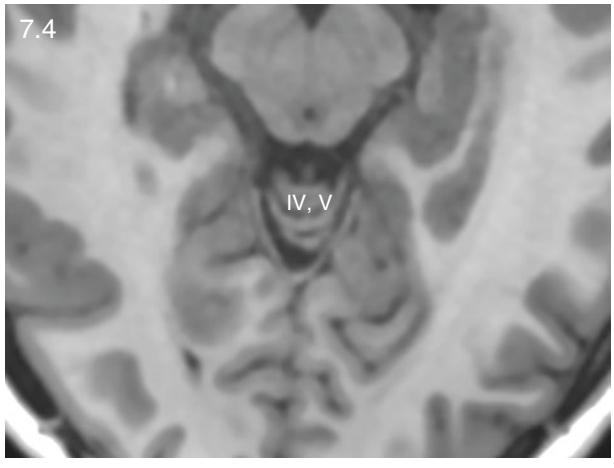
7.4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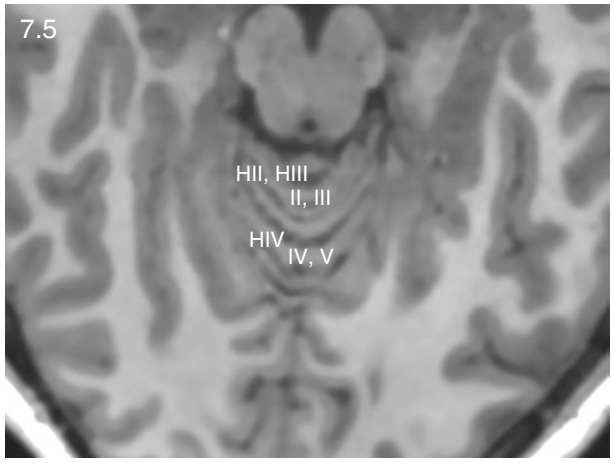
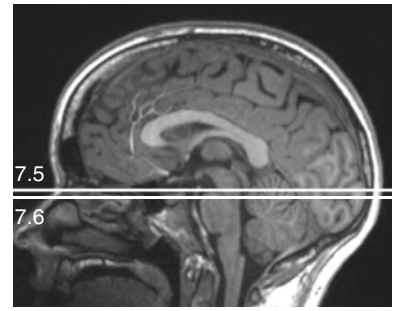
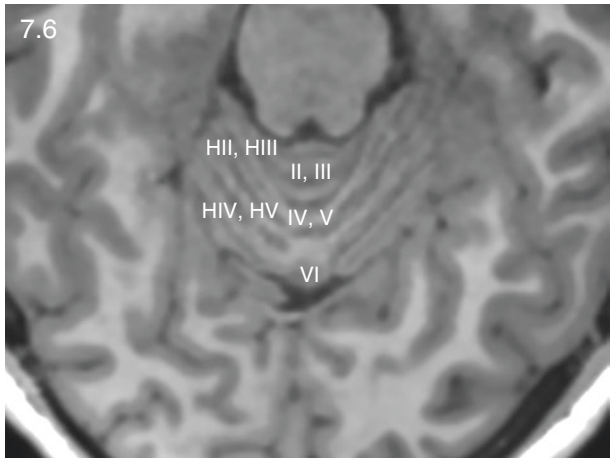
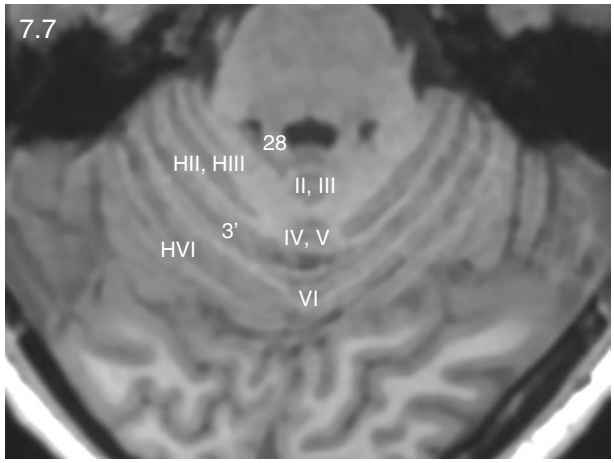
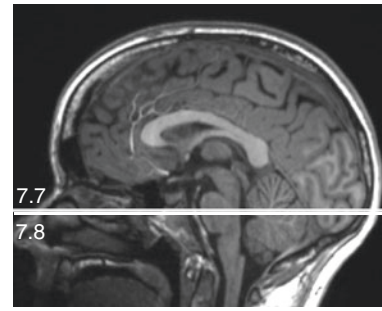
IV, V


7.5
HII, HIII
II, III
HIV
IV, V

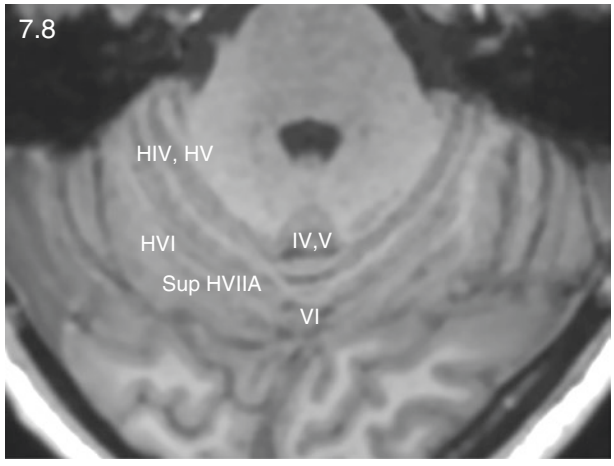

7.5
7.6

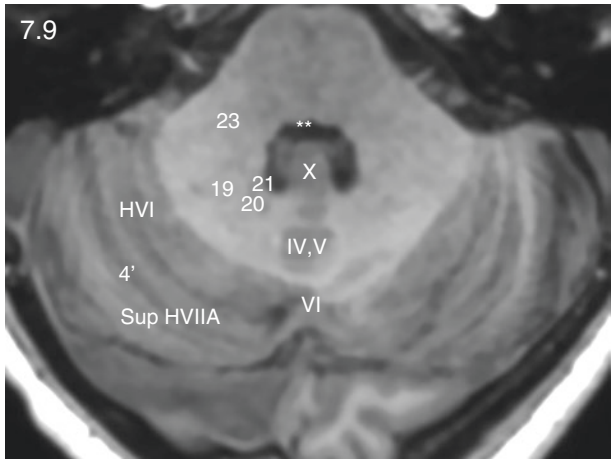

7.6
HII, HIII
II, III
HIV, HV
IV, V
VI

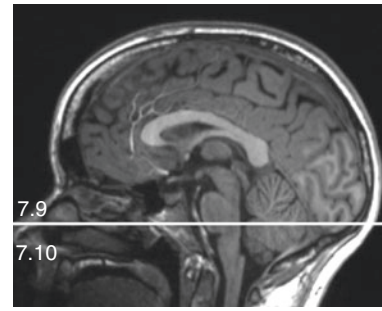




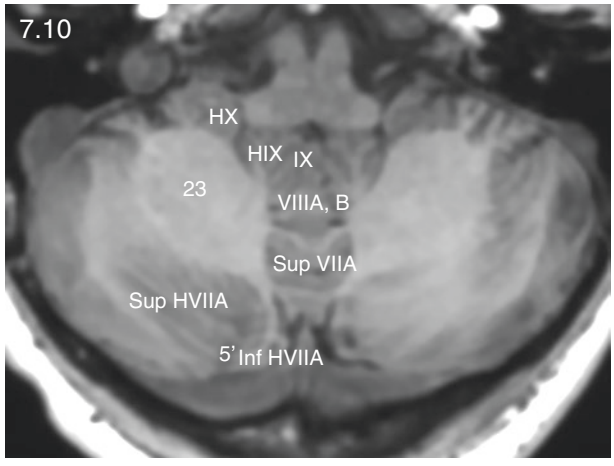
28	Superior cerebellar peduncle (brachium conjunctivum)

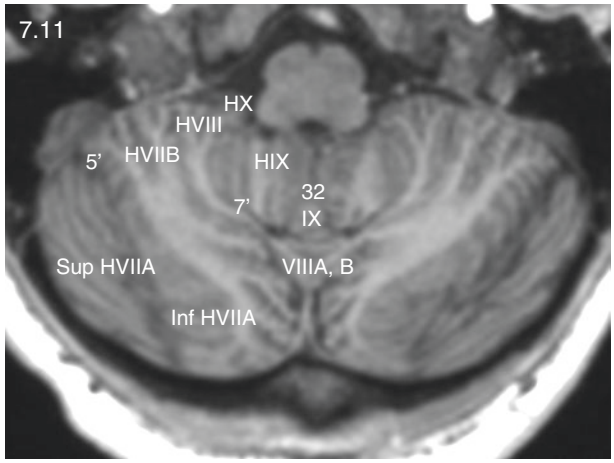


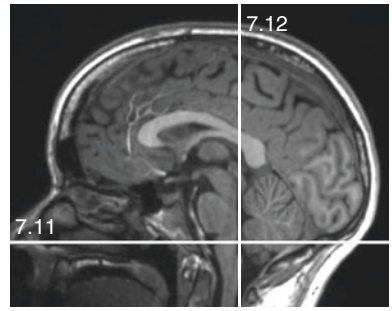




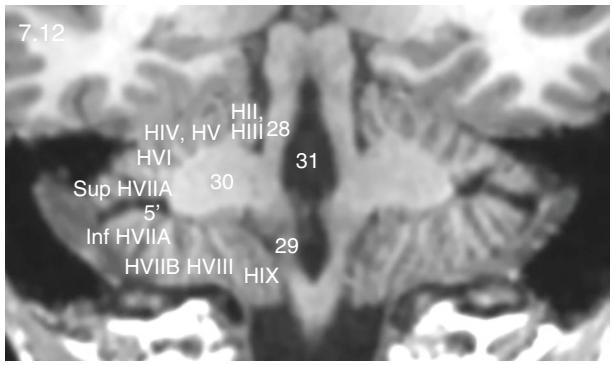
19	Dentate nucleus
20	Globose and emboliform nuclei
21	Fastigial nucleus
23	Middle cerebellar peduncle (brachium pontis)
**	Facial colliculus

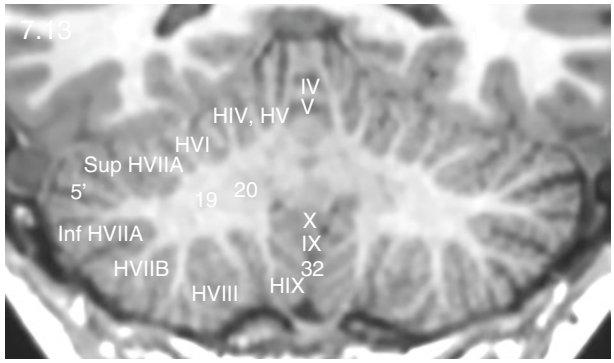


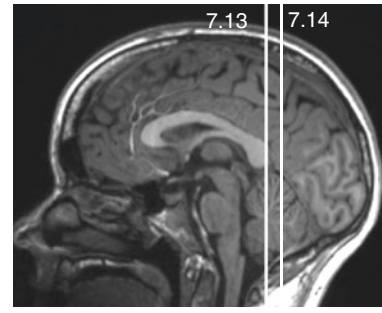




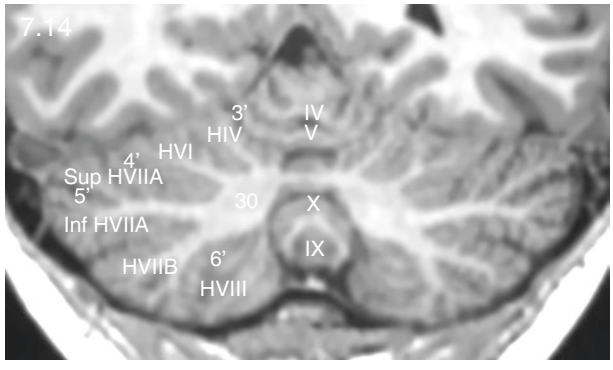
28	Superior cerebellar peduncle (brachium conjunctivum)
29	Inferior cerebellar peduncle
30	Corpus medullare
31	Fourth ventricle
32	Vallecula of the cerebellum

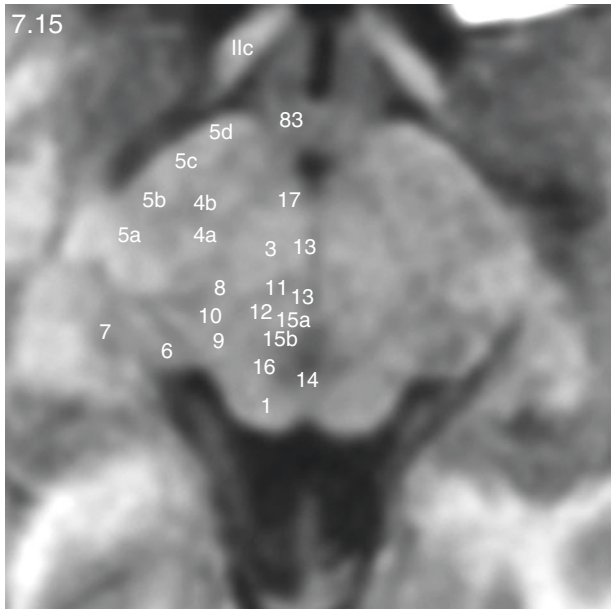


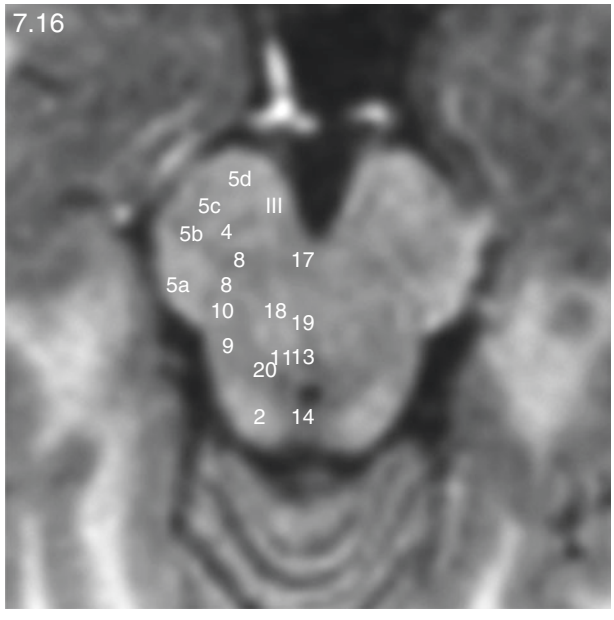


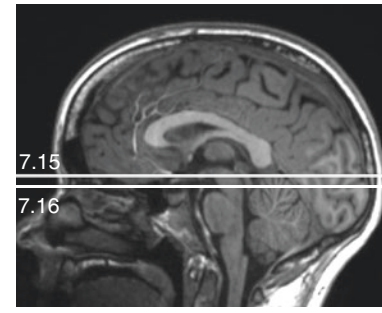


19	Dentate nucleus
20	Emboliform nucleus
30	Corpus medullare
32	Vallecula of the cerebellum

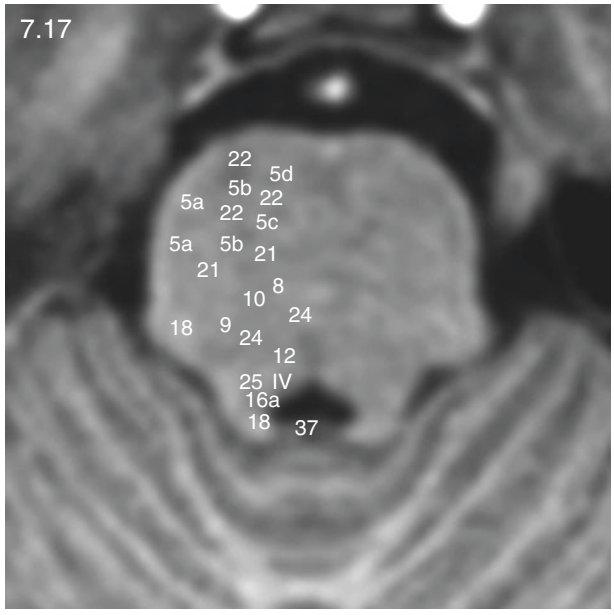


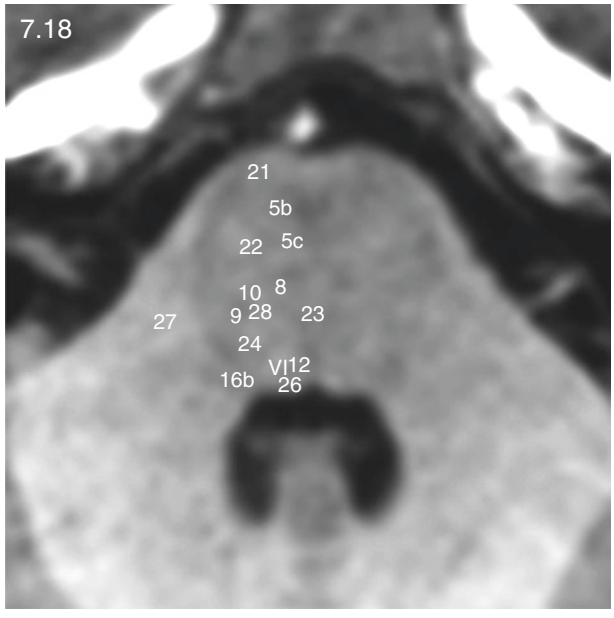


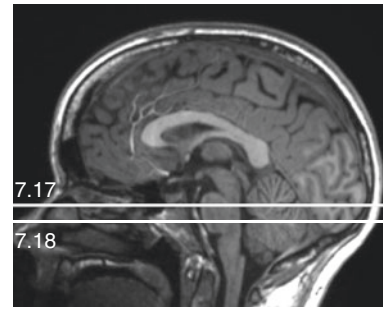




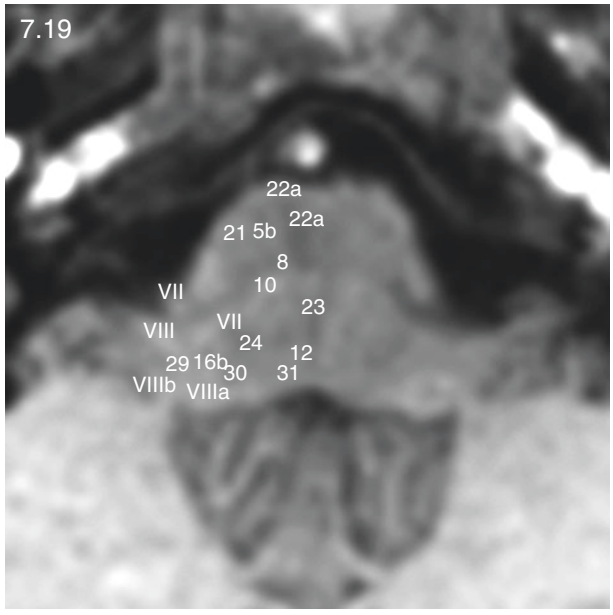
1	Superior colliculus
2	Inferior colliculus
3	Red nucleus
4	Substantia nigra
4a	Substantia nigra, pars compacta
4b	Substantia nigra, pars reticulata
5a	Cerebral peduncle, parietotemporopontine tract
5b	Cerebral peduncle, corticospinal tract
5c	Cerebral peduncle, corticonuclear tract
5d	Cerebral peduncle, frontopontine tract
6	Medial geniculate nucleus
7	Lateral geniculate nucleus
8	Medial lemniscus
9	Lateral lemniscus
10	Spinothalamic tract
11	Central tegmental tract
12	Medial longitudinal fasciculus
13	Dorsal raphae nucleus
14	Periaqueductal gray matter
15a	Oculomotor complex, principle motor nucleus
15b	Oculomotor complex, Edinger-Westphal nucleus
16	Trigeminal complex
17	Ventral tegmental area
18	Brachium conjunctivum
19	Decussation of the superior cerebellar peduncle
20	Reticular nuclei
83	Mammillary body
IIc	Optic tract
III	Oculomotor nerve

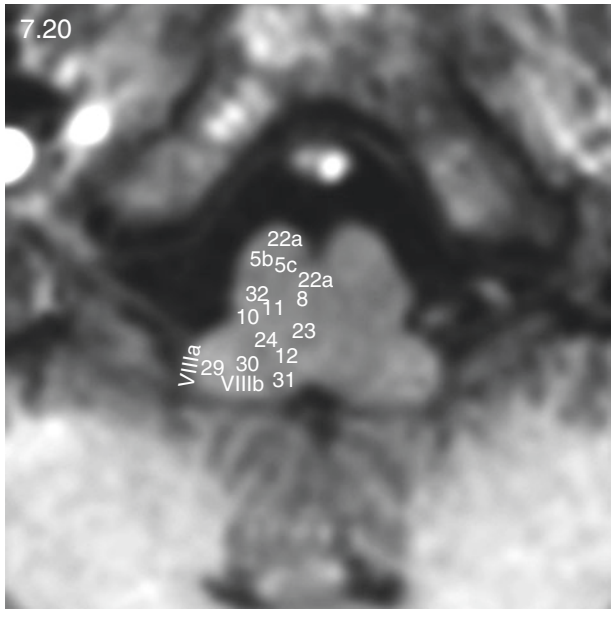


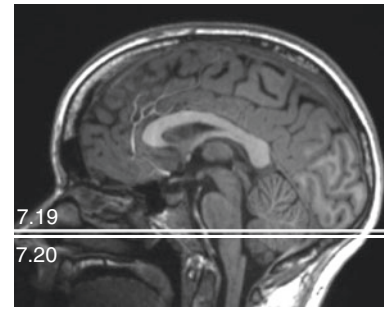




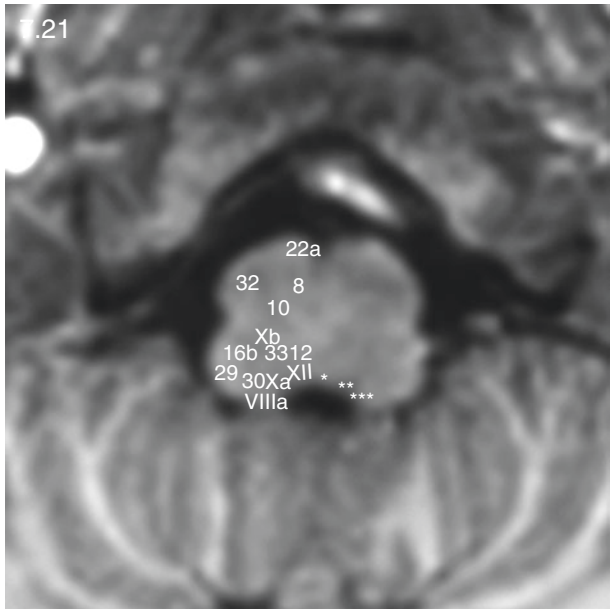
5a	Cerebral peduncle, parietotemporopontine tract
5b	Cerebral peduncle, corticospinal tract
5c	Cerebral peduncle, corticonuclear tract
5d	Cerebral peduncle, frontopontine tract
8	Medial lemniscus
9	Lateral lemniscus
10	Spinothalamic tract
12	Medial longitudinal fasciculus
16a	Trigeminal complex, mesencephalic nucleus
16b	Trigeminal complex, principle sensory nucleus
18	Superior cerebellar peduncle (brachium conjunctivum)
20	Reticular nuclei
21	Pontocerebellar fibers
22	Pontine nuclei
23	Pontine raphe nuclei
24	Pontine reticular nuclei
25	Locus coeruleus
26	Facial colliculus
27	Middle cerebellar peduncle (brachium pontis)
28	Superior olivary nucleus
37	Superior medullary velum
IV	Trochlear nucleus
VI	Abducens nucleus

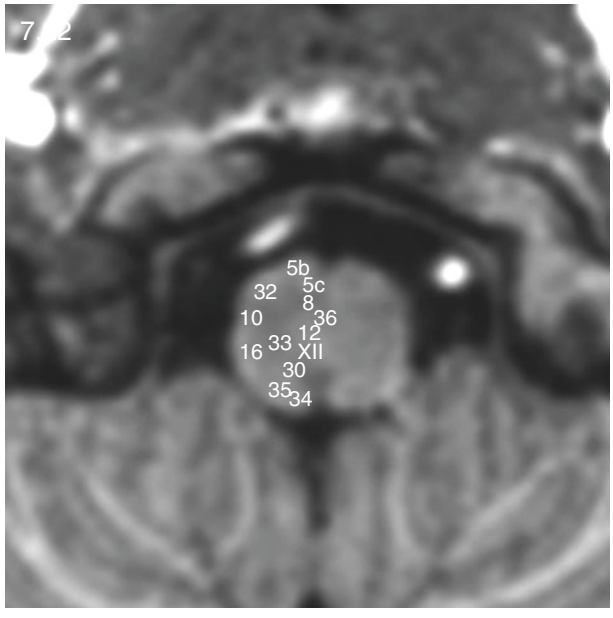


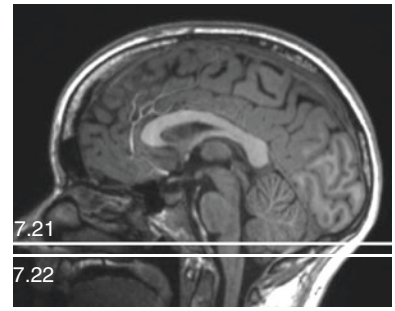




5b	Cerebral peduncle, corticospinal tract
5c	Cerebral peduncle, corticonuclear tract
8	Medial lemniscus
10	Spinothalamic tract
11	Central tegmental tract
12	Medial longitudinal fasciculus
16 b	Trigeminal complex, principle sensory nucleus
21	Pontocerebellar fibers
22a	Pontine nuclei, arcuate nuclei
23	Pontine raphe nuclei
24	Pontine reticular nuclei
29	Restiform body
30	Tract of nucleus solitarius
31	Nucleus prepositus hypoglossi
VII	Facial nerve
VIII	Vestibulocochlear nerve
VIIIa	Vestibulocochlear nerve, vestibular nuclei
VIIIb	Vestibulocochlear nuclei







5b	Cerebral peduncle, corticospinal tract
5c	Cerebral peduncle, corticonuclear tract
8	Medial lemniscus
10	Spinothalamic tract
12	Medial longitudinal fasciculus
16	Trigeminal complex
16 b	Trigeminal complex, principle sensory nucleus
21	Pontocerebellar fibers
29	Restiform body
30	Tract of nucleus solitarius
32	Inferior olivary nucleus
33	Bulbar reticular nuclei
34	Nucleus gracilis
35	Nucleus cuneatus
36	Decussation of Internal arcuate fibers
VIIIa	Vestibulocochlear nerve, vestibular nuclei
Xa	Vagus nerve, dorsal motor nucleus
Xb	Vagus nerve, nucleus ambiguus
XII	Hypoglossal nerve
*	Hypoglossal trigone
**	Vagal trigone
***	Vestibular trigone

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