Chapter 5
Vascular Supply and Territories of the Cerebellum

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Abstract Within the posterior circulation, Caplan and colleagues characterized brain and vascular structures as involving the proximal, middle, and distal posterior circulation territories. The *proximal intracranial posterior circulation territory* includes regions supplied by the intracranial vertebral arteries (ICVAs)-the medulla oblongata and the posterior inferior cerebellar arteries (PICAs)-supplied region of the cerebellum. The ICVAs join at the medullo-pontine junction to form the basilar artery (BA). The *middle intracranial posterior circulation territory* includes the portion of the brain supplied by the BA up to its superior cerebellar artery (SCA) branches- the pons and the AICA-supplied portions of the cerebellum. The BA divides to form the 2 posterior cerebral arteries (PCAs) at the junction between the pons and the midbrain, just beyond the origins of the SCAs. The *distal intracranial posterior circulation territory* includes all of the territory supplied by the rostral BA and its SCA, PCA and their penetrating artery branches- midbrain, thalamus, SCA-supplied cerebellum, and PCA territories.

Keywords Cerebellum • Vertebral artery • Brainstem • Basilar artery • Cerebellar arteries

5.1 Overview

Within the posterior circulation, Caplan and colleagues characterized brain and vascular structures as involving the proximal, middle, and distal posterior circulation territories (Caplan 1996, 2000; Caplan et al. 2004, 2005; Chaves et al. 1994; Savitz and Caplan 2005). The *proximal intracranial posterior circulation territory* includes

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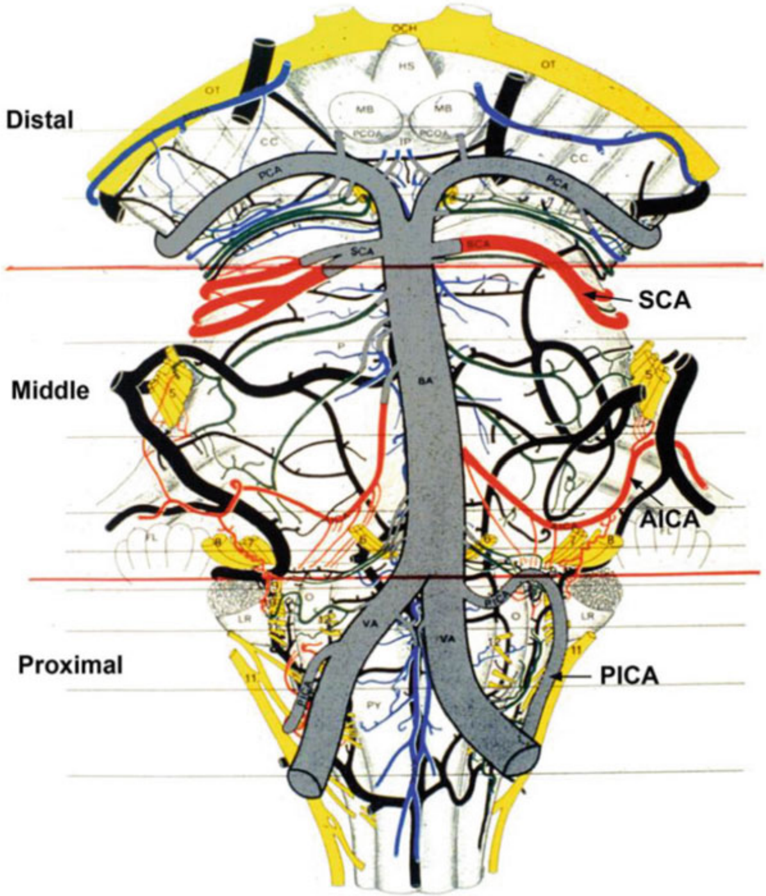


Fig. 5.1 Schema of the proximal, middle, and distal intracranial territories of the vertebro-basilar arterial system (Drawn by Laurel Cook-Lowe, modeled after a figure in Duvernoy HM 1978)

regions supplied by the intracranial vertebral arteries (ICVAs)-the medulla oblongata and the posterior inferior cerebellar arteries (PICAs)-supplied region of the cerebellum. The ICVAs join at the medullo-pontine junction to form the basilar artery (BA). The *middle intracranial posterior circulation territory* includes the portion of the brain supplied by the BA up to its superior cerebellar artery (SCA) branches- the pons and the AICA-supplied portions of the cerebellum. The BA divides to form the two posterior cerebral arteries (PCAs) at the junction between the pons and the midbrain, just beyond the origins of the superior SCAs. The *distal intracranial posterior circulation territory* includes all of the territory supplied by the rostral BA and its SCA, PCA and their penetrating artery branches- midbrain, thalamus, SCA-supplied cerebellum, and PCA territories. This distribution is shown diagrammatically in Fig. 5.1.

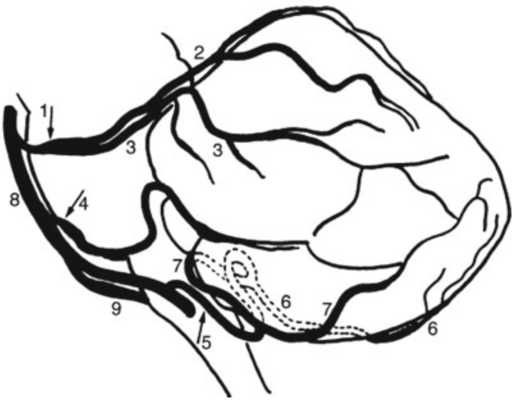


Fig. 5.2 Schematic diagram of the cerebellar arteries. *1* Superior cerebellar artery (*SCA*); *2* medial branch of the SCA; *3* lateral branch of the SCA; *4* anterior inferior cerebellar artery (*AICA*); *5* posterior inferior cerebellar artery (*PICA*); *6* medial branch of PICA; *7* lateral branch of PICA; *8* basilar artery; *9* vertebral artery (From Amarenco 1991)

The three surfaces of the cerebellum are: tentorial (or superior) facing the tentorium cerebelli, petrosal facing towards the petrous bone, and suboccipital facing the suboccipital bone located between the lateral and sigmoid dural sinuses (Lister et al. 1982). The PICAs encircle the medulla and supply the suboccipital cerebellar surface; the AICAs course around the pons and supply the petrosal surface of the cerebellum, and the SCAs encircle the midbrain and supply the tentorial, superior surface of the cerebellum (Lister et al. 1982).

The arteries to the cerebellum are distributed rostrocaudally so that the PICAs arises from the ICVAs, the anterior inferior cerebellar arteries (AICAs) arise from the BA, and the most rostral arteries, the SCAs, arise near the BA bifurcation (Fig. 5.2). The PICAs and the SCAs, the two largest arterial pairs have medial branches that supply mostly the vermian and paravermian portions of their respective regions of the cerebellum, and lateral branches which supply the cerebellar hemispheres. Infarcts in the cerebellum are often limited to the territory of one of these branches e.g. medial PICA (mPICA), lateral SCA (lSCA) etc. These cerebellar branch territory infarcts correspond to functional regions such as the inferior vermis or superior lateral neocerebellum. The AICAs, in contrast, supply only a small part of the anterior inferior cerebellum and the flocculus, but their major supply is to the lateral pontine tegmentum and the brachium pontis. The AICAs do not divide into medial and lateral major cerebellar branches but give off twigs to various structures.

5.2 Posterior Inferior Cerebellar Arteries (PICAs)

The PICAs usually originate from the ICVAs about 2 cm below the origin of the basilar artery, and, on average, about 8.6 mm above the foramen magnum (Marinkovic et al. 1995). The site of origin, however, varies from 14 mm below the foramen magnum to 26 mm above the foramen magnum (Marinkovic et al. 1995).

About 10 % arise from the basilar artery (Amarenco and Hauw 1989). Size varies; The diameters varied between 0.58 and 2.10 mm in one analysis (Amarenco and Hauw 1989). Some ICVAs end in PICA, and PICA can be absent in which case there usually is a large artery that arises from the proximal basilar artery that supplies both the PICA and AICA territories. Occasionally PICA is duplicated.

After coursing laterally and downward to go around the lateral medulla (the lateral medullary segment), the PICAs make a cranially directed loop and ascend between the dorsal portion of the medulla and the caudal part of the cerebellar tonsil on that side (the tonsillo-medullary segment) (Lister et al. 1982; Marinkovic et al. 1995). They then make a second loop above the cranial portion of the tonsil and descend along the inferior vermis coursing between the inferior medullary velum and the rostral portion of the tonsil (the telovelotonsillar segment). Finally the artery becomes superficial and supplies branches to the tonsil, medulla, choroid plexus and cerebellar cortex. Medial and lateral branches (mPICA, and lPICA) arise from the main trunks (Fig. 5.3) at variable locations between the two PICA loops. mPICA supplies the inferior vermis including the nodulus, pyramis, uvula, tuber, and sometimes the declive and the medial portions of the semilunar lobule, gracile lobule, and the tonsil (Chaves et al. 1994; Amarenco and Hauw 1989; Amarenco et al. 1989, 1993; Amarenco 1991; Gilman et al. 1981; Duvernoy 1978). mPICA often sends a supply to the dorsal medulla. lPICA supplies the inferior two thirds of the biventer, most of the inferior portion of the semilunar and the gracile lobules, and the anterolateral portion of the tonsil (Chaves et al. 1994; Amarenco and Hauw 1989; Amarenco et al. 1989, 1993; Amarenco 1991; Gilman et al. 1981; Duvernoy 1978). Figures 5.4, 5.5, and 5.6 show diagrammatically the supply territories of PICA, mPICA, and lPICA. The PICAs sometimes supply the deep cerebellar structures including the fastigial nuclei but usually do not supply the dentate nuclei (Amarenco and Hauw 1989).

Although many equate the Wallenberg syndrome with an occlusion of PICA causing infarction in the lateral medulla, PICA does not supply the lateral medullary tegmentum. This region is supplied by a group of parallel small arteries that originate directly from the intracranial vertebral artery and pass through the lateral med-

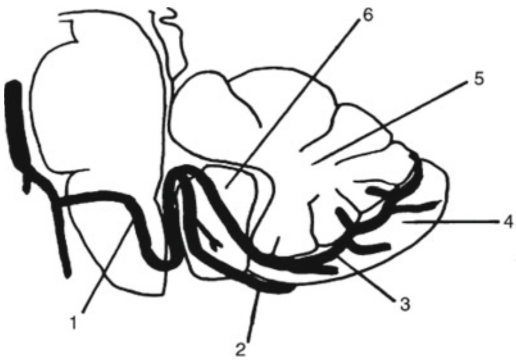


Fig. 5.3 Sketch showing course and branching of the Posterior inferior cerebellar artery (*PICA*). *1* PICA; *2* lateral branch of PICA; *3* medial branch of PICA; *4* cerebellar hemisphere; *5* cerebellar vermis; *6* cerebellar tonsil (Reproduced with permission from Amarenco et al. 1993)

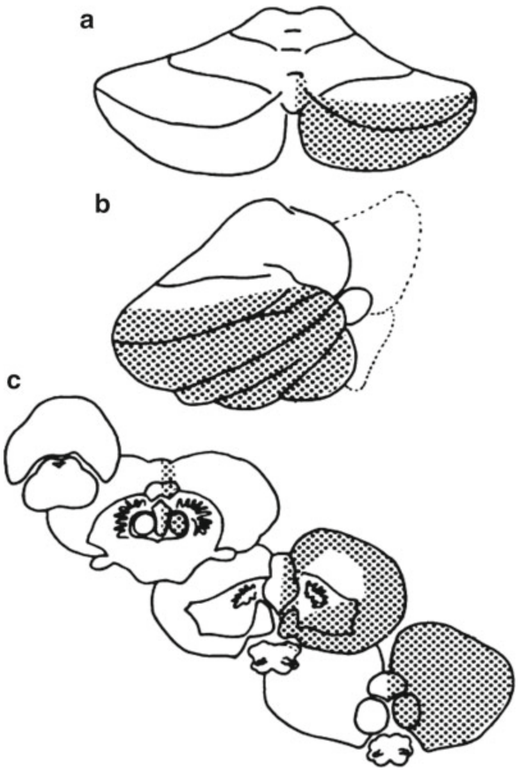


Fig. 5.4 The supply zone of PICA (Reproduced with permission from Amarenco 1991)

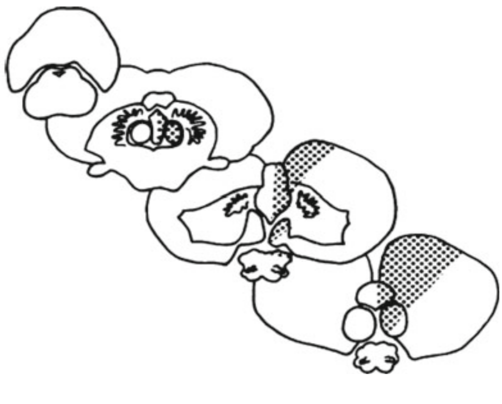


Fig. 5.5 The supply zone of the medial branch of PICA (Reproduced with permission from Amarenco 1991)

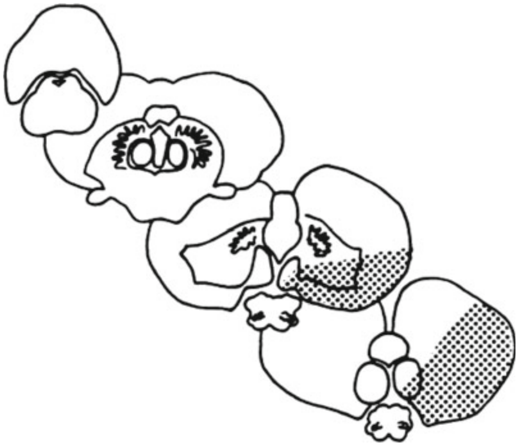


Fig. 5.6 The supply zone of the lateral branch of PICA (Reproduced with permission from Amarenco (1991)

Fig. 5.7 Right lateral medullary fossa. *1* Vertebral artery; *2* Posterior inferior cerebellar artery (*PICA*); *4* lateral medulalry fossa; *5* vagus nerve; *6* IV ventricle choroids plexus; *7* glossopharyngeal nerve; *8* vestibulo-cochlear nerve; *9* Facial nerve; *10* lateral pontine vein; *11* pons; *12* abducens nerve; *13* Olive; (**a**) A'- rami arising from PICA; (**b**) rami arising from the vertebral artery to supply the lateral medulla; (**c**) rami arising from the basilar artery; (**c**, **d**) Rami arising from AICA (From Duvernoy 1978)

ullary fossa to supply the lateral medulla (Fig. 5.7) (Duvernoy 1978). Sometimes the medial branch of PICA supplies a small area in the dorsal medulla that includes vestibular nuclei and the dorsal motor nucleus of the vagus. The medial branch of PICA supplies a triangular area with a dorsal base and a ventral apex towards the fourth ventricle on an axial mid-medullary and cerebellar section (Amarenco and Hauw 1989). Figure 5.8 is a sagittal section MRI showing a PICA infarct. Figure 5.9 shows a brain specimen with a medial PICA territory infarct. Figure 5.10 is a axial section MRI of a mPICA infarct.

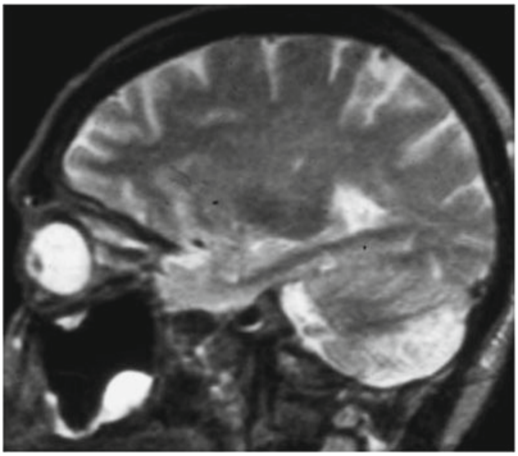


Fig. 5.8 MRI sagittal T2-weighted scan showing a PICA territory infarct (From Caplan 1996)

Fig. 5.9 Necropsy specimen showing an infarct in the territory of the medial branch of the posterior inferior cerebellar artery (From Amarenco et al. (1989) with permission)

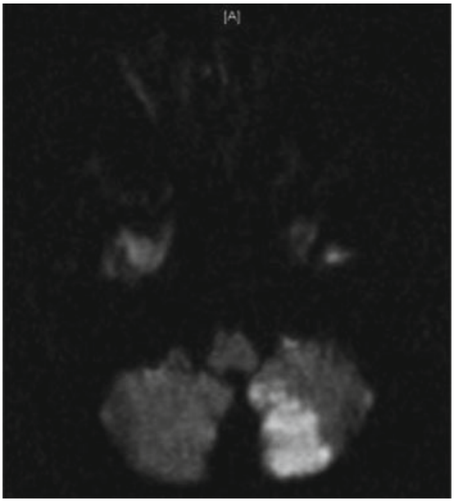


Fig. 5.10 MRI sagittal diffusion-weighted scan showing (**a**) mPICA territory infarct

5.3 Anterior Inferior Cerebellar Arteries (AICAs)

The AICAs are nearly constant arteries but their origins, sizes, and supply zones vary greatly. In 4 % of people, there is no AICA branch (Lazorthes 1961). The AICAs have the smallest territory of supply of any of the cerebellar arteries. The AICAs usually arise about 1 cm above the vertebrobasilar artery junction (Fig. 5.11), and sometimes from the middle third of the basilar artery. Occasionally, they can arise directly from the ICVA, or from a common trunk with PICA. The internal auditory arteries are usually branches of the AICAs but in some individuals they arise directly from the basilar artery. In one study the diameters of AICA ranged from 0.38 to 1.8 mm (mean 1.1 mm) (Marinkovic et al. 1995). After arising from the basilar artery the AICAs travel towards the cerebellopontine angle, passing below the Vth nerve, crossing the VIth nerve, and meeting the VIIth and VIIIth nerves at the cerebellopontine angle (Marinkovic et al. 1995; Amarenco and Hauw 1989, 1990a; Amarenco et al. 1993; Amarenco 1991; Gilman et al. 1981; Duvernoy 1978; Perneczky et al. 1981). After crossing the VIIIth nerve, the AICAs give rise to the internal auditory arteries and then divide into two branches. One branch courses laterally and inferiorly to supply the anterior inferior portion of the cerebellum on the petrosal surface. The other branch loops around the bundle made by the VIIth and VIIIth nerves, and supplies the flocculus, brachium pontis, middle part of the cerebellar hemisphere, and the lateral part of the pons (Marinkovic et al. 1995; Amarenco and Hauw 1989, 1990a; Amarenco et al. 1993; Amarenco 1991; Perneczky et al. 1981). The internal auditory arteries supply the facial and vestibulocochlear nerves as well as the structures of the inner ear.

Asymetry and reciprocal size relationship of AICA and PICA are common. Studies show a balance between AICA and PICA. In some individuals AICA can substitute for a hypoplastic PICA, taking over the supply of the inferior surface of the cerebellum (Stopford 1915–1916; Foix and Hillemand 1925; Atkinson 1949; Takahashi 1974). Usually the flocculus is always irrigated by AICAs, but for 3–5 % of people the AICA is replaced by the PICA (Lazorthes 1961). According to Lazorthes, in 40 % of individuals the AICA terminates on the flocculus; (Lazorthes

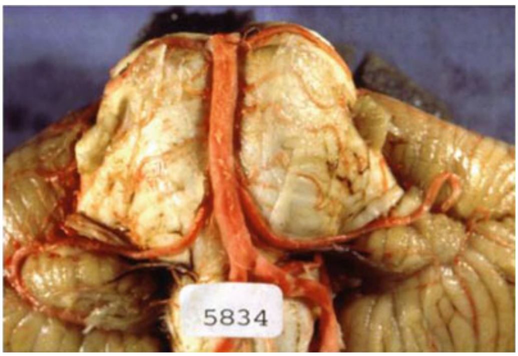


Fig. 5.11 Base of the brain at necropsy showing the origin of the Anterior Inferior Cerebellar arteries

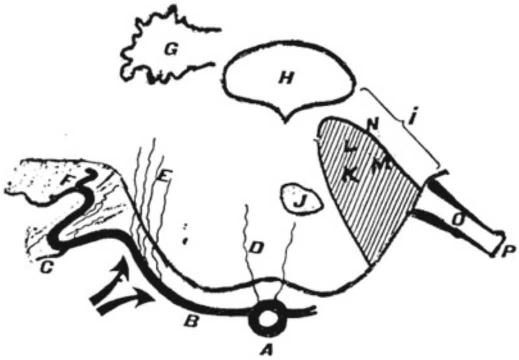


Fig. 5.12 Blood supply of the caudolateral pons from the Anterior Inferior Cerebellar Artery (*AICA*). The shaded area to the *right* is the supply of a lateral branch of AICA. (**a**) Basilar artery; (**b**) medial pontine segment of AICA; (**c**) loop segment of AICA around flocculus; (**d**) paramedian basilar artery branches; (**e**) brainstem branches of AICA; (**f**) flocculus; (**h**) IV ventricle; (**i**) brachium pontis; (**j**) medial lemniscus; (**k**) lateral spinothalamic tract; (**l**) motor nucleus of V; (**o**) Vll and Vlll cranial nerves; (**p**) internal acoustic meatus (From Perneczky et al. (1981) with permission

1961) in others it passes through the sulcus separating the anterior lobes and the semilunar lobules and the terminal branches supply the nearby lobules: anterior, simplex, superior semilunar, inferior semilunar, gracilis, and biventer in 18–50 % of individuals (Lazorthes 1961; Takahashi et al. 1968). Figure 5.12 is a schematic drawing of the AICA and its supply (Perneczky et al. 1981). Figure 5.13 shows the brainstem and cerebellar distribution of the AICA supply territory. Figure 5.14 is a necropsy specimen showing an AICA territory infarct at the level of the pons. Figure 5.15 is a saggital and axial section MRI of a AICA infarct.

5.4 Superior Cerebellar Arteries (SCAs)

The SCAs arise as the last pair of branches from the basilar artery just before the basilar artery bifurcates into the paired PCAs (Fig. 5.16). The third cranial nerves run between the SCAs and the PCAs near the posterior communicating arteries. In about 15 % of patients there are bifid SCAs. In one series the diameters ranged from 0.7 to 1.93 mm (mean 1.1 mm) (Marinkovic et al. 1995). The SCA encircles the brainstem close to or within the ponto-mesencephalic sulcus, just below the third nerve and just above the trigeminal nerve. While coursing around the midbrain, the SCAs give off branches that supply the brainstem including the superior portion of the lateral pontine tegmentum and the pontine and mesencephalic tectum. The SCAs have an early division within the cerebello-mesencephalic cistern where it divides into the mSCA and lSCA branches. Figure 5.17 shows the usual branching

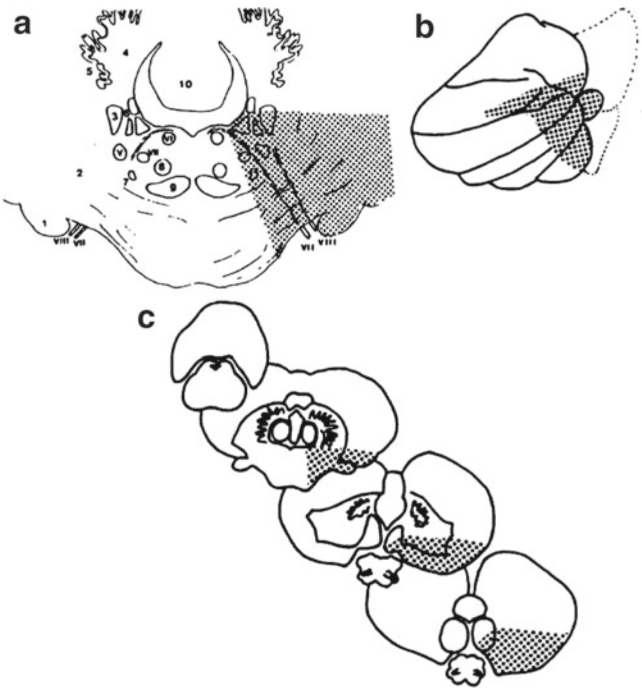
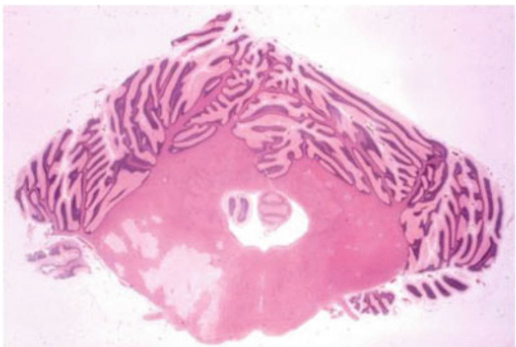


Fig. 5.13 Diagramatic depiction of the supply zones of the anterior inferior cerebellar arteries. (**a**) Shows the pontine territory. *1* Flocculus, *2* brachium pontis, *3* restiform body, *4* brachium conjunctivum, *5* dentate nucleus, *6* vestibular nuclei, *7* spinothalamic tract, *8* central tegmental tract, *9* medial lemniscus, *10* cerebellar nodulus. (**b**) Shows the cerebellar supply on a lateral view of the cerebellum and (**c**) shows the supply on cut sections of the cerebellum and brainstem. The supply zones are shaded (Reproduced with permission from Amarenco et al. 1993)

Fig. 5.14 Necropsy specimen (H & E stained) showing an anterior inferior cerebellar artery territory infarct



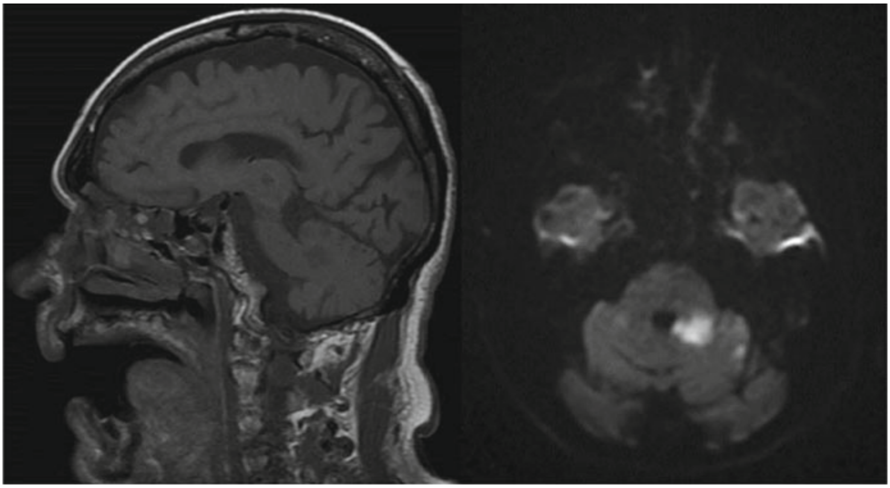


Fig. 5.15 MRI sagital T1 (*left*) and axial diffusion-weighted scan showing an AICA territory infarct

Fig. 5.16 Brain at necropsy showing the superior cerebellar arteries circling the midbrain and giving off branches

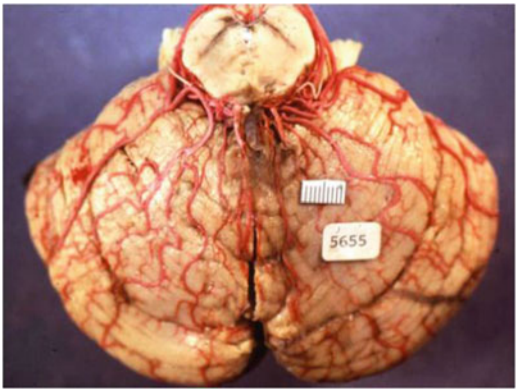
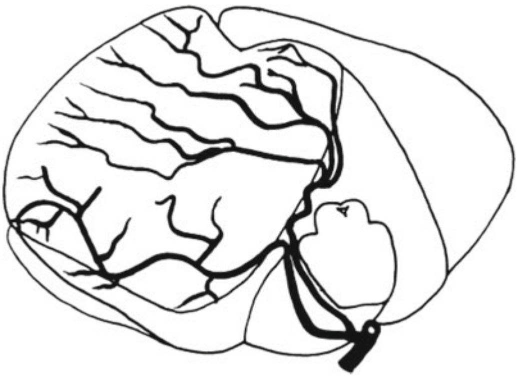


Fig. 5.17 Schematic diagram of the superior cerebellar artery (*SCA*) and its medial (*mSCA*) and lateral (*lSCA*) branches. The *top* branch is the mSCA and the *lower* branch is the lSCA (From Amarenco et al. (1991) with permission)



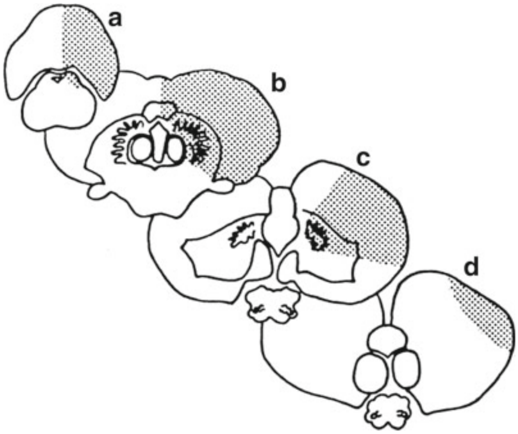


Fig. 5.18 The SCA supply territories are shaded (From Amarenco and Hauw 1989)

of the SCAs and the course of the lateral and medial branches. The mSCA branch extends more laterally than the mPICA. Occasionally these branches arise directly from the basilar artery and the SCAs.

Both the major branches of the SCAs course towards the pedunculo-cerebellar sulcus and reach the superior and anterior aspects of the cerebellum above the horizontal fissure. At the pedunculocerebellar sulcus, lSCA turns off at a right angle and follows the anterosuperior margin of the cerebellum anteriorly and laterally. A terminal deep branch of lSCA follows the superior cerebellar peduncle and reaches the dentate nucleus (Duvernoy 1978). The mSCAs mostly supply the superior portions of the vermis including the central, culmen, declive, and folium lobules; the lSCAs supply mostly the lateral portions of the cerebellar hemispheres including the anterior, simplex, and superior portion of the semilunar lobules. The SCAs also supply the cerebellar nuclei (dentate, fastigial, emboliform, and globose) as well as the bulk of the cerebellar white matter (Amarenco and Hauw 1989, 1990b; Amarenco et al. 1991, 1993; Amarenco 1991). Figures 5.18 and 5.19 show the cerebellar and brainstem supply territories of the SCA. Figure 5.20 is a necropsy specimen showing a large SCA territory infarct. Figure 5.21 shows three MRI scans s that illustrate the imaging distribution of various SCA territory infarcts. The distribution of the supply territories of the cerebellar arteries as found on CT and MRI scanning has been illustrated and reviewed (Savoiardo et al. 1987; Courchesne et al. 1989; Press et al. 1989, 1990).

5.5 Cerebellar Veins

The venous drainage of the cerebellum is divided into superficial veins, deep veins and draining groups. Superficial veins are divided according to the cortical surfaces they drain: superior hemispheric and superior vermian veins (tentorial surface),

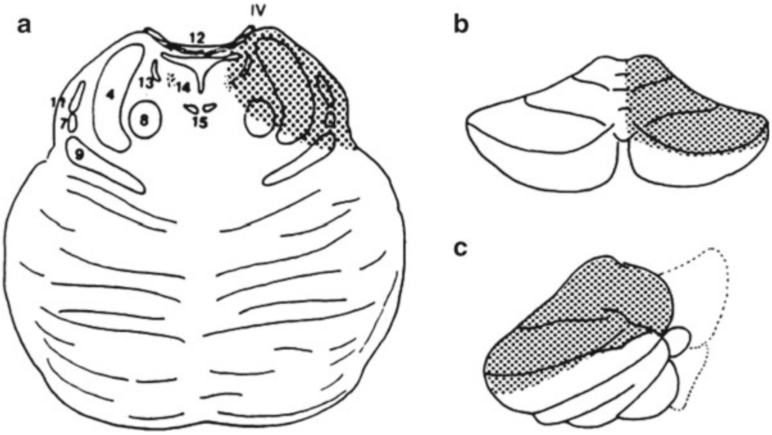


Fig. 5.19 Supply zones of the superior cerebellar arteries. (**a**) Shows the superior pontine supply. *4* Brachium conjunctivum, *7* lateral lemniscus, *8* cortico-tegmental tract, *9* medial lemniscus, *11* spinothalamic tract, *12* decussation of IV, *13* mesencephalic tract of V, *14* locus coeruleus, *15* medial longitudinal fasciculus. (**b**) Shows an antero-posterior view and C a lateral view of the cerebellum (From Amarenco and Hauw 1989)

Fig. 5.20 Necropsy specimens showing SCA territory infarct in the rostral pons. The pontine tectum and a small part of the dorsolateral pontine tegmentum are involved (From Amarenco and Hauw (1990), with permission)

inferior hemispheric and inferior vermian veins (suboccipital surface), and anterior hemispheric veins (petrosal surface) (Tschabitscher 1979; Kapp and Schmidek 1984; Matsushima et al. 1983). The major deep veins course in fissures between the cerebellum and brain stem. These are designated as the veins of the cerebellomes-encephalic, cerebellopontine and cerebellomedulary fissures. The veins that drain the cerebellar peduncles are referred to as the veins of superior, middle and inferior cerebellar peduncles (Matsushima et al. 1983). There are diffuse anastomosis between veins before they are collected into draining groups. The groups are designated according to the dural sinuses into which they drain. The Galenic group drains

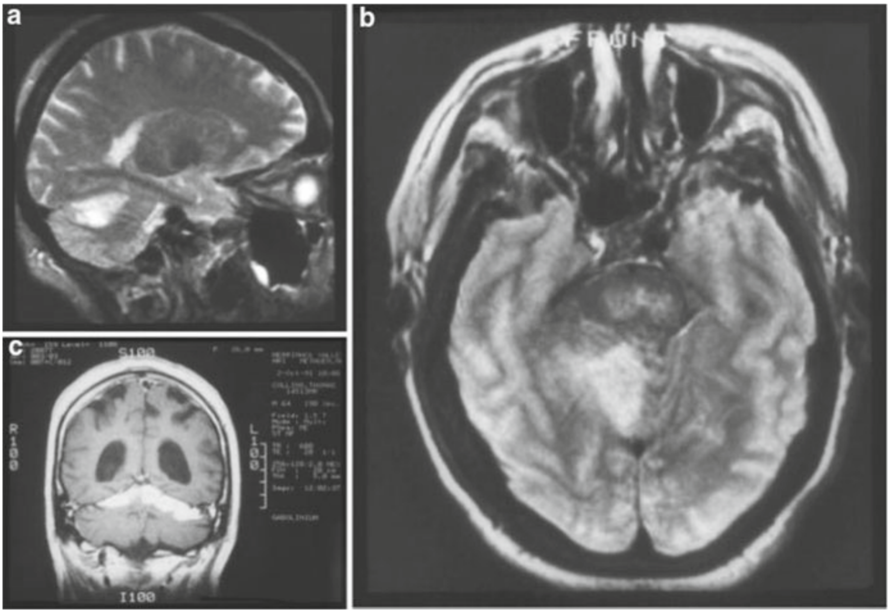


Fig. 5.21 MRI T2-weighted scans (From Caplan 1996). (**a**) Sagittal view showing SCA territory infarct. (**b**) Axial section showing small vermal cerebellar infarct in the territory of the medial branch of the superior cerebellar artery (*mSCA*). (**c**) Coronal section showing a bilateral SCA territory infarct appearing like "icing on a cake"

via the vein of Galen and the straight sinus. The petrosal group drains via the petrosal sinuses. The tentorial group drains into the torcula and transverse sinuses.

The superior and inferior veins of the cerebellum usually collected and drain into the midline draining groups: vein of Galen, straight sinus, or torcular. Many small veins drain into superior or inferior vermian veins before their connection with the vein of Galen or straight sinus. Some of the superior and inferior veins run laterally to the transverse sigmoid sinuses, or to the superior or inferior petrosal sinuses. The superior petrosal sinus collects anterior cerebellar veins, including branches from the precentral fissure, the medial tonsillar veins, the veins of the lateral recess, and some tributaries related to the cerebellar hemispheres (Huang and Wolf 1974; Lasjaunias et al. 1990; Rhoton 2000).

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