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# Vascular supply of the hindbrain: Basic longitudinal and axial angioarchitecture

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**Abstract**

The basic pattern of arterial vascularization is highly conserved across vertebrates and develops under neuromeric rules. The hindbrain has an angioarchitecture that is homologous to that of the spinal cord, and the hindbrain vascular system can be analyzed at the longitudinal and axial structures. During development, there are two main longitudinal arteries: the longitudinal neural artery and primitive lateral basilovertebral anastomosis. This review discusses the basic pattern of the blood supply of the hindbrain, the development of vascularization, and the anatomical variations, with a special reference to the embryological point of view of two main longitudinal anastomoses (longitudinal neural artery and primitive lateral basilovertebral anastomosis). The formation of commonly observed variations, such as fenestration and duplication of the vertebrobasilar artery, or primitive trigeminal artery variant, can be explained by the partial persistence of the primitive lateral basilovertebral anastomosis. Understanding the pattern and the development of the blood supply of the hindbrain provides useful information of the various anomalies of the vertebrobasilar junction and cerebellar arteries.

**Keywords**

Hindbrain, vascular supply, primitive lateral basilovertebral anastomosis, longitudinal neural artery, primitive trigeminal artery variant

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Neuromeres are regarded to reflect the basic developmental plan of the vertebrate brain.[1] They refer to a series of embryonic segmental units, or compartments, from which differentiate the different parts of the vertebrate brain. Neuromeres are classified into three large regions:[2,3] prosomeres in the recently expanded forebrain (includes the secondary prosencephalon, the diencephalon and the midbrain), rhombomeres in the hindbrain, and myelomeres in the spinal cord. The hindbrain later develops the pons, the medulla, and the cerebellum. In vertebrates, the rhombomeres have been intensively studied. The rostral-to-caudal patterning of the hindbrain is controlled by a series of genes including *Hox* complexes,[4] *Gbx2*,[5] and *Egf8*.[6]

Besides neuromeres, the segmental architecture of the vascular system of the central nervous system has attracted interest. The basic pattern of vascularization is highly conserved across vertebrates and develops under neuromeric rules.[3] Especially, the arterial structures of the hindbrain could be regarded as a transition from the simplified spinal arrangement to the complex cerebral pattern.[7] Understanding the homology of body plan helps to identify the extrinsic and intrinsic characteristics of the hindbrain arterial vascularization.

The hindbrain vascular system can be analyzed at the longitudinal and axial structures. During the development, there are two main longitudinal anastomoses, i.e. ventral longitudinal neural artery (LNA) and primitive lateral basilovertebral anastomosis (PLBA).[8] Bilateral LNAs fuse and develop basilar artery (BA), and PLBA on the hindbrain wall links transiently the transverse branches of the LNA. The partial persistence of the PLBA is associated with some anatomical variations of the vertebrobasilar circulation.[8,9] In this review, the basic pattern of the blood supply of the hindbrain, the development of vascularization, and the anatomical variations are discussed with a special reference to the embryological point of view of two main longitudinal anastomoses (LNA and PLBA).

## Arterial blood supply of the hindbrain

The spinal cord initially has a segmental arterial supply during development, which later turns into longitudinal anastomosis formed by fusion and regression.[7] The main

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vessel is the anterior spinal artery (ASA). On the axial plane, the ventral sulcal artery (VSA) on each side supplies the ipsilateral half of the cord, and the centripetal artery from the vasa corona penetrates radially into the spinal cord. Therefore, the intrinsic blood supply of the spinal cord includes the territories of the sulcal arteries ventrally (two-thirds of the cord) and those of the radial arteries (centripetal arteries) circumferentially (one-third of the cord), arising from the pial network or vasa corona.[10]

The perforators of the hindbrain follow the same pattern as that of the spinal cord (Figure 1A and B). Supplying the hindbrain are three types of axial arteries: the paramedian, short circumferential artery, and long circumferential artery.[3] The paramedian artery corresponds to the sulcal artery of the spinal cord. The short and long circumferential arteries enter at the anteromedial and at the posterolateral portions, respectively, and correspond to the vasa corona. Regarding the cerebellum, it is supplied by the superior cerebellar artery (SCA), the anterior inferior cerebellar artery (AICA), and the posterior inferior cerebellar artery (PICA), which are pial branches of long circumferential arteries.[3] Thus, the basic pattern of angioarchitecture of the brainstem is similar to the spinal cord, and homology is preserved (Figure 1).

The basic three-zonal pattern of ventricular (ependymal), mantle, and marginal layers is retained throughout the development of the entire neural tube. After primary neurulation, the neural tube changes shape due to proliferation of cells in the mantle layer. The roof plate and the floor plate are at the midline structures and develops from the mantle layer. The spinal cord can be divided into alar plates derived from the posterolateral parts of the neural tube, and basal plates derived from the anteromedial parts (Figure 1B), which are separated by the sulcus limitans of His.[11] The alar plates are united by a small thin roof plate and have incoming dorsal roots from the afferent or sensory part of the spinal cord, whereas the basal ones are united by a thin floor plate having outgoing ventral roots from the efferent or motor part of the spinal cord. In the hindbrain, the fourth ventricle is formed dorsally, and the pronounced expansion of the roof plate is the major topographical difference from the spinal cord.[12] Therefore, the alar plate is formed lateral to the basal one on each side. The cerebellum is formed from the alar plate (Figure 1C and D).

Puelles et al. have shown that paramedian (mediobasal and laterobasal) arteries directly penetrate the basal plate, while the short and long circumferential arteries supply the alar plate and correspond to ventroalar and dorsoalar arteries, which penetrate the spinal cord radially.[3] Circumferential branches of the BA and vertebral artery (VA) follow longer parallel courses relative to the dorsoventral dimension of all rhombomeres to supply their alar plate territories.[3]

## Development of blood supply of the hindbrain

In the early embryological period, the hindbrain is supplied by the carotid-vertebrobasilar anastomoses, which are arranged from rostral to caudal hindbrain as follows: the trigeminal, hypoglossal and proatlantal arteries (ProA). (Figure 2) These transient anastomoses regress with the development of the posterior communicating artery (PcomA), and the BA is supplied from the VAs finally.[8,13,14]

The primitive trigeminal artery (PTA) can be observed in an embryo of crown-rump length (CRL) 3–4 mm branching from the primitive internal carotid artery (ICA) opposite to the first arch at the level of the trigeminal ganglion. The PTA communicates directly with the primordial hindbrain channels, which later develops into bilateral LNAs. The LNA is primarily supplied by the PTA. As soon as the second aortic arch regresses, the primitive hypoglossal and ProA supply the caudal part of the LNA.

The PcomA is formed in an embryo of CRL 5–6 mm. Consequently, the PTA and hypoglossal artery dwindle at their carotid origin. The PcomA then becomes the source of blood supply to the cranial LNA instead of the PTA. The LNAs fuse along the midline to form the BA and the ASA. At this stage, the caudal part of the LNA intracranially is mainly supplied by (the anterior radial branch of) the ProA.

The BA is formed by midline fusion of the LNAs in an embryo of CRL 7–12 mm. The PTA may still be found at this stage, but it is usually already interrupted. Although the hypoglossal artery has already regressed by this point of time, the dorsal portion of the ProA remains as the transverse suboccipital part of the VA.

The stage of an embryo of CRL 12–14 mm is transitional one with regard to a significant feature of arterial development in the higher vertebrates. Specifically, this refers to the transition from the exclusive carotid supply of all cerebral arteries to the later substituted supply of the hindbrain region by the VAs.[8]

At the stage of an embryo of CRL 40 mm, the mature pattern of the cerebral arteries is complete. The basic direction of arterial blood flow to the hindbrain is from the ICA to the BA. Proximal BA and VAs are hypoplastic or aplastic in the case with the less demand of blood supply from the VAs (Figure 2A and B).

## PLBA

A longitudinal anastomosis temporarily present on the hindbrain wall connects the developing lateral branches of the LNA during arterial development (Figure 3). Elze[15] in 1907 and Barniville[16] in 1914 discovered these vessels in the human embryo, and in 1948, Padget described it as PLBA. Schmeidel also recognized it as a primary and important branch of the ProA in 1932.[17] However, there have been only a few case reports of PLBA,[18,19] and even fewer discussing PLBA in detail.[9]

The PLBA is derived from the primordial hindbrain channel and runs parallel to the LNA. It is supplied caudally by the posterior radicular branch of the ProA, and cranially by the lateral branches of the LNA and particularly the PTA. The PLBA passes between the 6th and 12th

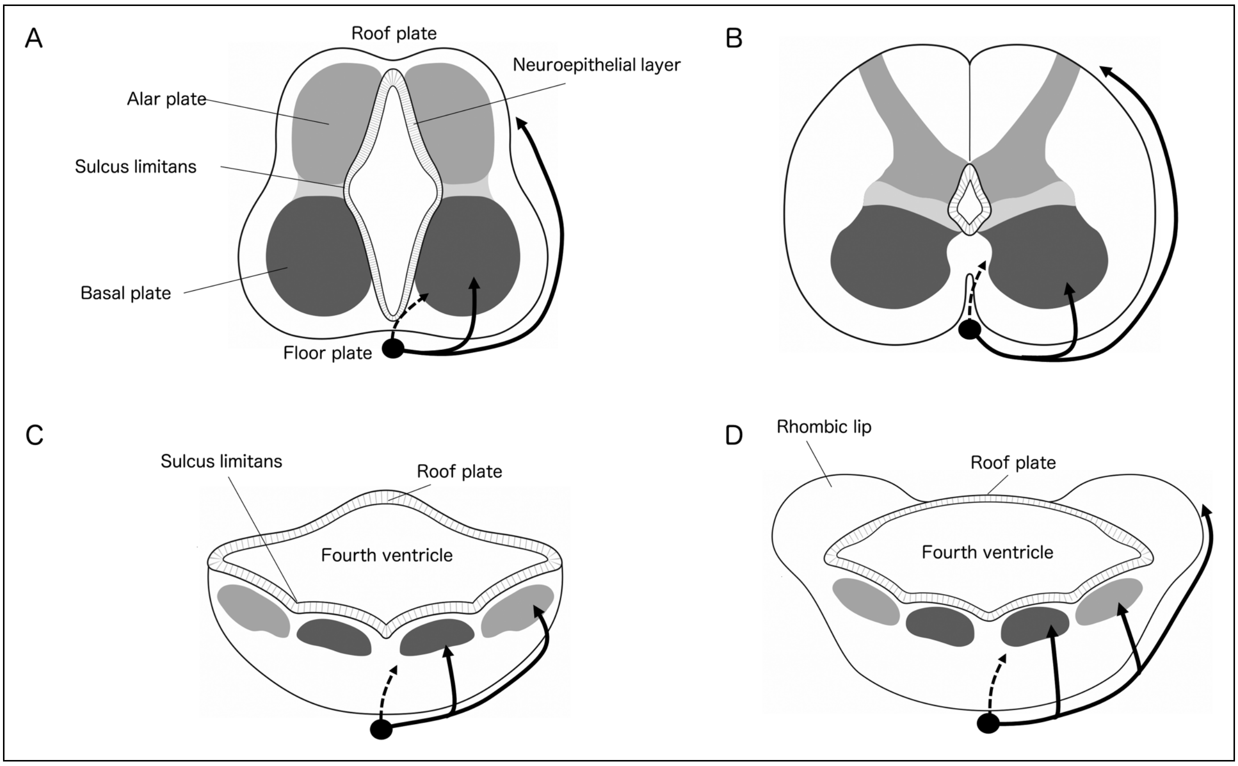


**Figure 1.** Basic arterial angioarchitecture. (a) The neural tube differentiates into the ventricular (ependymal), mantle, and marginal zones. The sulcus limitans separates the alar (dorsal) part (light gray) of the spinal cord and basal (ventral) part (dark gray) of the cord. (b) Spinal cord: The paramedian artery (dotted arrow) supplies the ipsilateral parenchyma centrifugally, and the circumferential (lateral) branches (arrows) of the vasa corona supply centripetally. (c) Medulla: The paramedian perforating artery (dotted arrow) supplies the ipsilateral parenchyma (basal plate) centrifugally, and short/long circumferential arteries (arrows) supply the anteromedial and posterolateral portions centripetally. (d) Pons: The basic arterial pattern is similar to that of the medulla. The rhombic lip (later developing the cerebellum) is supplied by the pial branch of the long circumferential arteries.

cranial nerves medially and between the 7th and 11th cranial nerves laterally (Figure 3A).[8]

There are many transverse channels between the LNA and the PLBA, and many transverse branches from the PLBA supplying the dorsal part of the hindbrain. Some of these will later constitute the proximal segments of the cerebellar arteries.[8,20] It is present in embryos of CRL 5–6 mm to 12–14 mm during the development of the cerebral arterial system.[8]

Moffat noted the lateral longitudinal artery (LLA) in rats, which corresponds to the PLBA by Padget in humans. In rats, the dorsal branch of the ProA connects directly to the LLA.[21] The LLA is present before the formation of the large lateral branches of the LNA. Moffat emphasized that the LLA of the rat is not a longitudinal anastomosis between the laterally directed branches of the LNAs, but is a primary vessel that later acquires anastomoses with the LNAs.[21] The ProA has a dorsal branch that connects the origin of the ipsilateral posterior lateral spinal artery (PLSA), which runs ventral to the dorsal nerve roots and also anastomoses with the dorsal branches of the LLA of the rat. Moffat strongly suggested that the PLBA and the PLSA represent the cranial and spinal portions of the same vascular channels.[9,22] The PLBA and its derivative may be seen as a hypertrophied posterior spinal artery system developed as an adaptation to the expansion of the rostral metencephalon (r0 + r1) into the cerebellum.[9] The development of the PLBA in humans bears a close resemblance to the LLA of the rat, except for the fact that in the human embryo, much of the PLBA disappears and some of its dorsal branches maintain numerous anastomoses with the PICA.[22]

The PLBA is a prominent vascular network from the fifth week to the seventh week of human hindbrain development.[8] It's derivative may be formed as a longitudinal axis from its plexiform surface network to match the hemodynamic demands of the hindbrain. From a different perspective, the PLBA may contribute to the preliminary step in forming the circumferential arteries (i.e. the alar arteries) from the BA and VAs. Additionally, the cerebellar arteries are later formed from these alar arteries by annexing the branches to the cerebellum (Figure 3B).

## Development of the cerebellum and cerebellar arteries

The hindbrain is composed of 12 segments, i.e. the isthmus (r0) and rhombomeres (r1–r11) according to Watson.[23] The isthmus lies between the caudal midbrain and the rhombomere 1(r1) and separates them from each other. The cerebellum is an outgrowth of the dorsal most alar plate of the caudal isthmus (r0) and the first

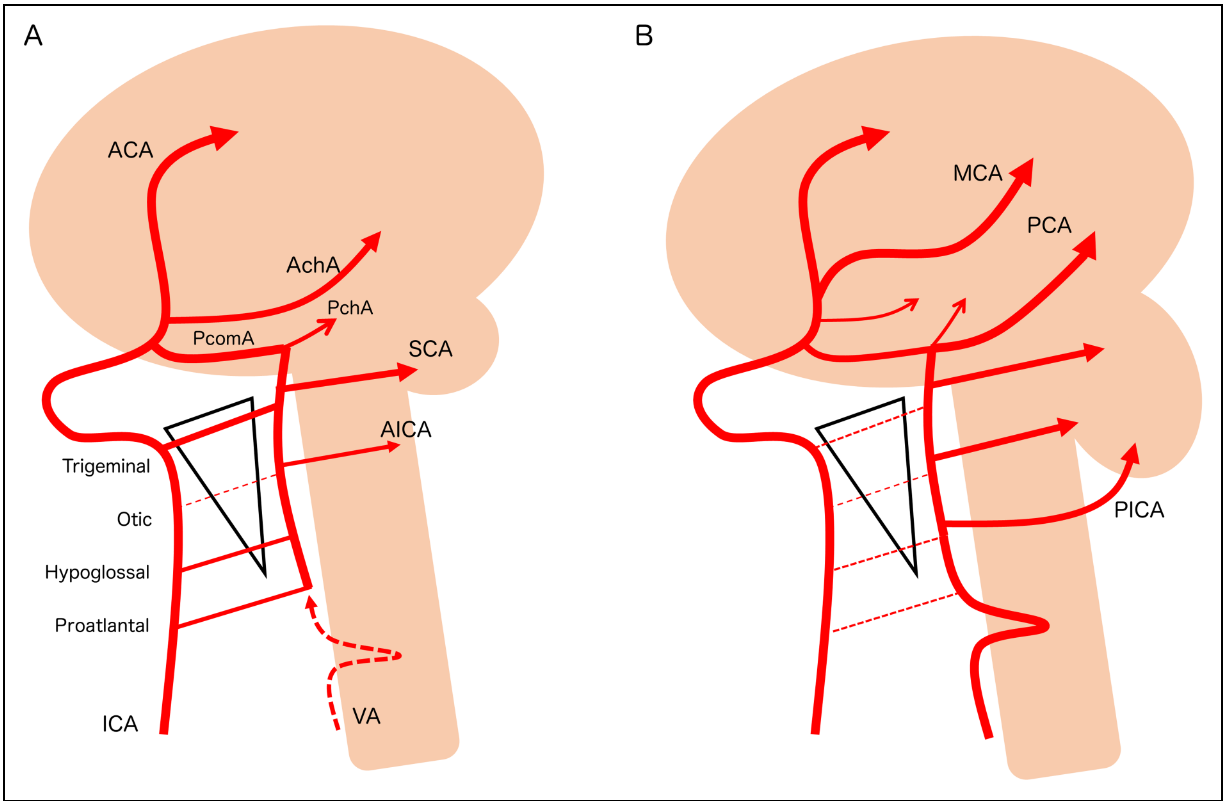


**Figure 2.** Hindbrain blood flow pattern and directional change. (a) At the early stage (the CRL 4 mm), the carotid-basilar anastomoses supply the hindbrain. (b) At 7–8 weeks. As the posterior communicating artery (PcomA) develop and vertebrobasilar arteries are formed, they start to supply the hindbrain, and the primitive carotid-vertebrobasilar anastomoses rapidly regress in about a week.
ACA: Anterior cerebral artery; AICA: Anterior inferior cerebellar artery; AchA: Anterior choroidal artery; CRL: Crown-rump length; ICA: Internal carotid artery; MCA: Middle cerebral artery; PICA: Posterior inferior cerebellar artery; PchA: Posterior choroidal artery; SCA: Superior cerebellar artery; VA: Vertebral artery.

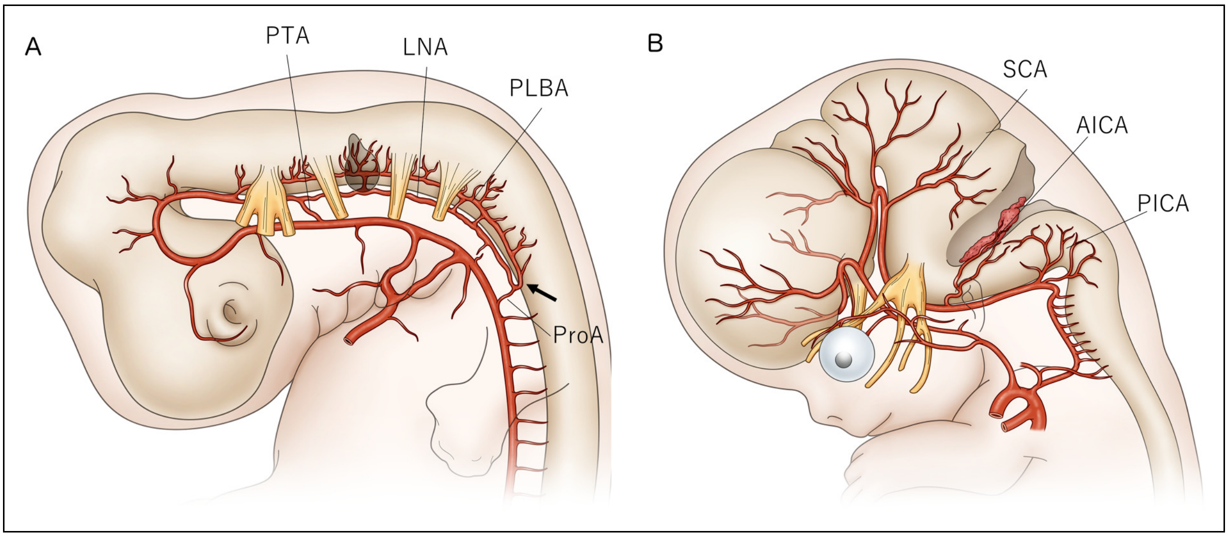


**Figure 3.** Summary of the primitive lateral basilovertebral anastomosis (PLBA) development based on Padget's observations.[8] (a) Representation of the cranial arterial system in embryos of CRL 5–7mm. The dorsal branch of the ProA connects directly to the PLBA, coursing cranially lateral to the LNA. A black arrow shows the dorsal branch of the ProA. The PLBA is a vascular network that later becomes a part of the cerebellar arteries. (b) In an embryo of CRL 16–18mm. The SCA develops and is the only artery supplying the cerebellar rudiment. The AICA only has the choroidal branch, and the main trunk of the PICA is not formed and exists as a vascular network on the lateral side of the medulla. At this time, the AICA and PICA do not have branches to the cerebellum.
AICA: Anterior inferior cerebellar artery; PTA: Primitive trigeminal artery; ProA: Proatlantal artery; PICA: Posterior inferior cerebellar artery; SCA: Superior cerebellar artery.

rhombomere (r1).[24,25] It is an integral part of the prepontine hindbrain, contradicting the old assumption that it forms a developmental unit with the pons.[23] The vermis of the cerebellum is mainly developed from the rhombic lip (dorsolateral part) of the isthmic alar plate, and the hemisphere from the r1 alar plate.[23–25]

Three arteries supply the cerebellum, which are the SCA, AICA, and PICA. These transverse arteries from the longitudinal channel (LNA and PLBA) are enlarged to meet the demands of the cerebellum and brain stem. In the early stages (an embryo of CRL 12–14 mm), only the SCA supplies the cerebellar rudiment. The potential stem of the AICA, arising at the eighth nerve level, terminates in the choroid plexus of the fourth ventricle in embryos of CRL 16–18 mm. However, the stem of future PICA may exit as branches of the VA. In an embryo of CRL 20–24 mm, the stem of the PICA may still be difficult to identify among the numerous arteries formed from the PLBA, supplying the dorsal part of the hindbrain. At this point in time, the cerebellar lobes are not yet formed. In an embryo of CRL 20–40 mm, the PICA is represented by a vessel terminating in the large choroid plexus of the fourth ventricle.[8] The period between cerebellar rudiment appearance and the development of the usual origin of the PICA from the VA extends from $30 \pm 1$ day (in an embryo of CRL 6–7mm) to nearly the end of the second month. During this period, following the development of the pontine flexure, the rhombic lips approach each other and the cerebellum comes into contact with the dorsal aspect of the myelencephalon.[20] In an embryo of CRL 40 mm, the circle of Willis is fully recognizable. Besides the SCA, the AICA and PICA have become more prominent in the vascular plexus that still covers the caudal hindbrain.

Macchi et al. reported the morphogenesis of the PICA with three-dimensional reconstruction in man.[20] They showed that the PLBA is a large channel and represents the main vessel on the lateral aspect of the hindbrain and its possible incorporation into the stem of the PICA with intriguing chronological events between the appearance of the PICA and the regression of the PLBA at the end of the eighth week[20] (Figure 3).

The SCA is the original cerebellar artery[7,26] and represents the hypertrophy of pial channel in relation to cerebellar development. The AICA is the artery for the labyrinthine system and is only recruited to participate in the cerebellar and choroidal supply.[27] The PICA is one of the lateral alar arteries and the last one acquired in humans, representing a radiculopial artery that annexed a cerebellar territory through the primitive choroid plexus of the fourth ventricle, when the cerebellum rolled over the myelencephalon. The AICA and PICA are homologous to pial arteries of the spinal cord, and their origins from the BA and VAs vary in each case. These arteries are hemodynamically balanced, and the dominancy of these arteries (AICA or PICA) is determined by the relative demand from the developing cerebellum and brainstem.

## Fenestration/duplication of vertebrobasilar arteries

Fenestration or duplication of the BA occurs longitudinally, and the retention of different remnants of two axes (LNA and PLBA) can account for the various variations of BA, VA, and cerebellar arteries (Figure 4). BA is formed by fusion of the embryologic LNAs in a rostrocaudal direction by approximately the fifth week,[8] (Figure 4(a)) and PLBA is a primary longitudinal vessel that later acquires anastomoses with the LNA.

Fenestration is one of the most common embryologic anomalies of the BA and is the result of incomplete fusion of the LNAs[8] (Figure 4A). While fenestration of the BA has been reported to be as high as 6% in postmortem studies, its angiographic prevalence has ranged from 0.04% to 0.6%.[28] BA fenestration occurs most commonly in the lower half of the BA[29] (Figure 4(b)). Fenestration of the intracranial VA was also reported.[30] Complete or near-complete nonfusion of the BA is exceptional but can be observed in clinical settings.[31,32]

On the other hand, duplications can occur where two embryologically different vessels fuse during development.[33] They are a partially duplicated vertebrobasilar junction, a variant that needs to be distinguished from BA fenestration. The role of the PLBA in the formation of vertebrobasilar duplications has been previously reported.[9,18,29] In a vertebrobasilar duplication, the lateral limb is a persistent segment of the PLBA, whereas the medial one corresponds to the VA.[9]

Delayed development of the PICA, due to the late vascularization of the posterior inferior portion of the cerebellar hemisphere, could explain the large variability in its pathway as well as many of its origins.[20] These PICA variations include unilateral agenesis and hypoplasia (which are the most common), double or duplicated, and epidural or extracranial origins. Usually, patients who do not have a PICA receive blood supply from the ipsilateral AICA to the posteroinferior part of the cerebellum (Figure 4C). Double-origin PICA and other variations such as extradural origin are due to transfer, regression, and persistence of various arterial segments of the embryologic vertebrobasilar system, including the PLBA.[34] The rostral trunk of the double origin represents the PICA proper, whereas the caudal one represents an anastomosis with PLBA[35] (Figure 4D).

The variable ramifications of AICA from the BA are also related to the recruitment of rostral or caudal transverse arteries during the embryologic stage. The selection of one or more transverse vessels as the future AICAs depends on the increased demand for developing the cerebellum. This explains the high variability in the relative position of bilateral AICAs, origin, multiplicity, and state of development.[36] AICA and PICA are lateral alar arteries, which divide into alar plate branches complementary to each other and then supply the cerebellum at later developmental stages.

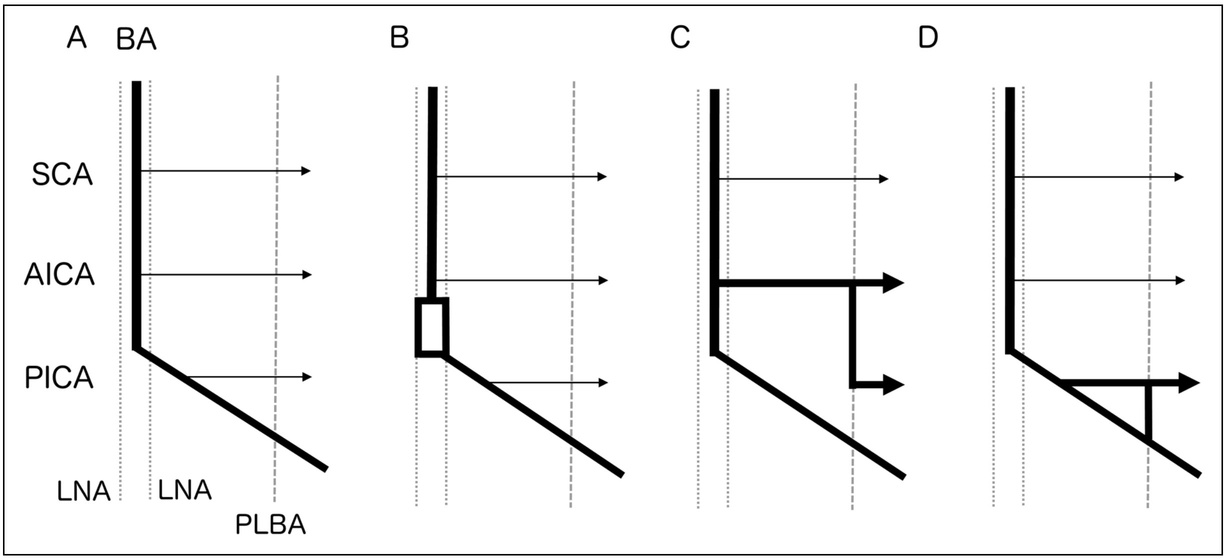


**Figure 4.** Development of normal and anomalous vertebrobasilar arteries. (a) Normal development. (b)Incomplete fusion of the longitudinal neural arteries (LNAs) results in the fenestration of the lower BA. (c) The common trunk of the AICA and PICA is due to the persistence of the PLBA. (d)The double origin of PICA is from the PICA proper and the persistence of the PLBA.
AICA: Anterior inferior cerebellar artery; BA: Basilar artery; PICA: Posterior inferior cerebellar artery; PLBA: Primitive lateral basilovertebral artery; SCA: Superior cerebellar artery.

## PTA variant

Analysis of the longitudinal and axial blood supply of the hindbrain helps to understand the pattern of PTA variants. The persistent PTA is the most common persistent primitive carotid- vertebrobasilar anastomosis with an incidence of approximately 0.5% to 0.7%.[37] The PTA commonly originates either from the posterolateral or posteromedial wall of the intracavernous ICA (C4/5) and merges with the BA between the SCA and AICA. The PTA connects to the fragments of the LNA in an embryo of CRL 4mm, regress as the VA replaces it as the source of blood supply to the hindbrain, and then disappears at the embryo of CRL 14-mm stage (Figure 5A and B).

A persistent PTA was classified by Salzman et al. in 1959 into three types[38] depending on the supplying area of posterior cerebral artery and SCA. Then, a trigeminal artery variant exclusively supplying a part of the cerebellum was reported, which was named the trigeminocerebellar artery or PTA variant. The reported incidence of PTA variants ranges from 0.02% to 0.76%.[37,39–41] This PTA variant supplies a part of the cerebellum that is usually covered by the SCA,[42] AICA,[43] PICA,[44] or exclusively supplies the brainstem without direct interaction with the BA.[45]

The persistence of a direct anastomosis between the ICA and the cerebellar artery, without the interposition of the BA, was explained by an incomplete fusion of the LNAs.[46] Conversely, Gregg et al. proposed that PTA variants result from the partial persistence of the PLBA.[9] The latter is a more reasonable explanation of PTA variants. Padget showed that the PTA establishes an anastomosis with the PLBA before joining the LNA.[8] As previously discussed, LNAs run parallel along the midline, and the PLBA is located laterally. Furthermore, the cerebellar arteries were recruited secondarily and formed from the transverse network of the PLBA.

From this point of view, several interpretations are possible. First, the PTA-cerebellar artery (SCA/AICA/PICA) variants result from the persistence of the part of the PLBA, and these variants occur when the transverse connection of the PTA to the LNA is absent[9] (Figure 5D-F). Second, PTA-paramedian/circumferential variants are the result of incomplete fusion of the LNAs[46] (Figure 5C). Depending on the site of incomplete fusion and remnant anastomoses, this may result in various patterns of PTA variants (Figure 5).

## PHA variant

The persistent primitive hypoglossal artery (PHA) is the second most common persistent carotid-vertebrobasilar anastomosis with an incidence ranging from 0.027% to 0.29%.[47,48] The PHA arises as a branch of the ICA and traverses the hypoglossal canal to join the lower portion of the vertebrobasilar artery. The ipsilateral VA and PcomA are often aplastic or hypoplastic. The size of the PHA probably depends upon the size of the VAs and contribution to the primary supply to the BA.[49] Brismar[47] defined three essential diagnostic criteria in describing the PHA: (a) the PHA leaves the ICA as an extracranial branch; (b) the PHA passes through the hypoglossal canal; (c) the PHA joins the caudal part of the BA.

There have been several reports of cases in which the hypoglossal artery originates from the external carotid artery (ECA)[50–55] (or ascending pharyngeal artery(AphA).[56,57]) The hypoglossal artery and nerve are related to rhombomere 8 and occipital somite 2–4,[58] and

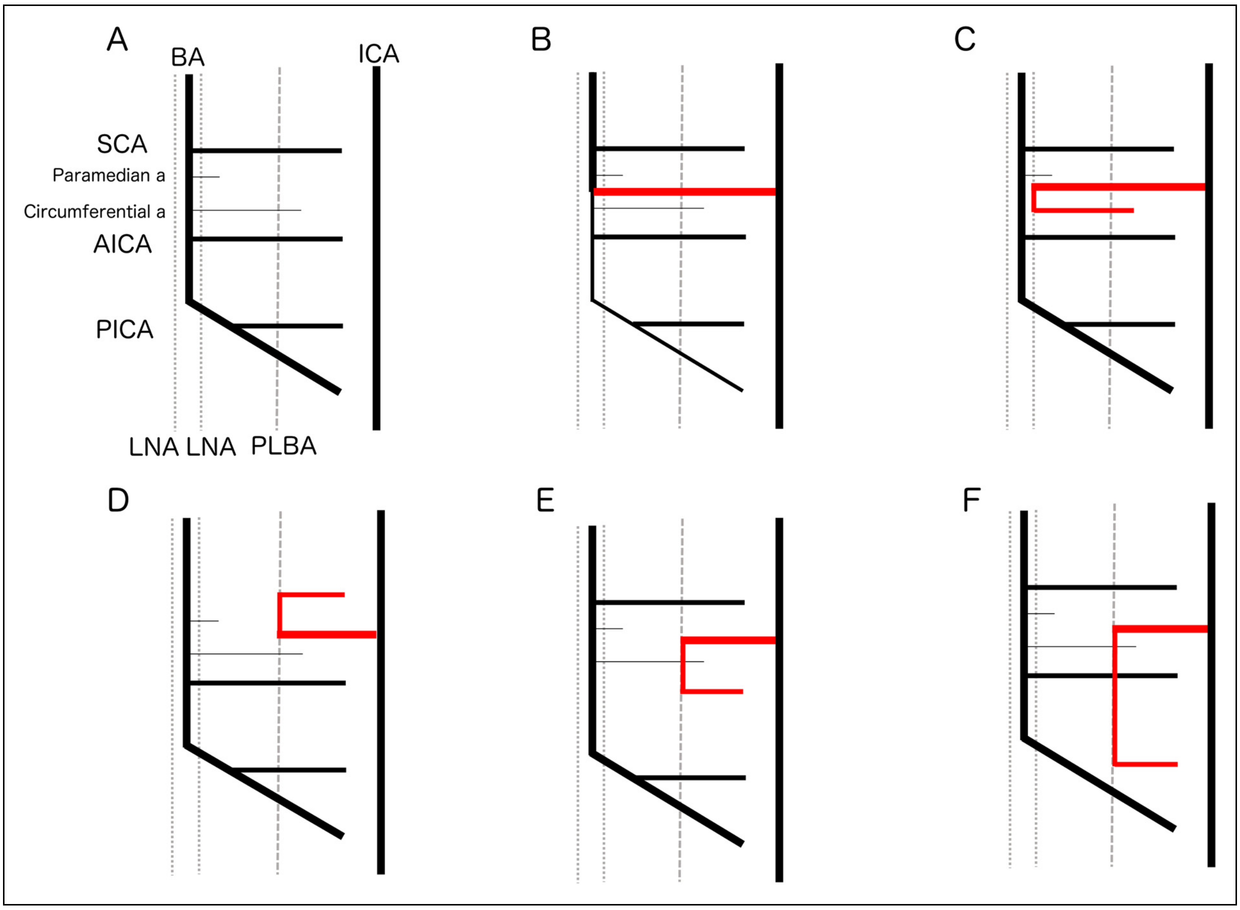


**Figure 5.** Normal and primitive trigeminal artery (PTA) variants. (a) Normal development. (b) PTA red in color. (c) PTA-circumferential variant is formed by the incomplete fusion of the longitudinal neural arteries (LNAs). (d) PTA-superior cerebellar artery (SCA) variant. (e) PTA-anterior inferior cerebellar artery (AICA) variant. (f) PTA-posterior inferior cerebellar artery (PICA) variant. These variants are formed by the incomplete fusion of the primitive lateral basilovertebral anastomosis (PLBA). PTA-cerebellar arteries variants are formed by the persistence of the PLBA.

the hypoglossal nerve is not a cranial nerve but generally regarded as a modified spinal nerve. Moreover, the hypoglossal canal is also regarded as a neural foramen probably between the occipital somites. Lasjaunias and colleagues presumed that the remnant of the PHA in adults was the hypoglossal branch of the AphA.[7] This hypothesis can explain the PHA originating from the ECA.

An extremely rare PHA known as the PHA variant has been reported on a few occasions. This hypoplastic PHA directly ends in the PICA (PHA-PICA) without an interposed segment of the BA via the hypoglossal canal, which arise from the extracranial segment of the ICA[49,59–61] or the ECA.[50,57] Schmeidel found in human embryo that the hypoglossal artery passed between the hypoglossal rootlets to join the PLBA without communicating with the LNA.[17] Morris and Moffat[62] stated that the embryonic hypoglossal arteries are composed of three parts: (a) the hypoglossal artery proper, (b) portions of the PLBA, and (c) the transverse anastomotic channels connecting the PLBA to the LNA. As described above, the variable origins of the PICA are explained chiefly by the remnants of the PLBA. The PHA-PICA variant results from persistence of the first and second part, and involution or failure of development of the third part of the PHA.

On the other hand, to our knowledge the PHA-SCA and the PHA-AICA variants have not been reported so far. We hypothesize the following: first, the PHA usually involutes during an embryo of CRL 5.5mm, earlier than the PTA and the ProA regress and before forming of the SCA;[8] second, the part of the connection of PHA to the PLBA located caudally on the hindbrain wall (i.e. closer to the stem of the PICA). Therefore, the PHA variant is more likely to connect to the PICA than AICA or SCA. Lastly, the PLBA regresses from rostral to caudal, according to the formation of the cerebellar arteries (first SCA, then AICA and PICA).

## Conclusion

The angioarchitecture of the hindbrain is homologous to the spinal cord and includes two main longitudinal arteries (LNA and PLBA). Partial persistence of the PLBA explains the formation of commonly observed variations, such as a fenestration and duplication of vertebrobasilar artery, PTA variant, or PHA variant. Understanding the pattern and the development of the blood supply of the hindbrain provides useful information of the various anomalies of the vertebrobasilar junction and cerebellar arteries.

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