



Branches and Variations of the Internal Carotid Artery

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The internal carotid artery (ICA) has the principal role to bring high-flow blood to a major part of the cerebral hemisphere. During the species evolution, the ICA takes always more importance [1–3]. Its secondary roles as dural, middle ear, and hypophysis supplies are less known [4, 5]. Even if the internal carotid artery is considered as a “stable” artery, with a very low rate of anatomical variations, some variants have been described in the literature [1, 6–8]. In this chapter, all anatomical variations encountered, and all branches of the ICA will be presented. Persistent carotido-vertebral arteries will be developed and explained in chapter “Carotido-Vertebral Anastomoses.” Anatomical variations as ICA origin of the occipital or ascending pharyngeal arteries will also be presented in chapters “Embryology and Variations of the Occipital Artery” and “Embryology and Variations of the Ascending Pharyngeal Artery”.

History

For more than 200 years, the internal carotid artery is one of the arteries that caught the most attention [4, 6, 9, 10]. In the beginning, scientists, anatomists, and also philosophers based their knowledge only on animal’s dissection and only in a second time, on human cadaveric dissection [1, 10]. In the last 50 years, angiographic studies always gave a more detailed analysis of little branches of the internal carotid artery [8, 9, 11–14]. Among the physicians who dedicated their studies to this artery, we can mention Malacarne, Stattin, Parkinson, and Rhoton for their studies and cadaveric dissections about ICA branches [3, 8, 15–17]. As for all cranio-facial arteries, Congdon and Padget allowed to under-

stand the embryologic basis of the ICA [2]. Altmann and Barry also furnished amazing works about the evolution of the aortic arches [1, 18]. Finally, Lasjaunias illuminated other physicians in the understanding of almost all anatomic variations of the ICA based on his embryologic knowledge [7, 19–23].

Embryology

The embryological vascular development starts early in the embryological life. The primitive heart is already recognizable at approximately 19 days (embryos of 2 mm) and paired ventral and dorsal aortas are formed and already have a cranial continuity, forming the first cranial arch. From 21 to 32 days (embryos of 3 to 12 mm), the other aortic arches are successively formed from front to back [1, 2, 10]. At the same time, the dorsal aortas give a cranial extension to the first aortic arch. At 28 days (embryos of 4–5 mm), the first aortic arch initiates to involute, followed by the second aortic arch [1, 2, 18]. Consequently, the six pairs of aortic arches are not all present at the same time. Each aortic arch has a different function, the two first one involute completely, the third arch persists and will become a part of the internal carotid artery, the fourth one persists and will give the adult aortic arch on the left and the brachiocephalic artery on the right. The fifth aortic arch will completely involute and the sixth one will become the pulmonary arteries [1, 2].

Common Carotid Artery

The embryological origin of the common carotid artery is not clear. Altmann in 1947 already postulated two different hypotheses [1]. The first one is that the common carotid artery derives from the ventral aorta between the third and fourth aortic arch and from the third aortic arch. The second hypothesis is that the common carotid artery derives

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directly from the aortic sac a second time after the formation of the aortic arches [1]. In her monograph, Padget (1948) did not insist on the embryological formation of the common carotid artery and considered it as the development of the ventral aorta between the third and fourth aortic arches [2]. Lasjaunias (1984), based on the fact that a segmental agenesis of the cervical internal carotid artery never influences the formation of the common carotid artery, considered that the third aortic arch could not participate in the formation of the distal common carotid artery [22]. In conclusion, the strongest hypothesis about the formation of the common carotid artery is that it originates from the ventral aorta between the insertion of the third and fourth aortic arches which have an important extension after the involution of the different other arches as described before [5, 7, 20, 22, 24].

External Carotid Artery

Also, for the external carotid artery, different hypotheses were postulated to explain its embryological development but the most probable is its direct origin from the aortic sac [9]. The ventral pharyngeal artery (which is the principal precursor of the external carotid artery) extends cranio-laterally from the aortic sac as early as the 5–6 mm stage. The ventral pharyngeal artery annexes later (24 mm stage) the maxillomandibular branch of the stapodial artery to become the external carotid artery. At approximately 40 days, the descent of the aortic sac favors the cranial migration of the external carotid artery origin along the common carotid artery to give the adult configuration [1, 2]. Lasjaunias strongly argued against a common embryological origin of internal and external carotid arteries, based on different types of segmental agenesis of the ICA always sparing the ECA development [7].

Internal Carotid Artery

Early in the development (first stage of Padget, embryos of 4–5 mm), the two first aortic arches initiate their natural regression allowing the internal carotid artery to be individualized [1, 2, 10, 18]. The embryological segments of the ICA are derived from the third aortic arch and from the dorsal aorta cranial to the third aortic arch. The dorsal aorta also regresses at the same time between the third and fourth aortic arches. In the 4–5 mm embryos, the primitive ICA bifurcation is already visible with its two divisions: anterior and posterior that will become in adult, the anterior cerebral artery and the posterior communicating artery [2]. The ICA, cranial to the posterior communicating origin, derives from the anterior division of the ICA; and not from the ICA itself. Consequently, the primitive ICA bifurcation is considered to be at the origin of the posterior communicating artery and not at the origin of the middle cerebral artery.

Embryologically, we could divide the internal carotid artery into seven different segments according to Lasjaunias [22].

These segments could be individualized as follows:

1. The first one corresponds to the third aortic arch from the origin of the ventral pharyngeal artery (future external carotid artery) to the junction between the third aortic arch and the dorsal aorta. In the adult, it corresponds to the cervical internal carotid artery.
2. The second segment is the dorsal aorta between the third and second aortic arch. Its distal part is the hyoid artery in the embryo and the caroticotympanic artery in the adult (ascending intrapetrous segment).
3. The third segment is the dorsal aorta between the second and first aortic arch. It corresponds in the embryo to the segment between the hyoid and the mandibular arteries, and, in the adult, between caroticotympanic artery and the Vidian artery (horizontal intrapetrous segment).
4. The fourth segment is the dorsal aorta between the first aortic arch and the origin of the trigeminal artery (and the primitive maxillary artery). In the adult, it corresponds to the segment between the Vidian artery and the origin of the meningo-hypophysary trunk (ascending foramen lacrum segment).
5. The fifth segment is the dorsal aorta between the origin of the trigeminal artery (and the primitive maxillary artery) and the origin of the primitive dorsal ophthalmic artery (PDOA, future inferolateral trunk-ILT). It corresponds in the adult to the horizontal cavernous segment between the meningo-hypophysary and infero-lateral trunks.
6. The sixth segment is between the origin of the PDOA and the anastomotic point of the primitive ventral ophthalmic artery (PVOA) on the internal carotid artery. This segment in the adult is the clinoid segment between the origin of the ILT and the OA.
7. The seventh segment is between the anastomotic point of the PVOA and the primitive carotid bifurcation. In the adult, this is the supraclinoid ICA from the origin of the OA to the origin of the posterior communicating artery.

It is important to note that the carotid bulb has not the same embryological origin than the other segments of the ICA. It originates from the pharyngo-occipital system that easily explains variations in origin of the ascending pharyngeal and occipital arteries [7, 22].

Fenestration and Duplication

Fenestrations and duplications involving the internal carotid artery are extremely rare anatomical variations [25, 26]. A fenestration is defined as the presence of two different vessel lumens corresponding to the same vessel (same embryologic

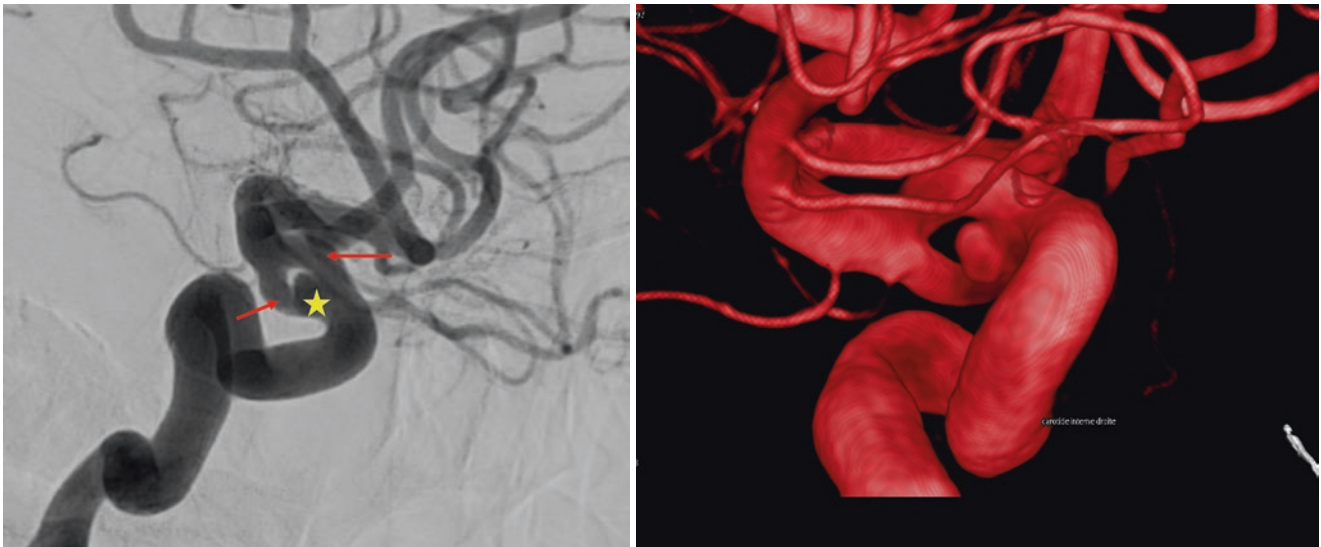


Fig. 1 Case of ICA fenestration associated with aneurysm. The lateral and 3D view of ICA DSA show a case of supraclinoid internal carotid artery fenestration (red arrows), associated with aneurysm formation on its proximal part (yellow star)

origin) [7]. On the other hand, a duplication is the presence of two different vessels from two different embryologic origins (persistence of an embryologic vessel) [7, 19]. Cases of duplication of the internal carotid artery are limited to its two first segments [19]. These cases correspond to the presence of an intra-tympanic flow of the ICA (aberrant ICA) associated with the persistence of the normal ICA [27]. Fenestrations could involve each segment of the ICA. The two most involved segments are the cervical and the supraclinoid segments [28]. Supraclinoid segment fenestration of the ICA is recognized as an anatomical predisposition for the formation of anterior circulation aneurysm, as shown in a case in Fig. 1 [29]. Isolated cases of fenestration involving petrous and cavernous segments of the ICA are also described [30].

Branches of the Internal Carotid Artery

The cervical segment of the ICA usually does not offer any branches. The possible branches originating from this segment are usually the result of a persistent embryonic artery or other embryological anomalies. The branches arising from the petrous, cavernous, and supraclinoid segment are listed below and illustrated in Fig. 2.

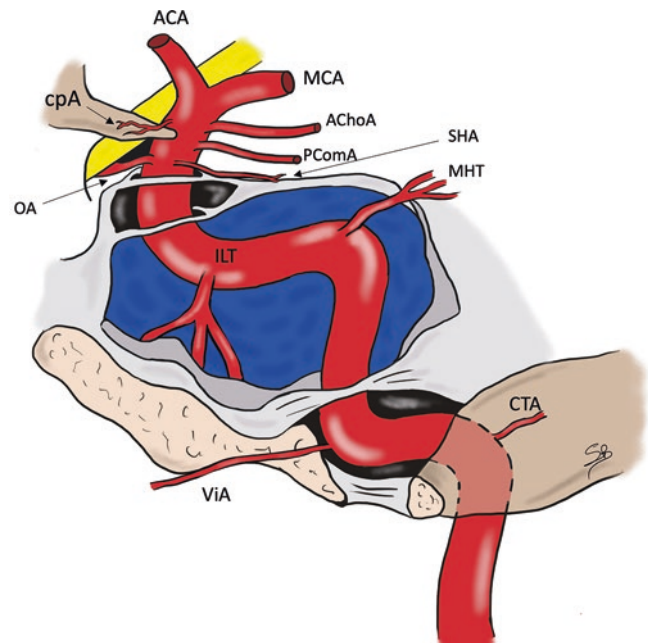


Fig. 2 Illustration of ICA branches. CTA carotico-tympanic artery, ViA vidian artery, MHT meningo-hypophyseal artery, ILT infero-lateral trunk, OA ophthalmic artery, SHA superior hypophyseal artery, PComA posterior communicating artery, AChOA anterior choroidal artery, cpA clinoid process artery, ACA anterior cerebral artery, MCA middle cerebral artery

Cervical Segment of the Internal Carotid Artery

Separate Origin ICA-ECA

The absence of the common carotid artery or separate origin of the external and internal carotid arteries is a rare anatomical variation with an incidence estimated inferior than 0.1% [15]. Only 87 cases have been described in the literature, among which almost all are unilateral (75 cases) and the majority is associated with a normal aortic arch (58% of cases) [15]. Lie (1968) proposed three different theories to explain this anatomical variation depending on the hypothesis on the development of the external carotid artery supported [31]. The first theory is the involution of the third aortic arch with persistence of the ductus caroticus (dorsal aorta between the third and fourth aortic arches). The second hypothesis is the failure of migration of the ECA origin which remains caudal to the third aortic arch. The third theory is the persistence of the ductus caroticus with involution of the distal part of the third aortic arch (its proximal part is the precursor of the ECA).

Aberrant ICA with Normal ICA Course

Aberrant ICA or intra-tympanic flow of the ICA is largely developed in the chapter “Embryology and Anatomy of the Internal Maxillary Artery.” The agenesis of the first two segments of the ICA could be complete or partial [32]. In rare cases, the agenesis of the cervical and petrous ICA is only partial and consequently, the cervical and petrous ICA seems duplicated. The normal course of the ICA is generally hypoplastic in these cases [27].

Pharyngo-Tympano-Stapedial Artery

In this variant, the cervical ICA presents another branch, which is the MMA. This was first described by Lasjaunias (1977) in its original publication [5]. The same case served as illustration in the textbook “Surgical Angiography” and

only one similar case was published by Baltsavias et al. (2012) [33]. The MMA arises from the cervical portion of the ICA, ascends along the cervical ICA, enters the tympanic cavity through the inferior tympanic canal, and follows the usual course of the stapedial artery. The two cases described were presented as “partial” persistence of the SA with only the MMA arising from the SA and the absence of the foramen spinosum. In this variant, an annexation of the SA by the inferior tympanic artery (branch of the ascending pharyngeal artery) with regression of the proximal part of the SA explains this vascular configuration. Therefore, the SA arises from the cervical instead of the petrous segment of the ICA [5, 7, 22, 24].

Petrous Segment of the Internal Carotid Artery

Vidian Artery

The vidian artery (ViA), also called the artery of the pterygoid canal, is an anastomotic vessel between the petrous internal carotid artery and the third segment of the internal maxillary artery [16]. The vidian artery is the remnant of the first aortic arch and courses in the pterygoid canal [34]. Its function is limited to the periosteal supply of the pterygoid canal and to the supply of the vidian nerve. The vidian artery is usually not seen on normal angiography but could be enlarged in case of internal carotid artery stenosis or tumoral process of the skull base [34]. Figure 3 shows a rare case of ViA visible on DSA.

Carotico-Tympanic Artery

The carotico-tympanic artery is a little artery arising from the ascending petrous segment of the ICA and corresponds to the carotid remnant of the stapedial artery (second aortic arch) [7]. Its supply is limited to a part of the middle ear. This artery can anastomose with the inferior tympanic artery and enlarge the inferior tympanic canal in case of intra-tympanic flow of the ICA [22].

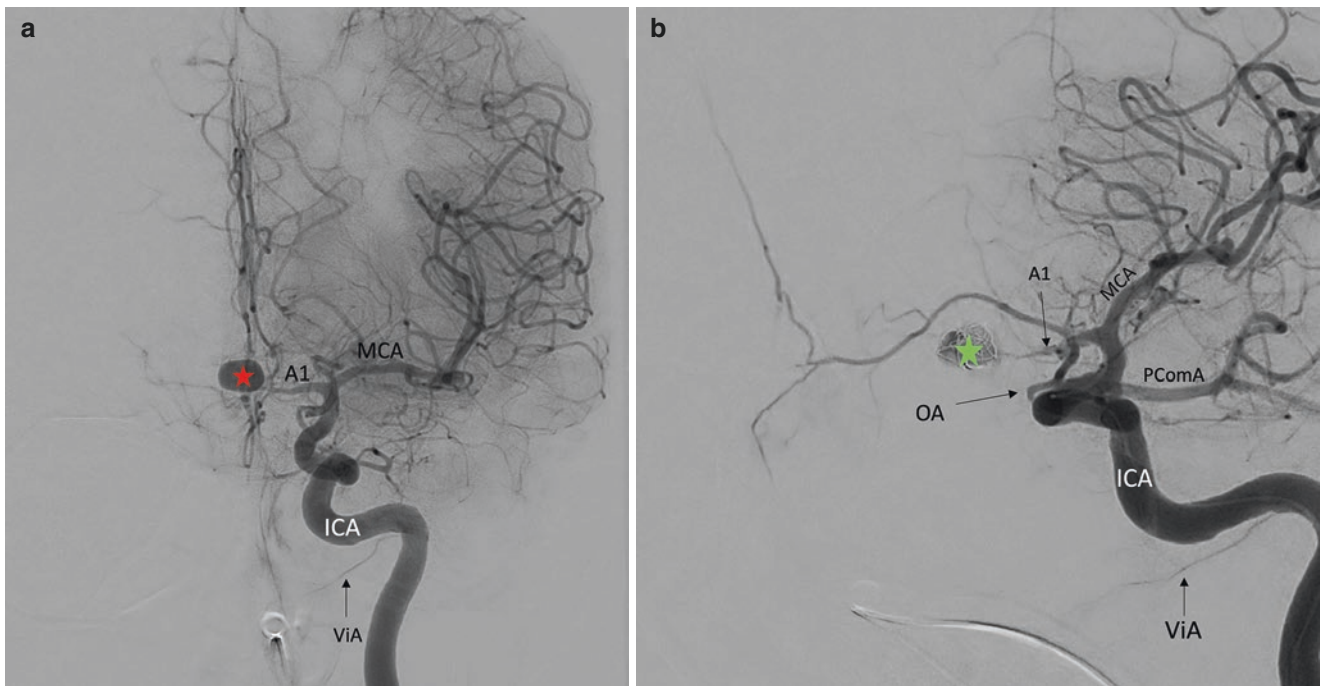


Fig. 3 DSA showing the vidian artery. The figure shows the case of a patient who arrived to our emergency department after unusual headache and the CT scan showed a subarachnoidal hemorrhage associated with multiple aneurysms. The image shows an antero-posterior (a) and lateral (b) DSA view after left internal carotid artery (ICA) injection. In Figure a and b, the first visible branch of the ICA is the vidian artery

(ViA). It is also visible the ICA bifurcation into A1 and middle cerebral artery (MCA), and the ruptured aneurysm of the anterior communicating artery (red star). In Fig. B, the ViA is still visible, as well as the posterior communicating artery (PComA), the ICA bifurcation, and the aneurysm during the phase of coiling (green star)

Cavernous Segment of the Internal Carotid Artery

The cavernous segment of the ICA is very stable and usually it is not affected by major anatomic variations other than segmental agenesis, described in chapter “Segmental Agenesis of the Internal Carotid Artery.” This segment of

the ICA presents two major branches, the meningo-hypophyseal and the infero-lateral trunks, that supply the dura of the central skull base [8, 16]. Their embryology, variations, and functions are well described in chapter “Dural Branches of the Internal Carotid Artery.” Figure 4 presents a case of dural arterio-venous fistulas supplied by these two ICA branches.

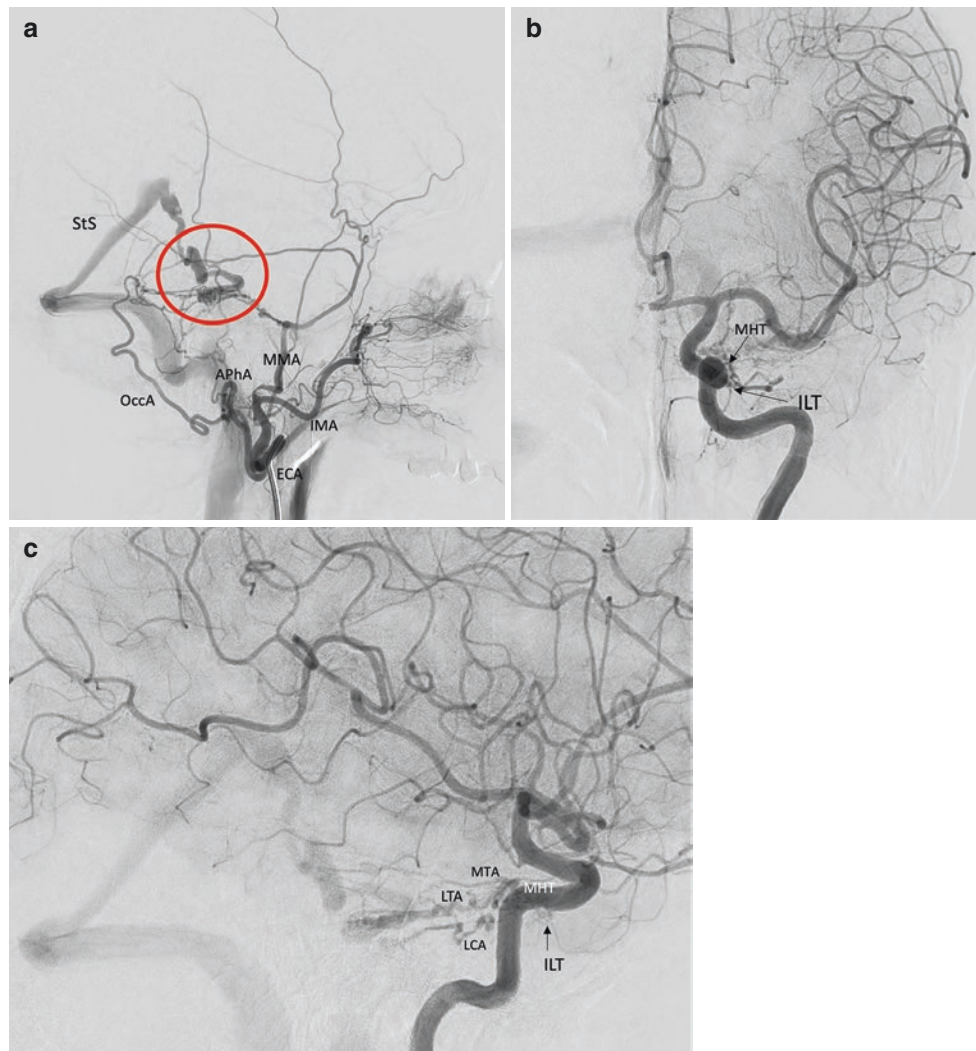


Fig. 4 Case of dural arterio-venous fistula supplied by branches of MHT. The meningo-hypophyseal trunk (MHT) and the infero-lateral trunk (ILT) are usually difficult to see in a normal DSA. However, they can be enlarged and consequently visible in case of dAVFs. Fig. **a** shows a case of dural arterio-venous fistula (red circle) located at the petrous apex on the left side. The major feeders come from the external carotid artery (ECA), and especially from dural branches of the occipital artery (OccA), the ascending pharyngeal artery (APhA), and the middle meningeal artery (MMA), whose origin from the internal maxillary artery (IMA) is also visible. The venous drainage is from the superior petrous vein, the transverse pontine vein and later into the Galen vein and the straight sinus (StS). Fig. **b** and **c** show respectively an antero-posterior and lateral view after left ICA injection. In both the projections, the MHT and ILT are visible. The MHT divides into the marginal tentorial artery (MTA), the lateral tentorial artery (LTA), and the lateral clival artery (LCA). The inferior hypophyseal artery is not visible. The ILT is visible at its origin from the internal carotid artery on its infero-lateral aspect

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Supraclinoid Segment of the Internal Carotid Artery

Ophthalmic Artery

Embryologic development and anatomical variations of the ophthalmic artery are largely explained in chapter “Embryology and Variations of the Ophthalmic Artery,” thus they will not be treated in this chapter.

Superior Hypophyseal Artery

The superior hypophyseal artery (SHA) is an artery or a group of arteries that arises from the medial wall of the supraclinoid portion of the ICA [11, 35]. The SHA could be composed from one to five arteries with a predilection for two distinct branches (anterior and posterior in 40% of cases) [35]. It supplies the anterior hypophysis, the pituitary stalk, and the optic nerve and chiasma [17, 36]. Four distinct

branches are generally individualized: (1) recurrent optic, (2) chiasmatic, (3) infundibular, and (4) descending branch. The two last branches often present a rich anastomotic network with contralateral similar branches called the circuminfundibular anastomosis [35].

Perforators

The supraclinoid segment of the ICA is the origin of important perforator arteries that supply the optic nerve, chiasma and tract, the temporal uncus, the floor of the third ventricle, and the anterior perforating substance [17, 36]. These perforators arise from the ophthalmic and the choroidal segments of the artery, the communicating segment does not bear any perforating arteries in more than 60% of cases. These little branches often take their origin on the postero-medial wall of the ICA [37].

Posterior Communicating Artery

The posterior communicating artery is embryologically the caudal division of the primitive internal carotid artery. Its embryology, variations, and branches are exposed in chapter “Embryology and Anatomy of the Posterior Communicating Artery and Basilar Artery.”

Anterior Choroidal Artery

The anterior choroidal artery has an important role in the embryologic development of brain hemispheres. This artery is largely exposed in chapter “Embryology and Variations of the Anterior Choroidal Artery.”

Artery of the Anterior Clinoid Process

The artery of the anterior clinoid process is the only dural branch of the ICA that does not arise from its cavernous segment [38]. All details known about this artery are exposed in the chapter “Dural Branches of the Internal Carotid Artery.”

Terminal Branches

The terminal branches are the anterior cerebral artery and the middle cerebral artery with different embryologic origin. Embryology and anatomic variations of these two arteries are respectively developed in chapters “Embryology,

Anatomy, and Variations of the Anterior Cerebral Artery” and “Cortical and Perforating Branches of the Middle Cerebral Artery.”

References

1. Altmann F. Anomalies of the internal carotid artery and its branches; their embryological and comparative anatomical significance; report of a new case of persistent stapedia artery in man. *Laryngoscope*. 1947;57(5):313–39.
2. Padgett DH. The development of cranial arteries in the human embryo. *Contrib Embryol Carneg Instn*. 1948;212:205–62.
3. Parkinson D. A surgical approach to the cavernous portion of the carotid artery. Anatomical studies and case report. *J Neurosurg*. 1965;23(5):474–83. <https://doi.org/10.3171/jns.1965.23.5.0474>.
4. Curnow J. Two instances of irregular ophthalmic and middle meningeal arteries. *J Anat Physiol*. 1873;8(Pt 1):155–6.
5. Lasjaunias P, Moret J, Manelfe C, Theron J, Hasso T, Seeger J. Arterial anomalies at the base of the skull. *Neuroradiology*. 1977;13(5):267–72.
6. Fisher AG. A case of complete absence of both internal carotid arteries, with a preliminary note on the developmental history of the Stapedial artery. *J Anat Physiol*. 1913;48(Pt 1):37–46.
7. Lasjaunias P, Bereinstein A, Ter Brugge KG. *Surgical neuroangiography*. Berlin: Springer edition; 2001.
8. Parkinson D. Collateral circulation of cavernous carotid artery: anatomy. *Can J Surg*. 1964;7:251–68.
9. Tode. *Medizinisch-chirurgische Bibliothek*. Copenhagen: 1787.
10. Legait E. Le réseau admirable carotidien. *Biol Med (Paris)*. 1947;36(9–10):139–65.
11. McConnell EM. The arterial blood supply of the human hypophysis cerebri. *Anat Rec*. 1953;115(2):175–203. <https://doi.org/10.1002/ar.1091150204>.
12. Cortes O, Chase NE, Leeds N. Visualization of tentorial branches of the internal carotid artery in intracranial lesions other than Meningiomas. *Radiology*. 1964;82:1024–8. <https://doi.org/10.1148/82.6.1024>.
13. Manelfe C, Tremoulet M, Roulleau J. Arteriographic study of the intracavernous branches of the internal carotid. *Neurochirurgie*. 1972;18(7):581–98.
14. Manelfe C, Tremoulet M, Roulleau J. Intracavernous collaterals of the internal carotid artery. 2. Angiographic study. *Ann Radiol (Paris)*. 1974;17(3):268–70.
15. Vasovic L, Trandafilovic M, Vljakovic S. Congenital aplasia of the common carotid artery: a comprehensive review. *Biomed Res Int*. 2019;2019:9896138. <https://doi.org/10.1155/2019/9896138>.
16. Martins C, Yasuda A, Campero A, Ulm AJ, Tanriover N, Rhoton A Jr. Microsurgical anatomy of the dural arteries. *Neurosurgery*. 2005;56(2 Suppl):211–51; discussion –51. <https://doi.org/10.1227/01.neu.0000144823.94402.3d>.
17. Rhoton AL Jr. The supratentorial arteries. *Neurosurgery*. 2002;51(4 Suppl):S53–120.
18. Barry A. The aortic arch derivatives in human adult. *Anat Rec*. 1951;111(2):221–38.
19. Chng SM, Alvarez H, Marsot-Dupuch K, Mercier P, Lasjaunias P. “Duplicated” or “multiple” cervical internal carotid and vertebral arteries from fenestration, duplication and vasa vasorum to segmental rete. *Interv Neuroradiol*. 2004;10(4):301–7. <https://doi.org/10.1177/159101990401000403>.
20. Lasjaunias P, Moret J, Doyon D, Vignaud J. C5 collaterals of the internal carotid siphon: embryology, angiographic anatomi-

- cal correlations, pathological radio-anatomy (author's transl). *Neuroradiology*. 1978;16:304–5. <https://doi.org/10.1007/bf00395282>.
21. Lasjaunias P, Moret J, Mink J. The anatomy of the inferolateral trunk (ILT) of the internal carotid artery. *Neuroradiology*. 1977;13(4):215–20. <https://doi.org/10.1007/bf00344216>.
 22. Lasjaunias P, Santoyo-Vazquez A. Segmental agenesis of the internal carotid artery: angiographic aspects with embryological discussion. *Anat Clin*. 1984;6(2):133–41.
 23. Willinsky R, Lasjaunias P, Berenstein A. Intracavernous branches of the internal carotid artery (ICA). Comprehensive review of their variations. *Surg Radiol Anat*. 1987;9(3):201–15.
 24. Lasjaunias P, Moret J. Normal and non-pathological variations in the angiographic aspects of the arteries of the middle ear. *Neuroradiology*. 1978;15(4):213–9.
 25. Banach MJ, Flamm ES. Supraclinoid internal carotid artery fenestration with an associated aneurysm. Case report. *J Neurosurg*. 1993;79(3):438–41. <https://doi.org/10.3171/jns.1993.79.3.0438>.
 26. Sgreccia A, Coskun O, Di Maria F, Rodesch G, Consoli A. Fenestration of the supraclinoid segment of the ICA and associated aneurysms: a case report with literature review. *Acta Neurochir*. 2018;160(6):1143–7. <https://doi.org/10.1007/s00701-018-3551-7>.
 27. Koenigsberg RA, Zito JL, Patel M, Swartz JD, Goldofsky E, Zahtz G. Fenestration of the internal carotid artery: a rare mass of the hypotympanum associated with persistence of the stapedia artery. *AJNR Am J Neuroradiol*. 1995;16(4 Suppl):908–10.
 28. Dey M, Awad IA. Fenestration of supraclinoid internal carotid artery and associated aneurysm: embryogenesis, recognition, and management. *World Neurosurg*. 2011;76(6):592 e1–5. <https://doi.org/10.1016/j.wneu.2011.04.019>.
 29. Jha N, Crockett MT, Singh TP. Unusual right internal carotid artery supraclinoid segment fenestration associated with multiple aneurysms treated with flow diversion and coiling. *BMJ Case Rep*. 2018;2018 <https://doi.org/10.1136/bcr-2018-227020>.
 30. Uchino A, Saito N, Kurita H, Ishihara S. Persistent trigeminal artery arising from the arterial ring/fenestration of the cavernous segment of the internal carotid artery. *Surg Radiol Anat*. 2012;34(7):651–4. <https://doi.org/10.1007/s00276-011-0927-2>.
 31. Lie TA. The congenital anomalies of the carotid arteries. Amsterdam/New York: Excerpta Medica Foundation; 1968.
 32. Aladwan A, Mack M, Gstottner W, Vogl TJ. Duplication of internal carotid artery: a rare case of tympanic mass. *Eur Radiol*. 2005;15(12):2525–7. <https://doi.org/10.1007/s00330-004-2507-x>.
 33. Baltsavias G, Kumar R, Valavanis A. The pharyngo-tympano-stapedial variant of the middle meningeal artery. A case report. *Interv Neuroradiol*. 2012;18(3):255–8. <https://doi.org/10.1177/159101991201800302>.
 34. Osawa S, Rhoton AL Jr, Seker A, Shimizu S, Fujii K, Kassam AB. Microsurgical and endoscopic anatomy of the vidian canal. *Neurosurgery*. 2009;64(5 Suppl 2):385–411; discussion –2. <https://doi.org/10.1227/01.NEU.0000338945.54863.D9>.
 35. Doglietto F, Prevedello DM, Belotti F, Ferrari M, Lancini D, Schreiber A, et al. The superior hypophyseal arteries: anatomical study with an endoscopic endonasal perspective. *Oper Neurosurg (Hagerstown)*. 2019;17(3):321–31. <https://doi.org/10.1093/ons/opy393>.
 36. Joo W, Funaki T, Yoshioka F, Rhoton AL Jr. Microsurgical anatomy of the carotid cave. *Neurosurgery*. 2012;70(2 Suppl Operative):300–11; discussion 11–2. <https://doi.org/10.1227/NEU.0b013e3182431767>.
 37. Marinkovic SV, Milisavljevic MM, Marinkovic ZD. The perforating branches of the internal carotid artery: the microsurgical anatomy of their extracerebral segments. *Neurosurgery*. 1990;26(3):472–8.; discussion 8–9. <https://doi.org/10.1097/00006123-199003000-00015>.
 38. Salunke P, Singh A, Rekhapalli R. Dural artery from supraclinoid internal carotid artery to anterior clinoid process: origin, course, and clinical implications. *World Neurosurg*. 2018; <https://doi.org/10.1016/j.wneu.2018.12.071>.