



The ophthalmic artery: a new variant involving two branches from the supracavernous internal carotid artery

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Abstract

Purpose We report an extremely rare, double ophthalmic artery configuration.

Methods We present 2D- and 3D-angiographic features of an anomalous origin of the ophthalmic artery.

Results The double ophthalmic artery was the result of the persistence of the primitive dorsal ophthalmic artery combined with the presence of a second orbital artery originating from the supracavernous internal carotid artery, passing through the superior orbital fissure and into the orbit to furnish the muscular, lacrimal and ethmoidal arteries and the medial long posterior ciliary artery.

Conclusions A heretofore undocumented instance of ophthalmic artery duplication is presented. Knowledge of such variations is important for the planning of endovascular treatments and the comprehension of unusual angiographic images. Such fine arterial variants may very well be frequent, but difficult to demonstrate on simple 2D angiographies. Multiplanar reconstructions of 3D angiography data make it possible to diagnose rare, but embryologically predictable arterial variants.

Keywords Ophthalmic artery · Angiography · Anatomy · Embryology

Introduction

The ophthalmic artery is notable for its composite nature and complex development [3, 8]. In the embryo, there are several successive phases involved in the establishment of blood supply to the eye and its adnexa. Several primitive arteries branch off from the intra and supracavernous internal carotid artery and the future anterior cerebral artery, develop for a time, then regress to ultimately yield their territories to the definitive ophthalmic artery.

We report here what is to our knowledge the first observation of a double-supracavernous origin of the ophthalmic artery, involving one branch emerging from the usual position on the internal carotid artery and another from

this latter's terminus, opposite the posterior communicating artery, corresponding to a persistent primitive dorsal ophthalmic artery. Our observation sheds new light on the embryology of the ophthalmic artery and argues in favor of Padgett's description of it.

Observation

A male patient, born in 1969 and having no notable ophthalmic history, was admitted in 1999 for a subarachnoid hemorrhage due to the rupture of an aneurysm on the anterior communicating artery. The aneurysm was treated endovascularly, but bleeding reoccurred in 2013. Over the course of disease, the patient had several angiographies, but it was a 3D acquisition taken in 2018 that finally enabled the discovery of two arteries supplying the orbit from the supracavernous internal carotid artery. The finer artery emerged from the anteromedial face of the terminal segment opposite the bifurcation of the posterior communicating artery, passed through the optic canal inferior to the optic nerve (Fig. 1a, b, c), and branched into the lateral long posterior ciliary artery and the central retinal artery (Fig. 2a, b). The more voluminous artery emerged from the usual ophthalmic level—but

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Fig. 1 Axial 3D-angiography of the internal carotid artery. **a** Axial 3D maximal intensity projection (MIP) reconstruction. Thick-slice axial (**b**), oblique sagittal (**c**) and oblique coronal (**d**) multiplanar reconstructions show the persistent primitive dorsal ophthalmic artery (arrowheads) emerging from the anteromedial face of the terminus of the internal carotid artery and passing through the optic canal inferior to the optic nerve, and the “principal” orbital artery emerging from the lateral face of the internal carotid artery and passing through the superior orbital fissure under the anterior clinoid process (arrow) to join the orbit

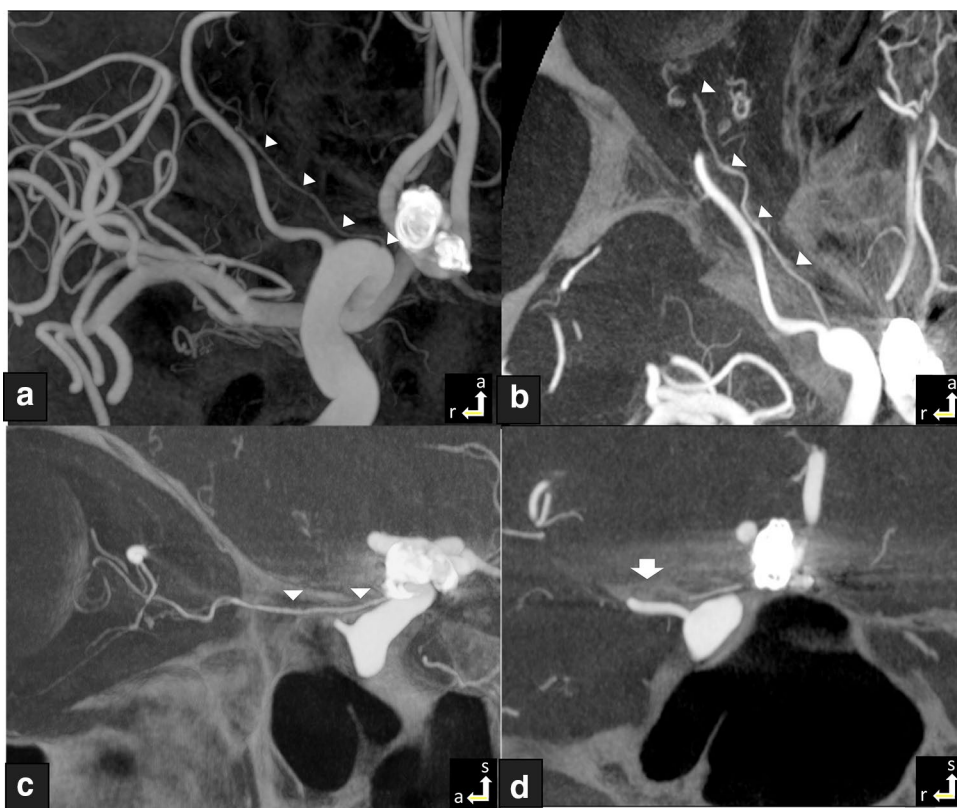


Fig. 2 Oblique sagittal reconstructions (**a, b**) show the path of the persistent primitive dorsal ophthalmic artery furnishing the lateral long posterior ciliary artery (double arrowhead) and the central retinal artery (arrowhead). Thick-slice axial (**c**) and sagittal (**d**) reconstructions show the principal orbital artery furnishing the muscular (m: inferior muscular artery), ethmoidal (e: anterior ethmoidal artery), nasal and frontal branches as well as the medial long posterior ciliary artery (arrow)



from the anterolateral face—of the internal carotid artery, passed through the most medial part of the superior orbital fissure (Fig. 1b, d) and into the orbit to furnish the muscular, lacrimal and ethmoidal arteries and the medial long posterior ciliary artery (Fig. 2c, d).

No intra- or extra-orbital anastomoses were visible between these two arteries.

Discussion

In the embryo, two contingencies must merge to ensure blood supply to the orbital content by the ophthalmic artery. The contingency for the “orbital” elements (muscles, lacrimal gland, etc.) comes from the upper division of the embryonic stapedial artery (future middle meningeal artery). The contingency for the “ocular” elements (neurosensory; retina, optic nerve, etc.) comes from the internal carotid artery or its branches and furthermore changes with growth.

According to Padget [7] and Moffat [6], orbital vascularization in the embryo proceeds as follows.

In the 4- to 6-mm embryo (Fig. 3a), the optic vesicle is supplied by the lateral branch of the primitive internal maxillary artery (the medial branch of that artery supplies the Rathke’s pouch region).

The primitive olfactory artery, a branch of the cranial division of the internal carotid artery, gives rise to the cortical branches of the future anterior cerebral artery. It also transiently provides a small number of branches to the network of arteries at the base of the optic vesicle.

During this stage of embryonic growth, the primitive dorsal ophthalmic artery will quickly develop from the terminus of the internal carotid artery, passing thereafter through the future optic canal to join the optic vesicle (Fig. 3b). It gives rise to the embryonic hyaloid artery (which ultimately provides the future central retinal artery) and the embryonic temporal (or lateral) ciliary artery.

In the 7- to 12-mm embryo (Fig. 3c), the primitive ventral ophthalmic artery develops from the internal carotid artery opposite the anterior choroidal artery and furnishes the embryonic nasal (or medial) ciliary artery.

In the 16- to 18-mm embryo (Fig. 3d), these primitive dorsal and ventral ophthalmic arteries anastomose alongside the optic nerve.

In the 18- to 24-mm embryo (Fig. 3e), the trunk of the ophthalmic artery appears in its definitive position. The proximal segments of the primitive arteries regress and the distal segments join the trunk of the definitive ophthalmic artery.

In the 20-mm embryo, the orbital branch of the stapedial artery passes through the superior orbital fissure and joins the peri-optic anastomosis of the primitive ophthalmic

arteries to form a peri-optic ring from which emerge all collateral branches of the ophthalmic artery.

In our patient, we observed one very thin artery emerging from the terminal segment of the internal carotid artery, passing through the optic canal and branching into the central retinal artery and the lateral long posterior ciliary artery. This artery thus corresponded to a persistent primitive dorsal ophthalmic artery.

We also observed a second more voluminous artery reflecting the “orbital” contingency of the embryonic stapedial artery and the embryonic nasal ciliary artery, this latter being furnished by the primitive ventral ophthalmic artery. Thus, these embryonic stapedial and nasal ciliary arteries anastomosed during embryonic development. In contrast, anastomosis with the primitive dorsal ophthalmic artery did not occur or regressed.

The initial segment of this second unusual artery raises several questions. Since it passed through the superior orbital fissure, it can be neither a persistent primitive ventral ophthalmic artery nor the initial segment of the definitive ophthalmic artery. The passage through the superior orbital fissure suggests instead the upper (supraorbital) division of the embryonic stapedial artery, which, in adults, normally becomes the orbital branches of the middle meningeal artery. In our patient, the more voluminous artery emerged from the internal carotid artery’s lateral face, whereas the ophthalmic artery normally emerges from its medial face. Thus, was this a case of a secondary extra-orbital anastomosis? Hayreh [2] reported a case of an ophthalmic artery emerging from the internal carotid artery and passing through the superior orbital fissure, but supplied no in-depth discussion of it.

The embryology of the ophthalmic artery and the emergence of the primitive ophthalmic arteries remain controversial. Padget [7] and Moffat [6] described the primitive dorsal and ventral ophthalmic arteries as branching, respectively, from opposite the posterior communicating artery and from opposite the anterior choroidal artery with a passage through the optic canal, whereas Lasjaunias [5] stated that the primitive dorsal ophthalmic artery branches from the intracavernous carotid, with a passage through the superior orbital fissure. According to Lasjaunias, the emergence of an artery opposite the anterior choroidal artery is an intermediate step in the “migration” of the primitive ventral ophthalmic artery (which originates from the anterior cerebral artery) along the internal carotid artery and ultimately to its definitive position.

Our observation of two persistent arteries, one of which corresponded to Padget’s description of the initial primitive dorsal ophthalmic artery, lends credence to that author’s narrative, as well as to Komiyama’s “revived embryology” of the ophthalmic artery [4], recently revisited by Gregg [1].

Variations in the origin of the ophthalmic artery are numerous but infrequent. Rarely, it may branch from the

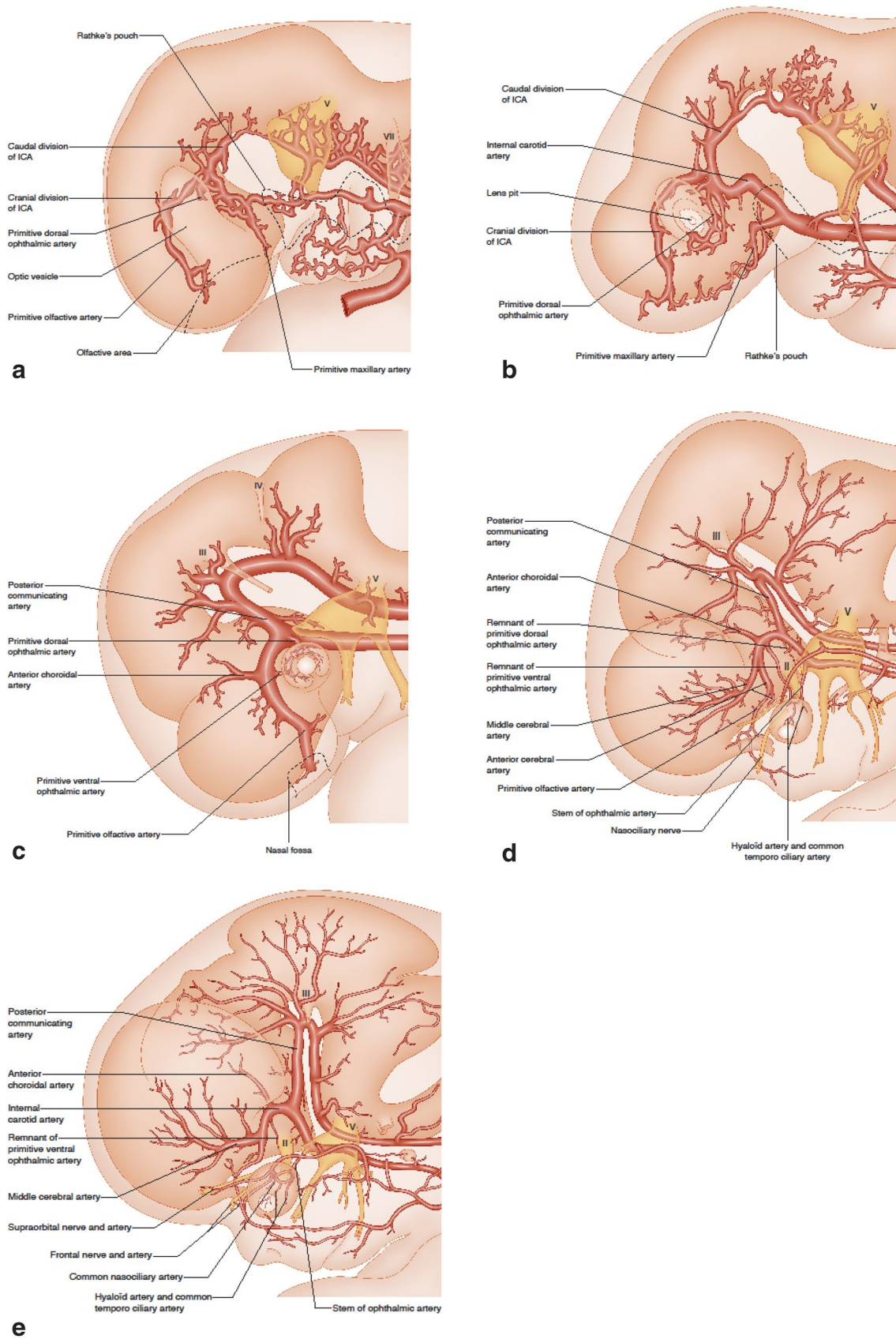


Fig. 3 Orbital vascularization in embryo. Schematic representation adapted from Padgett [7]. **a** Stage 1: 4-mm embryo. **b** Stage 2: 5- to 6-mm embryo. **c** Stage 3: 9-mm embryo. **d** Stage 5: 18-mm embryo. **e** Stage 6: 24-mm embryo

anterior cerebral artery or the intra or distal supracavernous internal carotid artery. Rarer still, it may show a double origin, from both the intra and supracavernous segments. The emergence of the ophthalmic artery from the internal carotid artery opposite the posterior communicating artery has been reported on rare occasions, but always as a unique vessel furnishing all orbital vascularization. In contrast, the persistent artery emerging from that location in our case was very fine and paired with a second, more voluminous artery. To our knowledge, our case is the first of its kind to be reported in the literature. Such fine arterial variants may very well be frequent, but difficult to demonstrate. Ours was indeed not visible on simple 2D angiographies due to its small diameter and other overlying vessels on lateral views. Multiplanar reconstructions of 3D angiography data make it possible to visualize the trajectories of very fine arteries despite the presence of overlying vessels and thus diagnose rare, but embryologically predictable arterial variants.

Author contributions SB: data analysis, manuscript writing. LL: data collection, data analysis. FZ: data collection, data analysis. BG: data analysis. RA: data analysis, manuscript writing. MB: data analysis, manuscript writing.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflicts of interest directly or indirectly related to the research.

Research involving human participants and/or animals There was no use of animals for the present article by any of the authors.

Informed consent Informed consent was obtained from the patient for the use of his data in the present article.

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