Accurate Course and Relatıonships of the Intraorbital Part of the Ophthalmıc Artery in the Sagittal Plane

Author S. Erdogmus, F. Govsa

Affiliation Department of Anatomy, Faculty of Medicine, Ege University, Izmir, Turkey

Key words
- ophthalmic artery
- orbit
- microsurgical approach
- lacrimal artery
- anterior ethmoidal artery
- central retinal artery
- posterior ciliary artery
- muscular branches

Abstract

Introduction: Knowledge of variations in the course and distribution of the intraorbital part of ophthalmic artery (OA) is necessary for the diagnosis and treatment of anterior cranial and orbital disorders.
Material: 38 human cadaver dissections to demonstrate the microsurgical anatomy of the intraorbital part of the OA were studied in three stages, considering its neighbourhood with the optic nerve in the sagittal plane.
Results: The first part of the OA was located on the inferolateral aspect of the optic nerve in 89.47 %. The diameter and the length of the first part of the OA were 1.69 ± 0.34 mm and 7.58 ± 0.89 mm. 73.68 % of the cases crossed the optic nerve superiorly, and 26.31 % inferiorly. The diameter and length of the second part of the OA were as 1.52 ± 0.29 mm and 4.12 ± 0.85 mm. The diameter and length of the third part of the OA were 1.07 ± 0.18 mm and 4.12 ± 0.85 mm. The first branch of the intraorbital part of the OA was the central retinal artery in 26.31 % of the specimens.
Conclusion: A better understanding of the vascular anatomy of the orbit should allow for the modification of surgical techniques to reduce bleeding during biopsy or excision of orbital structures.

Introductıon

The ophthalmic artery (OA) is important with its contribution to feeding the orbital and ocular structures [1]. The ophthalmic artery has the following branches: central retinal artery, lacrimal artery, muscular branches, posterior ciliary arteries, supraorbital artery, posterior ethmoidal artery, anterior ethmoidal artery, meningeal branch, medial palpebral arteries, supratrochlear artery, and dorsal nasal artery [2–7]. Most authors have described the ophthalmic artery as having several anastomoses with branches of the external carotid artery, e.g., the middle meningeal with the recurrent meningeal, the facial with the frontal or dorsal nasal, and the superficial temporal with the supraorbital artery [8–10]. In this way, a sideways connection of the internal carotid artery with the external carotid artery is complete.

Different clinical problems may require a surgical approach to the orbit, e.g., fracture of the orbit, tumor of the orbital, diplopias, extraocular muscle resection and bleeding of aneurysms [11, 12]. It is necessary to be familiar with the variations in the course of the ophthalmic artery and its branches for evaluating and treating various orbital disorders, especially those of vascular origin [5–7, 13–15]. Unexpected bleeding in the orbit may result in intraoperative haematoma and swelling. The intraoperative swelling along the designed double-eyelid line or temporary ptosis may prevent surgeons from taking an accurate measurement of the height of this fold.

Several anatomic studies have described in detail the diameter of the artery, but without a limited description of its topoanatomic relations to the adjacent structures within the orbit [3, 16]. In the present study we investigated the microsurgical anatomy of the intraorbital part of the OA and its relation to the optic nerve in the sagittal layer.

Material and Methods

For this study, dissection was performed on 19 adult male cadavers (total of 38 orbits) with no macroscopic pathologies of the head or orbital regions. They had been fixed with 10 % formalin in the Department of Anatomy, Faculty of Medi-

Bibliography
DOI 10.1055/s-2007-985862
Minim Invas Neurosurg 2007; 50: 1–7

ISSN 0946-7211

Correspondence
Prof. Dr. F. Govsa
Ege Üniversitesi
Tıp Fakültesi Anatomi Anabilim Dalı
35100 Izmir
Turkey
Tel.: + 90/232/390 33 66
Fax: + 90/232/339 35 46
fgovsa@yahoo.com or
figen.govsa@ege.edu.tr

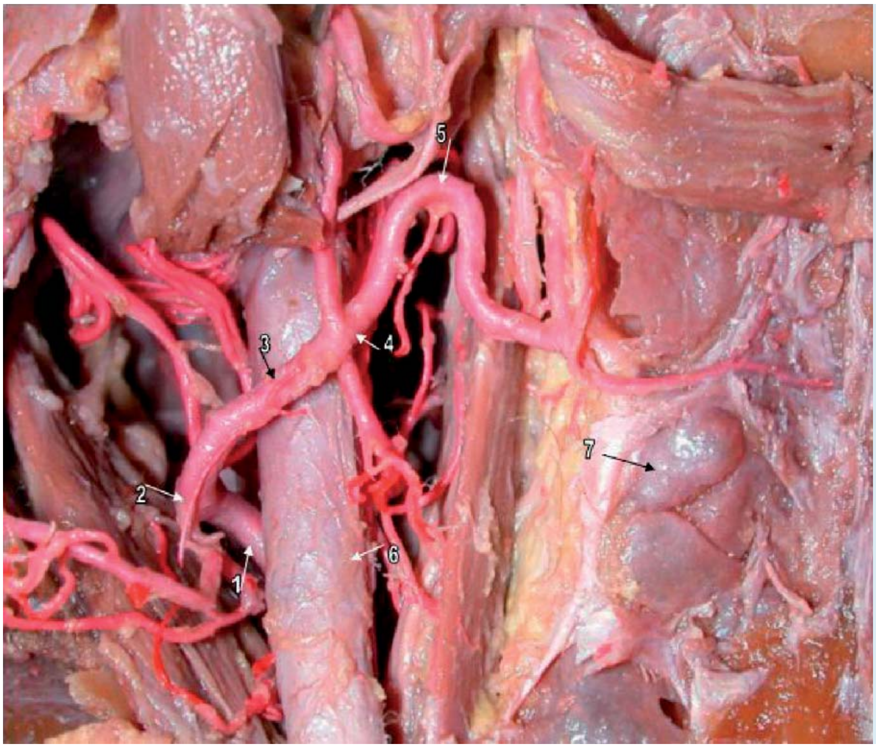

Fig. 1 . Intraorbital course of the ophthalmic artery (OA). 1 = first part of the OA, 2 = angle of the OA, 3 = second part of the OA, 4 = bend of the OA, 5 = third part of the OA, 6 = optic nerve.

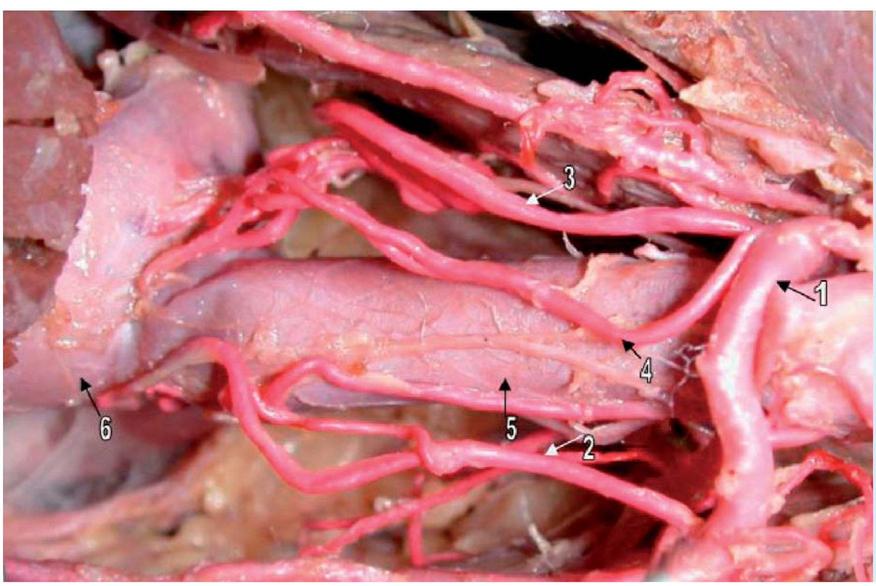

Fig. 2 Photo showing the posterior ciliary arteries (PCA) in relation to the optic nerve. 1 = ophthalmic artery, 2 = medial PCA, 3 = lateral PCA, 4 = superior PCA, 5 = optic nerve, 6 = eyeball.

cine, Ege University. The skulls were opened and the brains removed, in order to define better and investigate in detail the OA and its branches. Liquid latex neoprene 601 A mixture coloured with powder eosin paint was injected through the internal carotid artery before the dissection.

Dissection was carried out by the superior approach following collapse of the roof of the orbit. The orbital part of the frontal bone was removed by careful dissection, thus enabling visualisation of the orbital structures. Firstly, the supraorbital, posterior and anterior ethmoidal arteries hidden within the fatty tissue between the superior oblique and levator palpebrae superioris muscles became visible. To visualise the deeper structures, it was necessary to cut and pull forward the frontal nerve and the supraorbital artery. A medial cut through the muscular body was performed in the levator palpebrae superioris and superior rectus muscles followed by distraction forward and backward.

By means of a high-speed drill, the bony walls of the optic canal were removed. After removal of the bony walls and the connective fatty tissue of the orbit, the intraorbital part of the OA was studied. In the course of the dissection of each orbit, the origin, position, branches, course and anatomic relations of the intraorbital branches of the OA were carefully noted. Measurements were carried out by means of a digital callipre in millimetres. Student's t-test was applied to the data for statistical analysis. The findings were recorded by a digital camera.

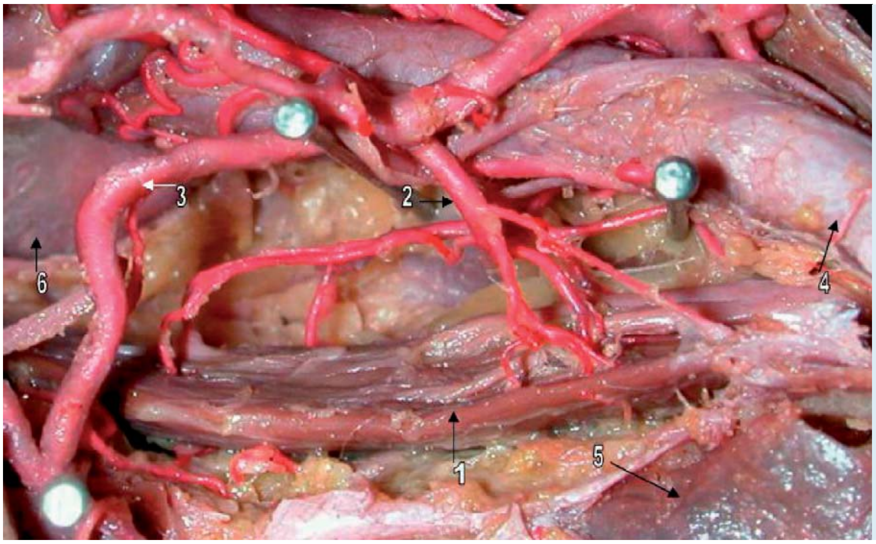

Fig. 3 The medial rectus is supplied by the inferomedial muscular trunk and ophthalmic artery. 1 = medial rectus, 2 = inferomedial muscular trunk, 3 = ophthalmic artery, 4 = optic nerve, 5 = ethmoid cells, 6 = eyeball.

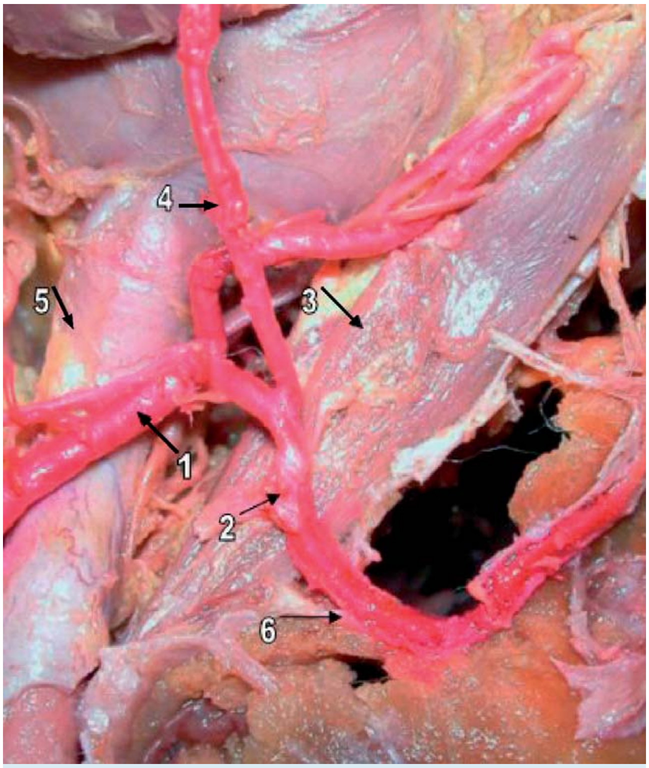

Fig. 4 The trunk of the posterior ethmoidal and the supraorbital arteries originating from the bend of the ophthalmic artery. 1 = ophthalmic artery, 2 = posterior ethmoidal artery, 3 = superior oblique muscle, 4 = supraorbital artery, 5 = optic nerve, 6 = posterior ethmoidal canal.

Results

The course of the intraorbital part of the ophthalmic artery (OA) was macroscopically studied in three stages, considering its neighbourhood with the optic nerve in the sagittal plane. The first part, from the point where the OA entered the orbit to the curving point serving as the beginning of the second part: the first part lay very close to with the optic nerve, free of orbital fat. In the first layer of the orbit, the intraorbital course of the OA was straight in most of the specimens. This part usually ran along the inferolateral aspect of the optic nerve. The second part of the intraorbital course of the OA began where the artery approached the lateral side of the optic nerve and started to cross over it at a right, acute, or obtuse angle. The point where the artery changed direction and shape presented the end-point of the second part of the intraorbital segment. The second part coursed towards the superomedial part from the inferolateral part of the optic nerve, crossing the optic nerve from either superiorly or inferiorly. The third part of the intraorbital OA stretched from the curving point of the superomedial last section of the second part towards the end of the orbit (**Figs. 1–4**). The third part was located on the medial part of the optic nerve and the eyeball, and the lateral part of the superior oblique and the medial rectus muscles reached the medial wall of the orbit close to the anterior ethmoid foramen. It was generally anchored to the medial wall of the orbit by the short stout trunk of the anterior ethmoid artery, and then ran forwards close against the medial wall, passed below the trochlea, and then usually ran upwards and forwards to lie nearly midway between the medial palpebral ligament and the orbital margin. The measurements of the all parts of the OA are given in **Table 1**. The topographical details of the all parts of the OA are given in **Table 2**. There were no significant differences between the diameter and the length parameters of the right and of the left sides ($p>0.05$).

The OA was displaced in two points (**Fig. 1**): the first of these was the connection point of the first and second parts, defined as "angle", and the second one was the connection point of the second and third parts, defined as "bend" [1]. The angle was well defined and observed to be obtuse. The bend was clear enough but was not as well-defined as the angle.

The first branch of the intraorbital part of the OA was the central retinal artery in 26.31 %, the central retinal and medial posterior ciliary arteries in 21.05 % on the right. The number and percentage of origin of the first branch of the intraorbital part of the OA are summarized in **Table 3**.

Central retinal artery (CRA)

In all cases, the central retinal artery originated from the OA. The CRA was observed to be a single branch (57.89 %) and trunk (42.11 %) on the right. On the left, the source of the arterial supply was the same, including a single branch (52.63 %), and trunk (47.37 %). Bilaterally, in 42.11 % of the cases, the CRA was observed to be symmetrical. The topographical data of the CRA are shown

Table 1 Measurements of the intraorbital parts of the ophthalmic artery (mm) ($p > 0.05$)

Part	Diameter Mean ± mm (min-max)		Length Mean ± mm (min-max)	
	Right side	Left side	Right side	Left side
first part	1.69 ± 0.34 (0.84–2.02)	1.64 ± 0.36 (1.01–2.15)	7.58 ± 0.89 (5.79–8.92)	7.49 ± 0.84 (5.71–8.65)
second part	1.52 ± 0.29 (0.84–1.97)	1.57 ± 0.26 (1.42–1.94)	4.12 ± 0.85 (1.98–5.54)	4.12 ± 0.89 (1.87–5.25)
third part	1.07 ± 0.18 (0.76–1.58)	1.09 ± 0.17 (0.70–1.42)	6.47 ± 1.07 (4.98–8.02)	6.53 ± 1.00 (4.95–8.02)

Table 2 Site of origin of branches from ophthalmic artery (OA) in relation to the optic nerve ($p > 0.05$)

Vessel	Over optic nerve			Under optic nerve		
	Number – incidence (n– %)		Branches	Number–incidence (n– %)		Branches
	Right	Left		Right	Left	
first OA	9–47.4	9–47.4	CRA	1–5.3	1–5.3	CRA
	2–10.5	3–15.8	MPCA	3–15.8	2–10.6	LPCA
	3–15.8	4–21.	LPCA	1–5.3	2–10.5	LA
	1–5.3	3–15. 8	LA	1–5.3	1–5.3	IMMT
	–	1–5.3	IMMT			
angle OA	5–26.3	7–36.8	CRA	1–5.3	1–5.3	LPCA
	5–26.3	3–15.8	MPCA	1–5.3	1–5.3	ILMT
	11–57.9	12–63.1	LPCA			
	3–50	2–40	SPCA			
	11–57.9	10–52.6	LA			
	2–10.5	3–15.8	ILMT			
second OA	1–16.7	–	SPCA	3–15.8	2–10.5	CRA
	1–5.3	–	PEA	1–5.3	–	LPCA
	3–15.8	1–5.3	IMMT	1–16.7	–	SPCA
				–	1–5.3	PEA
				2–10.5	–	IMMT
bend OA	7–36.8	9–47.34	MPCA	1–5.26	1–5.3	CRA
	1–16.7	2–40	SPCA	3–15.78	1–5.3	MPCA
	1–5.3	2–10.5	LA	–	1–20	SPCA
	11–57.9	14–73.7	SOA	4–21.1	1–5.3	LA
	12–63.1	15–78.9	PEA	5–26.3	3–15.8	SOA
	10–52.6	14–73.7	IMMT	5–26.3	3–15.8	PEA
	12–63.2	14–73.7	AEA	2–10.5	2–10.5	IMMT
				4–21.1	2–10.5	AEA
third OA	–	1–5.3	MPCA	2–10.3	2–10.5	MPCA
	2–10.5	2–10.5	SOA	1–5.3	1–5.3	AEA
	1–5.3	1–5.26	PEA			
	1–5.3	1–5.26	AEA			
LA	8–42.1	10–52.6	ILMT	2–10.5	1–5.3	ILMT
PCA	5–26.3	2–10.5	ILMT	2–10.5	–	ILMT
	1–5.3	–	IMMT			

OA = ophthalmic artery; CRA = central retinal artery; MPCA = medial posterior ciliary artery; LPCA = lateral posterior ciliary artery; SPCA = superior posterior ciliary artery; LA = lacrimal artery; ILMT = inferolateral muscular trunk; IMMT = inferomedial muscular trunk; SOA = supraorbital artery; PEA = posterior ethmoidal artery; AEA = anterior ethmoidal artery

in **Tables 2, 4**. There were no significant differences between the vascular diameters of the right and left sides ($p>0.05$).

Posterior ciliary arteries (PCA)

The PCA ran forward to the optic nerve medially, laterally, or superiorly (**Fig. 2**). When the branching type of the PCA was investigated, it was observed that 63.15 % of the cases on the right demonstrated a pattern of branching as 1 medial and 1 lateral, and 36.84 % had 1 medial, 1 lateral and 1 superior PCA. In 73.68 % of the cases on the left, a branching type of 1 medial and 1 lateral PCA, and in 26.31 % 1 medial, 1 lateral and 1 superior PCA were observed. Bilaterally, in 57.89 % 1 lateral and 1 medial PCA, and in 21.05 % 1 lateral, 1 medial and 1 superior PCA branches divided symmetrically. The data for the medial PCA, lateral PCA and superior PCA are demonstrated in **Tables 2, 4**. There were no significant differences between the vascular diameters of the right and left sides in any subject ($p>0.05$).

Lacrimal artery

The details of the lacrimal artery are shown in **Tables 2, 4**. The outer diameter of the lacrimal artery is given in **Table 4**. There were no significant differences between the vascular diameters of the right and the left sides in any subject ($p>0.05$). In 68.42 % of the cases on the right and in 52.63 % of the cases on the left, the lacrimal artery was present and the lacrimal nerve was seen in a superolateral position with respect to the origin of the artery. The recurrent meningeal branch was seen in 6 cases on the right, and in 5 on the left. On the right, of the 6 cases, 2 passed through the meningo-orbital foramen and 4 passed through the superior orbital fissure and entered the middle cranial fossa. On the left, of the 5 cases, 2 passed through the meningo-orbital foramen and 3 passed through the superior orbital fissure and entered the middle cranial fossa. In this case, the lacrimal gland was the site of an intraorbital anastomosis between internal and external carotid systems.

Supraorbital artery

The supraorbital artery was observed as a single branch (84.22 %), and a trunk (15.78 %) on the right. On the left, the source of the arterial supply was the same, including a single branch (84.21 %), and a trunk (15.78 %) (**Fig. 4**). The topographical details of the supraorbital artery are given in **Tables 2, 4**. There were no significant differences between the vascular diameters of the right and the left sides in any subject ($p>0.05$).

Muscular branches

In all cases, the muscular branches originated from the OA, and generally from the inferior face of it, just after crossing the optic nerve (**Fig. 3**). The inferomedial muscular trunk arose from the second part of the OA (63.16 %) and the inferolateral muscular trunk arose from the lacrimal artery (43.36 %). The data for the inferolateral and inferomedial muscular trunks are given in **Tables 2, 4**. There were no significant differences between the vascular diameters of the right and left sides in any subject ($p>0.05$).

Posterior ethmoidal artery (PEA)

The PEA was observed in all cases (**Fig. 4**). The anatomic details of the PEA are given in **Tables 2, 4**. The diameter of the intracranial part of the PEA was measured as 0.45 ± 0.12 mm (range: 0.32–0.57). No significant differences between the vascular diameters of the right and left sides ($p>0.05$).

Anterior ethmoidal artery (AEA)

Bilaterally, in 94.73 % of the cases, the AEA was observed to be symmetrical and in the form of a single branch. Mostly, the AEA was thicker than the PEA. The data for the AEA are summarized in **Tables 2, 4**. There were no significant differences between the vascular diameters of the right and left sides in any subject ($p>0.05$).

Discussion

Visual and neurological deficits may arise from inflammatory processes (infectious lesions, orbital pseudotumour), vascular lesions (aneurysms, thrombosis of orbital veins) and neoplastic lesions (meningioma) in the orbit [12, 17, 18]. Lesions in orbit present with different neuro-ophthalmic symptoms and signs, depending on their sizes and locations. The ocular ischaemic syndrome effects of hypoperfusion of the globe are useful models studying disorders of the orbital circulation [19, 20]. Recent advances in orbital ultrasound techniques have provided a non-invasive method of examining flow velocities in the orbital vessels, particularly the OA [21–23]. Microanatomic knowledge of the complex bony, dural, vascular and neural relationship of the origin of the OA is necessary for the diagnosis and important for the treatment of orbital disorders and aneurysms. Regarding the direction of the origin of the OA from superior wall of the internal carotid artery were located in the medial third 71–79 % of the cases, the central third in 16–21 % of the cases and lateral third in 5.3 % [9, 24]. The OA originated from the intradural portion of internal carotid artery in 95 %, and extradural 5 % (**Fig. 5**). The intraorbital part of the OA and its three segments are well shown on the lateral projection of the injections of the internal carotid artery, and may supply various types of dural lesions, sphenoid and ethmoid tumours, or dural arteriovenous fistulae through OA deep or superficial recurrent or ethmoidodural branches [25]. Mittra et al. demonstrated that blood flow velocities in the OA, the PCA and CRA arteries were significantly lower compared with those of a healthy age-matched group [26]. The vascularisation of the dural convexity and related lesions, including meningiomas, may be provided by the system of the OA through different anomalous meningeal vessels [27–29]. Meningiomas of the brain convexity supplying anomalous meningeal vessels

Table 3 Incidence of the first branch of the intraorbital part of the OA ($p > 0.05$)

The first branch	Right side n - (%)	Left side n - (%)	Bilaterally n - (%)
CRA	5–26.3	9–47.4	5–26.3
CRA + MPCA	4–21.1	5–26.3	3–15.8
LPCA	3–15.8	2–10.6	1–5.3
RNB	2–10.5	1–5.3	1–5.3
CRA + MPCA + IMMT	2–10.5	1–5.3	1–5.3
LA	2–10.5	–	–
CRA + LPCA + SOMA	1–5.3	–	–
CRA + IMMT + LPCA	1–5.3	–	–

CRA = central retinal artery; MPCA = medial posterior ciliary artery; LPCA = lateral posterior ciliary artery; SOMA = superior oblique muscle artery; RNB = recurrent meningeal branch; LA = lacrimal artery; IMMT = inferomedial muscular trunk

Table 4 Diameter of the intraorbital branches of the OA (mm) ($p > 0.05$)

Branches	Right side Mean ± mm (min-max)	Left side Mean ± mm (min–max)
central retinal artery	0.64 ± 0.12 (0.49–0.87)	0.58 ± 0.2 (0.41–0.9)
lateral posterior ciliary artery	0.68 ± 0.09 (0.52–0.82)	0.67 ± 0.14 (0.43–0.78)
medial posterior ciliary artery	0.65 ± 0.12 (0.43–0.97)	0.65 ± 0.14 (0.41–0.90)
superior posterior ciliary artery	0.48 ± 0.11 (0.34–0.65)	0.54 ± 0.09 (0.42–0.67)
lacrimal artery	1.02 ± 0.17 (0.74–1.37)	1.03 ± 0.16 (0.72–1.38)
supraorbital artery	0.82 ± 0.18 (0.56–1.17)	0.83 ± 0.17 (0.58–1.17)
inferolateral muscular trunk	0.63 ± 0.11 (0.41–0.78)	0.63 ± 0.09 (0.44–0.78)
inferomedial muscular trunk	0.66 ± 0.1 (0.47–0.85)	0.67 ± 0.16 (0.41–1.02)
posterior ethmoidal artery	0.66 ± 0.21 (0.32–1.0)	0.63 ± 0.19 (0.33–0.98)
anterior ethmoidal artery	0.92 ± 0.2 (0.52–1.46)	0.88 ± 0.15 (0.41–1.02)

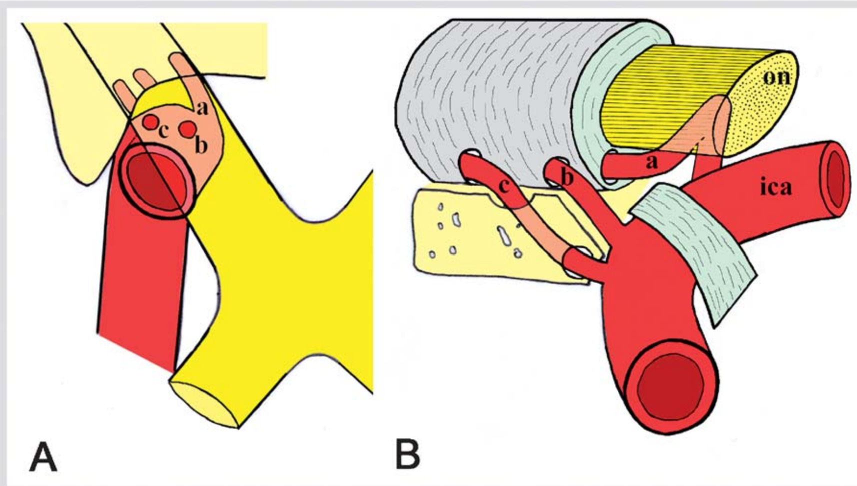

Fig. 5 Schematic drawing of **A** origin (a medial, b central, c lateral) and **B** classification (a intradural type, b extradural supraoptic strut type, c extradural transoptic strut type) of the ophthalmic artery. on = optic nerve, ica = internal carotid artery.

of OA origin may pose some problems concerning their possible preoperative endovascular treatment [30,31]. In fact, in these cases preoperative embolisation is dangerous and should be avoided because of the risk of superselective catheterisation of the OA and migration of embolising material into the ophthalmic circle with sudden visual deficits.

Certain anatomic variations of the OA can be understood as a consequence of evolution [32,33]. Embryologically, the OA provides the intraorbital structures while the supraorbital branch of the former stapedial artery provides the supply of the orbital structures. Embryological studies demonstrated various anomalies in the course of the OA by constructing a schematic location of segments of atrophy or under the development of the main trunk of the OA [32,33]. The atrophic segments were the variations of the lacrimal and supraorbital arteries. The authors described three possible locations of the atrophic segments of the artery: a) proximal to the lacrimal artery, b) between the lacrimal and supraorbital arteries; c) distal to the supraorbital artery. According to studies described embryologically, the first part of the OA supplies visual structures, the second part is a anastomotic channel (a complete or incomplete ring, lateral or medial) and the third supplies orbital but non-visual structures. The CRA always comes from the first part of the OA, never after a second segment, whatever variations there may be [1,2,16,33].

This study confirms the well-known variability of the intraorbital part of ophthalmic arterial branches and their relation to the optic nerve. Our data concerning the topographical features support and comply with those of a limited number studies carried out by other researchers. We must also not exclude the possibility that the fixation methods used may have resulted in some narrowing of the arteries, thereby distorting the measurements. Endonasal and neurosurgical operations to the orbit can severely damage some of the branches as well as the main trunk of ophthalmic arteries. It is important to differentiate the intraorbital part of the OA. The surgeon must choose the appropriate surgical technique in an effort to preserve the normal circulation in the orbit. The progress of new methods provides increased possibilities for studying the blood circulation in the orbit, thus emphasising the importance of a detailed knowledge about anatomic variations.

References

1 *Hayreh SS*, *Dass R*. The ophthalmic artery II. Intra-orbital course. Brit J Ophthal 1962; 46: 165–185
2 *Hayreh SS*. The ophthalmic artery III. Branches. Brit J Ophthal 1962; 46: 212–246
3 *Jimenez-Castellanos J*, *Carmona A*, *Castellanos L*, *Catalina-Herrera CJ*. Microsurgical anatomy of the human ophthalmic artery. A mesoscopic study of its origin, course and collateral branches. Surg Radiol Anat 1995; 17: 139–143
4 *Jo-Osvatic A*, *Basic N*, *Jukic T*, *Nikolic V*, *Stimac D*. Topoanatomic relations of the ophthalmic artery viewed in four layers. Surg Radiol Anat 1999; 21: 371–375
5 *Erdogmus S*, *Govsa F*. Importance of the anatomic features of the lacrimal artery for orbital approaches. J Craniofac Surg 2005; 16: 957–964
6 *Erdogmus S*, *Govsa F*. Topography of the posterior arteries supplying the eye and relations to the optic nerve. Acta Ophthalmol Scand 2006; 84: 642–649
7 *Erdogmus S*, *Govsa F*. The anatomic landmarks of ethmoidal arteries for the surgical approaches. J Craniofac Surg 2006; 17: 280–285
8 *Berthelot JL*, *Hureau J*. Clinical anatomical study of the macroscopic anastomoses of the ophthalmic artery in the periorbital region. Anat Clin 1987; 3: 271–278
9 *Lang J*, *Kageyama I*. The ophthalmic artery and its branches, measurements and clinical importance. Surg Radiol Anat 1990; 12: 83–90
10 *Kerty E*. The ophthalmology of internal carotid artery dissection. Acta Ophthalmol Scand 1999; 77: 418–421
11 *Natori Y*, *Rhoton Jr AL*. Transcranial approach to the orbit: microsurgical anatomy. J Neurosurg 1994; 81: 78–86
12 *Lee WC*, *Ku PKM*, *Hasselt AC Von*. New guidelines for endoscopic localization of the anterior ethmoidal artery: A cadaveric study. Laryngoscope 2000; 110: 1173–1178
13 *Santis M De*, *Anderson KJ*, *King DW*, *Nielson J*. Variability in relationships of arteries and nerves in the human orbit. Anat Anz 1984; 157: 227–231
14 *Duccase A*, *Delattre JF*, *Segal A*, *Desphieux JL*, *Flament JB*. Anatomical basis of the surgical approach to the medial wall of the orbit. Anat Clin 1985; 7: 15–21
15 *Couch JM*, *Somers ME*, *Gonzalez C*. Superior oblique muscle dysfunction following anterior ethmoidal artery ligation for epistaxis. Arch Ophthalmol 1990; 108: 1110–1113
16 *Govsa F*, *Erturk M*, *Kayalioglu G*, *Pinar Y*, *Ozer M A*, *Ozgur T*. Neuroarterial relations in the region of the optic canal. Surg Radiol Anat 1999; 21: 329–335
17 *Forbes G*. Vascular lesions in the orbit. Neuroimaging Clin N Am 1996; 6: 113–122
18 *Sato S*, *Suga S*, *Ohira T*, *Takayama H*, *Kawase T*. Aneurysm of the ophthalmic artery trunk. Acta Neurochir (Wien) 1999; 141: 321–322
19 *Lieb WE*, *Flaharty PM*, *Ho A*, *Sergott RC*. Color Doppler imaging of the eye and orbit. A synopsis of a 400 case experience. Acta Ophthalmol Suppl 1992; 204): 50–54
20 *Martini E*, *Guiducci M*, *Campi L*, *Cavallini GM*. Ocular blood flow evaluation in injured and healthy fellow eyes. Eur J Ophthalmol 2005; 15: 48–55

21 *Ettl A*, *Salomonowitz E*, *Koornneef L*, *Zonneveld FW*. High-resolution MR imaging anatomy of the orbit. Correlation with comparative cryosectional anatomy. Radiol Clin North Am 1998; 36: 1021–1045
22 *Ettl A*, *Zwrtek K*, *Daxer A*, *Salomonowitz E*. Anatomy of the orbital apex and cavernous sinus on high-resolution magnetic resonance images. Surv Ophthalmol 2000; 44: 303–323
23 *Aviv RI*, *Casselman J*. Orbital imaging: Part 1. Normal anatomy. Clin Radiol 2005; 60: 279–287
24 *Erdogmus S*, *Govsa F*. Anatomic features of the intracranial and intracanalicular portions of ophthalmic artery: for the surgical procedures. Neurosurg Rev 2006; 29: 213–218
25 *Maillot CI*, *Froelich S*, *Kehrli P*. Ophthalmic artery, optic nerve and meninges: reciprocal relations. J Neuroradiol 2000; 27: 93–100
26 *Mittra RA*, *Sergott RC*, *Flaharty PM*, *Lieb WE*, *Savino PJ*, *Bosley TM*, *Hedges Jr TR*. Optic nerve decompression improves hemodynamic parameters in papilledema. Ophthalmology 1993; 100: 987–997
27 *Liu Q*, *Rhoton Jr AL*. Middle meningeal origin of the ophthalmic artery. Neurosurgery 2001; 49: 401–407
28 *Kikuchi K*, *Kowada M*. Case report: saccular aneurysm of the intraorbital ophthalmic artery. Br J Radiol 1994; 67: 1134–1135
29 *Kleinschmidt A*, *Sullivan TJ*, *Mitchell K*. Intraorbital ophthalmic artery aneurysms. Clin Experiment Ophthalmol 2004; 32: 112–114
30 *Maiuri F*, *Donzelli R*, *Divitiis O de*, *Fusco M*, *Briganti F*. Anomalous meningeal branches of the ophthalmic artery feeding meningiomas of the brain convexity. Surg Radiol Anat 1998; 20: 279–284
31 *Batista LL*. Intraorbital ophthalmic artery aneurysm. Neuroradiology 2003; 45: 335–336
32 *Pretterklieber ML*, *Schindler A*, *Krammer EB*. Unilateral persistence of the dorsal ophthalmic artery in man. Acta Anat (Basel) 1994; 149: 300–305
33 *Sudakevitch T*. The variation in the system of the trunks of the posterior ciliary arteries. Br J Ophthal 1947; 31: 738–760