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Anatomical Study of the Eyeball Arterial Blood Supply in the Adult Donkey (*Equus asinus*)

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Abstract | It is essential to comprehend the donkey's ocular artery supply in order to diagnose and treat eye disorders. In order to assist corrective surgeries, this study identified particular variations in the ocular arteries of donkeys in comparison to other species. Ten healthy adult donkey's cadavers were used. Six of them were injected with heparin into the common carotid artery and they are subsequently washed with a warm saline solution of 0.9%. 60% gum milk latex neoprene, stained with red Rottring ink, was injected in order to examine the artery supply. For radiography, 50 g of lead oxide powder was injected into the other four heads after being dissolved in 100 ml of red gum milk latex. The samples were dissected, and a digital camera with a 5x magnification was utilized to record the fine details of the vessels and their branches. The results revealed that the majority of the blood flow to the donkey's eyes ball was supplied by the external, internal, and infra-orbital arteries. The origin, course, and distribution of the donkey's eye ball's arterial blood supply were also recorded. The anatomical information gathered from this study will be beneficial to veterinary surgeons doing interventional operations on donkeys with eye disorders.

Keywords | Arterial blood supply, Anatomy, Donkey, Eye, Radiography

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INTRODUCTION

The donkey, *Equus asinus,* is a member of the Equidae family and is the primary load carrier in pack transportation (Attia, 2017). The donkey differs slightly from the horse in one particular way: it has bigger, more noticeable eyes. Working donkeys are more likely to experience acute or long-term health issues, with eye issues being particularly prevalent. The primary organ of vision, the eye, is situated in the orbit and is utilized to gather information from our surrounding. Like horses, donkeys graze with their heads down and their backs to the sun, allowing them to see both close and distant objects in the same range of vision (Burnham, 2002). There are many similarities and major variances in the structure of the eyes between horses and donkeys, which reflect their varied evolutionary demands and adaptations.

The external ocular artery, which emerges from the maxillary artery in animals, is the primary source of the eye vascular supply (Sisson and Grossman, 1975; Simoens *et al*.,1996; Dyce *et al*., 2009) in horse. The external ocular artery supplies the ciliary and choroido-retinal arteries with a number of branches, including orbital, bulbar, lacrimal, supraorbital, and big anastomosis branches, to the internal ophthalmic artery (Simoens *et al*., 1996).

The blood supply of the eyes has been documented in a variety of animals, including the buffalo (Beyrami *et al*., 2021), camel (Noor and El-bably, 2018), sheep (Simoens *et al*., 1981), chinchilla (Kuchinka, 2015), giraffe (O'Brien *et al*., 2016), yak (Shao *et al*., 2008), ox (Steven, 1964), horse (Ninomiya and Inomata, 2014), and mouse (Ninomiya and Inomata, 2006). Few literatures have been produced about the donkey's eye.

In equine practice, ocular disorders are commonly diagnosed (El-Tookhy *et al*., 2007; Abu-Seida *et al*., 2021; Wafy *et al*., 2023). In particular, donkeys suffering from ocular disorders are frequently reported. According to El-Tookhy *et al*. (2007) and Wafy *et al*. (2023), the most frequent ocular disorders in donkeys include nasolacrimal gland obstruction, cataract, ocular tumor, corneal laceration, keratitis, and parasitic infestation. Following a review of the veterinary literature, studies on the impact of gender and maturity on the ocular vasculature as well as on documenting normal and abnormal findings from ocular ultrasonography exams performed on donkeys were carried out (El-Tookhy *et al*., 2007; Wafy *et al*., 2021; 2023).

Understanding the donkey's ocular artery supply is critical for future research on eye diagnosis and related clinical procedures. As a result, the origin, course, and distribution of the donkey's eye ball's arterial blood supply were investigated in this study.

MATERIALS AND METHODS

Ten healthy adult donkey's cadavers were obtained from Cairo University's Veterinary Medicine Faculty Morgue in Giza, Egypt. To prevent blood coagulation and blood from lingering in the vessels, six of them were injected with heparin (Cal Heparin 5000 IU) into the common carotid artery and they are subsequently washed with a warm saline solution of 0.9%. After euthanasia, a Nelaton catheter (size 6F to 8F; MA Medical Company) was inserted through the common carotid artery. 60% gum milk latex neoprene, stained with red Rottring ink, was injected in order to examine the artery supply. Before analyzing the arterial arborisation and distribution patterns, the catheter was kept for three to five days at room temperature (25 °C) in a container with 10% formalin solution, 2% phenol, and 1% glycerin to allow the latex to solidify.

For radiography, 50 g of lead oxide powder was injected into the other four heads after being dissolved in 100 ml of red gum milk latex (Frewein and Herbal, 2012). The exposure parameters for x-ray purposes were 15 mA, 55 kV, and 100 cm FFD. The samples were dissected, and a digital camera with a 5x magnification was utilized to record the fine details of the vessels and their branches.

RESULTS AND DISCUSSION

The external ophthalmic artery (Figure 1 and Figure 2A/2) and the infra-orbital artery (Figure 1, Figure 2A/27 and Figure 3/10), which originated from the maxillary artery and provided the majority of the arterial blood supply to the donkey's eyeball. The external carotid artery (Figure 1, Figure 2A/28 and Figure 3/3) was seamlessly extended into *A. Maxillaris* at the *M. pterygoideus* medialis.]

A. Ophthalmica externa

The external ophthalmic artery (Figure 1 and Figure 2A/2) was the main artery of the orbit, which originated from the dorsal artery of the maxillary artery (Figure 1 and Figure 3/4) that passed rostrally, accompanying the optic nerve, to enter the periorbita through the optic canal (Figure 2B/OP). The external ophthalmic artery gave off several branches including the supraorbital artery, lacrimal artery, external ethmoidal arteries, muscular branches, dorsal posterior ciliary artery, lateral long posterior ciliary artery, and anastomosing branch of the internal ophthalmic artery, which distributed along ocular muscles within the orbit.

A. Supraorbitalis

The supraorbital artery (Figure 2K/5) originated from the external ophthalmic artery (Figure 1 and Figure 2A/2). It supplied the dorsal rectus muscle (Figure 2K/DR) by traveling dorso-medially in a zigzag pattern. It then continued dorsally until it reached the supraorbital foramen then it terminated by deep and superficial branches. The deep muscular branch (Figure 2K/5") penetrated the dorsal oblique muscle while the superficial branch (Figure 2K/5') passed rostrally to supply the forehead, the upper eyelid, and the frontal sinus. The supraorbital artery gave off the dorsal anterior ciliary artery (Figure 2K/6) and it anastomosed with the dorsal oblique muscular artery (Figure 2K/11) and external ethmoidal artery (Figure 1 and Figure 2L/10) during its course.

A. Lacrimalis

The lacrimal artery (Figure 2E/8) was a conspicuous, large branch arose from the external ophthalmic artery. It distributed between the lateral and dorsal rectus muscles in a rostro-lateral manner. Along its course, it gave off muscular branches from the lateral rectus muscle (Figure 2O/9) and the muscular branch that supplied the lacrimal gland by passing around its circumference (Figure 2E / LG). Then, it penetrated the lacrimal gland, periorbita, and terminates by two branches: the lateral superior palpebral arteries (Figure 2E/8') and the lateral inferior palpebral arteries (Figure 2E/8"),which supplied the lateral part of the orbit by muscular branches, the skin of frontal region, frontoscatularis muscle, and eyelids (Figure 2B/16). The lacrimal artery anastomosed with the dorsal posterior ciliary artery (Figure 2C/30).

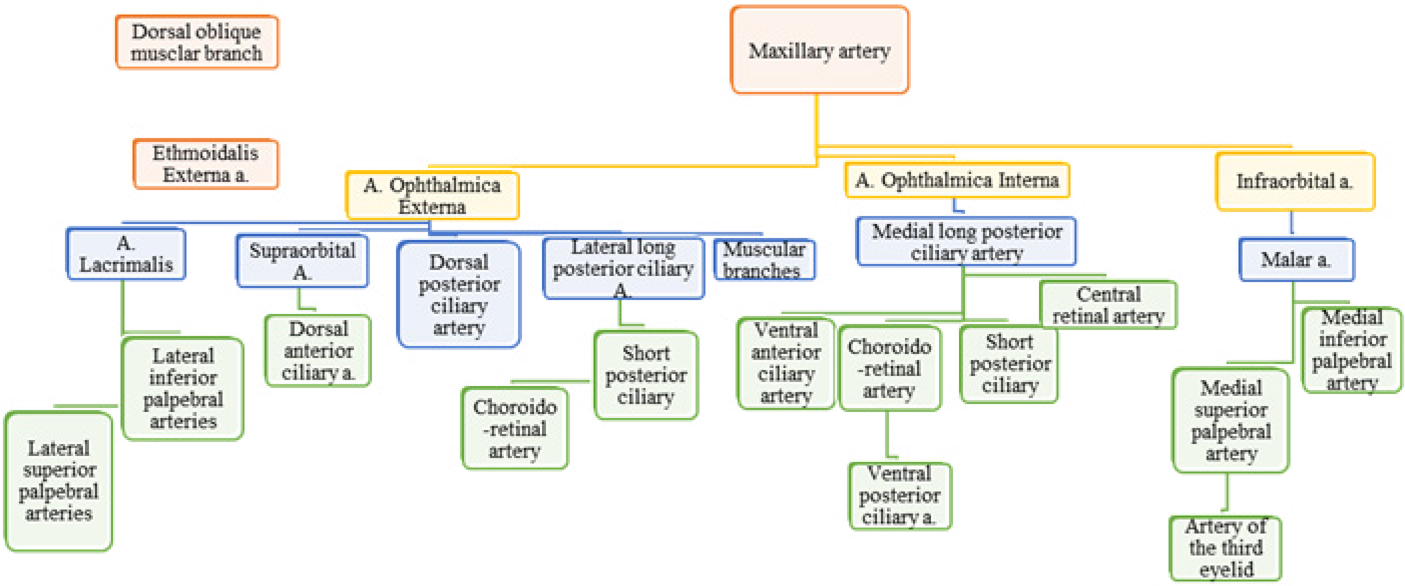

Figure 1: Experimental design showing the sequence of the arterial blood supply of donkey's eye.

Aa. Palpebralis superior lateralis

The lateral superior palpebral artery was situated where the lacrimal artery terminated (Figure 2E/8'). After entering the lacrimal gland, it traveled rostrally through the periobita and entered the superior eyelid. It anastomosed with the malar artery's medial superior palpebral artery (Figure 1 and Figure 2I/24»).

Aa. Palpebralis inferior lateralis

The other termination of the lacrimal artery was the lateral inferior palpebral artery (Figure 2E /8"). It moved in the direction of the inferior eyelid, rosto-laterally. It anastomosed with the malar artery's medial inferior palpebral artery (Figure 2I/24').

A. Ethmoidalis externa

The external ethmoidal artery was the external ophthalmic artery's continuation (Figure 1 and Figure 2L/10). The anterior and posterior ethmoidal arteries (Figure 2C/32, 33) respectively exited the orbit through the ethmoidal foramen to enter the nasal cavity after distributing on the ventral aspect of the ocular muscles to supply the ventral rectus muscle. During its course, it gave branches out to the medial side to supply the lateral border of the dorsal oblique muscle (Figure 2K/11). It anastomosed with the supra-orbital artery (Figure 2K/5).

Ramus muscularis obliquus dorsalis

The dorsal oblique muscular branch (Figure 2K/11) was a long fine muscle branch originating from the external ethmoidal artery (Figure 1 and Figure 2L/10). It supplied the dorsal rectus muscle by passing rostrally at its lateral border and continuing to the dorsal oblique muscle's lateral border (Figure 2C/DO). The supraorbital artery and this artery were anastomosed (Figure 2K/5).

Rami musculares

The lacrimal artery emerged as three to five small muscle branches (Figure 2K/16) that nourish the skin of the frontal region after passing through the periorbita and lacrimal gland. Additionally, tiny branches that came from the ciliary artery (Figure 2F/16) and the external ophthalmic artery (Figure 2C/16) to supply the rectus and retractor oculi muscles. The medial superior and inferior palpebral arteries of the malar artery gave rise to fine branch as well (Figure 2I/16).

A. Ciliares posteriors dorsalis

The dorsal posterior ciliary artery (Figure 2C/ 30) was a large branch that originated from the external ocular artery. It entered the sclera and exits as two to three tiny, short posterior ciliary arteries after passing dorsally and rostrally between the retractor oculi and the dorsal rectus muscle (Figure 2F/14).

Aa. Ciliares posteriors longae lateralis

The lateral long posterior ciliary artery (Figure 2F/15) was a long branch that emerged from the external ophthalmic artery near the medial portion of the optic nerve. It entered the ventral rectus muscle and traveled rostral-medially along the optic nerve between the retractor bulbi before entering the ventral oblique muscles to supply it. Along the way, it produced a muscular branch that supplied the chordioretinal artery (Figure 2F/18), the lateral rectus muscle (Figure 2H/LR) and two to three small short posterior ciliary arteries (Figure 2F/14).

Aa. Ciliares posteriors longae medialis

The medial long posterior ciliary artery (Figure 2F/12) originated from the internal ophthalmic artery (Figure 2N/4)

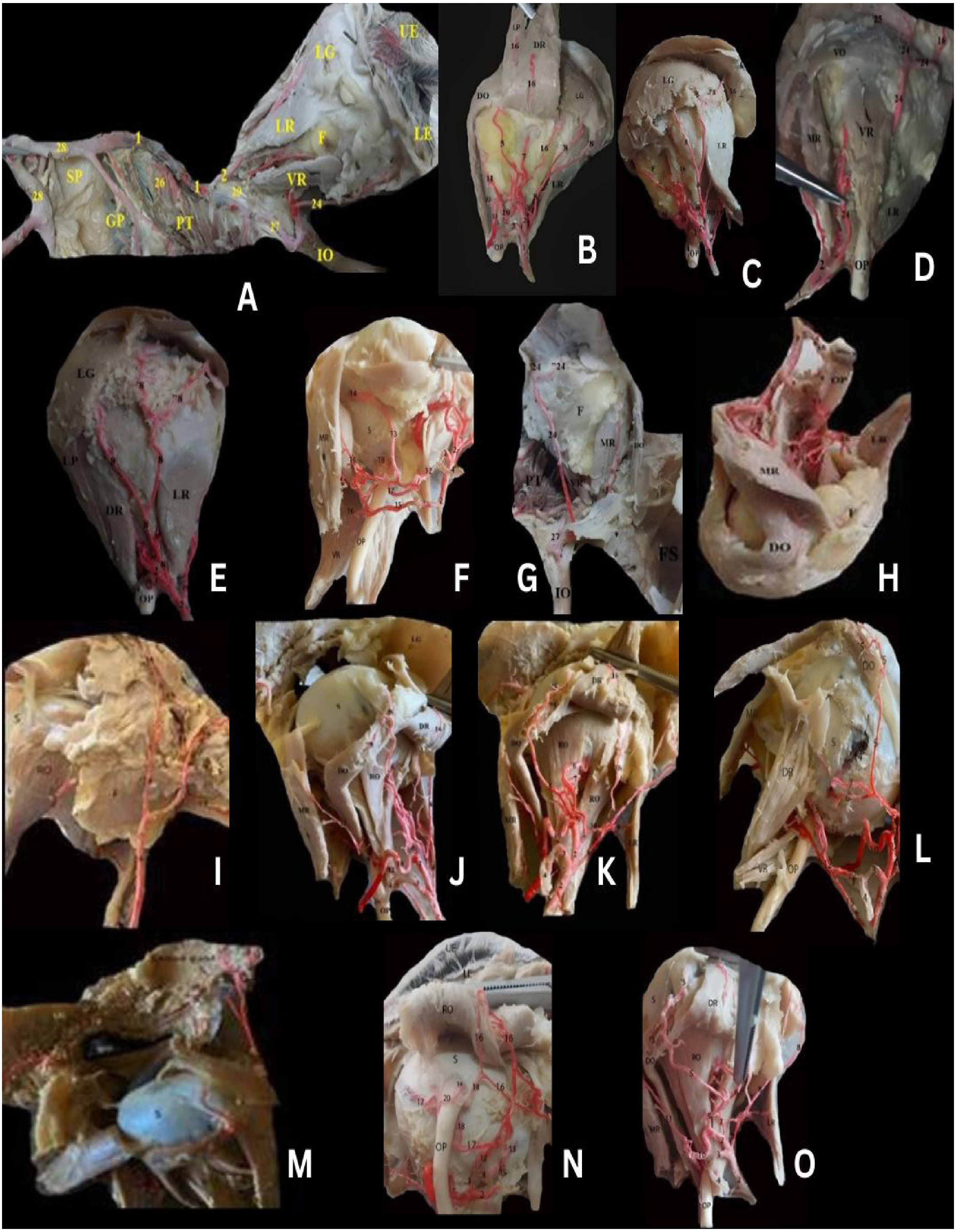

Figure 2: (A to O) All anatomical Figures with distinctive descriptions.
A. The main arterial supply of the eyeball (Lateral view of Right eye). UE. upper eye lid, LE.lower eye lid, LG. lacrimal gland, LR. lateral rectus, VR. ventral rectus M., IO. infra-orbital canal, F. peri-orbital fat, PT. pterygoideus M., GP.

Guttural pouch. SP. Styloid process of hyoid,1. Maxillary A, 2. External ophthalmic A, 24. Malar A., 26. Artery of ptergoideus M., 27. Infra orbital A., 28. External carotid A., 29. Maxillary nerve**, B.** Branches of the external ophthalmic artery (Dorsolateral view). LG. lacrimal gland, LR. lateral rectus, OP. Optic Nerve, F. peri-orbital fat, S. sclera, RO. Retractor oculi M., 1. Maxillary A, 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A., 5. Supra-orbital A. 7. Dorsal posterior ciliary A., 8. Lacrimal A., 8' Lateral superior palpebral A. 8' Lateral inferior palpebral A'. 9. Muscular branch of LR muscle, 10. External ethmoidal A 11. Dorsal oblique muscular branch, 15. Long posterior ciliary A., 16. Muscular branches 30. Anastomosing branch between 7 & 8**, C.** Course of external ophthalmic artery (Dorsal view). LG: lacrimal gland, LR: lateral rectus, OP. Optic Nerve, DR Dorsal rectus., LP. Levator palpebral M., DO. Dorsal oblique M., 1. Maxillary A, 2. External ophthalmic A 3. Anastomosing branch, 5. Supra-orbital A. 7. Dorsal posterior ciliary A., 8. Lacrimal A., 8' Lateral superior palpebral A, 10. External ethmoidal A 11. Dorsal oblique muscular branch 16. Muscular branches 30. Anastomosing branch between 7 & 8, 32. Anterior ethmoidal A. 33. posterior ethmoidal A. **D.** Distribution of the malar artery (Ventro-Medial view). LR: lateral rectus, OP. Optic Nerve, VR. Ventral rectus M., MR Medial rectus, VO. Ventral oblique M.,2. External ophthalmic A., 16. Muscular branches, 24. Malar A., 24'. Medial inferior palpebral A. 24" Medial superior palpebral A., 25. Anastomosis 24" with lateral one. **E.** Distribution of the lacrimal artery (Lateral view). LG. lacrimal gland, LR. lateral rectus, OP. Optic Nerve, DR Dorsal rectus M., LP. Levator palpebral M., 1. Maxillary A, 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A., 8. Lacrimal A., 8' Lateral superior palpebral A. 8' Lateral inferior palpebral A'. 9. Muscular branch of LR muscle, 15. Long posterior ciliary A., 30. Anastomosing branch between 7 & 8. **F.** Origin and distribution of medial and lateral long ciliary artery (Ventromedial view). MR. Medial rectus M., OP. Optic Nerve, VR. Ventral rectus M., S. sclera, 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A., 12. Medial long posterior ciliary A., 13. Ventral anterior ciliary A., 14. Short posterior ciliary A., 15. Lateral Long posterior ciliary A., 16. Muscular branches 17. Central retinal A., 18. Chordio-retinal A. **G.** Origin of infraorbital artery (Ventral view). VR. ventral rectus M., IO. infra-orbital canal, DO. Dorsal oblique M, MR Medial rectus M, F. peri-orbital fat, PT. pterygoideus M, FS. Frontal sinus, 24. Malar A., 24'. Medial inferior palpebral A. 24" Medial superior palpebral A.,27. Infra orbital A. **H.** Muscular branches that supply ocular muscles (Ventral view)., DO. Dorsal oblique M, MR Medial rectus M, F. peri-orbital fat, OP. Optic Nerve, LR. lateral rectus, 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A., 12. Medial long posterior ciliary A., 13. Ventral anterior ciliary A., 15. Long posterior ciliary A.,16. Muscular branches 17. Central retinal A.,18. Chordio-retinal A **I.** Origin of artery of third eyelid (Medial view). F. peri-orbital fat, RO. Retractor oculi M., S. sclera, 16. Muscular branches,19. Anastomosis 24' with lateral one, 24. Malar A., 24'. Medial inferior palpebral A. 24" Medial superior palpebral A. 25. Anastomosis 24" with lateral one, 31. Artery of third eye lid. **J.** Distribution of supraorbital artery (Dorso-medial view). LG. lacrimal gland, MR Medial rectus, DR Dorsal rectus, OP. Optic Nerve, DO. Dorsal oblique M, RO. Retractor oculi M., S. sclera, 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A., 5. Supra-orbital A., 5'. Superficial branch of 5, 5".Deep branch of 5, 6. Dorsal anterior ciliary artery, 7. Dorsal posterior ciliary A., 8. Lacrimal A ., 10. External ethmoidal A .,12. Medial long posterior ciliary A., 16. Muscular branches. **K.** Origin the dorsal anterior ciliary artery. (Dorsal view). DO. Dorsal oblique M, MR Medial rectus, LR. lateral rectus, RO. Retractor oculi M., 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A., 5. Supra-orbital A., 5'. Superficial branch of 5, 5".Deep branch of 5, 6. Dorsal anterior ciliary artery, 7. Dorsal posterior ciliary A., 8. Lacrimal A . '. 9. Muscular branch of LR muscle, 10. External ethmoidal A,16. Muscular branches, 30. Anastomosing branch between 7 & 8, **L.** Origin of the posterior ciliary arteries (Posterior view). DO. Dorsal oblique M, MR Medial rectus,LR. lateral rectus, OP. Optic Nerve, VR. ventral rectus M., DR Dorsal rectus, S. sclera, 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A., 5. Supra-orbital A., 5'. Superficial branch of 5, 5".Deep branch of 5, 6. Dorsal anterior ciliary artery, 7. Dorsal posterior ciliary A., 10. External ethmoidal A 11. Dorsal oblique muscular branch, 12. Medial long posterior ciliary A., 13. Ventral anterior ciliary A., 14. Short posterior ciliary A., 15. Long posterior ciliary A. **M** Anastomosis lateral superior palpebral artery with medial one (Anterior view). UE. upper eye lid, S. sclera,). DO. Dorsal oblique M, RO. Retractor oculi M, LR. lateral rectus, F. peri-orbital fat, C. cornea, 8. Lacrimal A., 8' Lateral superior palpebral A. 8' Lateral inferior palpebral A'. 9. Muscular branch of LR muscle, 19. Anastomosis 24' with lateral one. **N.** origin of central retinal artery and ventral posterior ciliary artery (Posterior view). UE. upper eye lid, LE. lower eye lid, S. sclera, RO. Retractor oculi M, OP. Optic Nerve, 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A., 12. Medial long posterior ciliary A., 13. Ventral anterior ciliary A., 14. Short posterior ciliary A., 15. Long posterior ciliary A., 16. Muscular branches, 17. Central retinal A.,18. Chordio-retinal A., 20. Ventral posterior ciliary A. **O.** Dorsal anterior and posterior ciliary artery (Dorsal view). S. sclera, RO. Retractor oculi M, DO. Dorsal oblique M, DR Dorsal rectus, MR Medial rectus, LR. lateral rectus, OP. Optic Nerve, 2. External ophthalmic A., 3. Anastomosing branch, 4. Internal ophthalmic A, 5. Supra-orbital A., 5'. Superficial branch of 5, 5".Deep branch of 5, 6. Dorsal anterior ciliary artery, 7. Dorsal posterior ciliary A 8. Lacrimal A.9. Muscular branch of LR muscle., 10. External ethmoidal A 11. Dorsal oblique muscular branch.

in the ventro-medial region of the optic nerve. It formed an anastomosis branch with the external ophthalmic artery (Figure 2N/3). Along the way, it directed rostrally to the orbit and gave off branches out to the ventral anterior ciliary artery (Figure 2N /13), choroido-retinal artery (Figure 2F/18), 2-3 fine short posterior ciliary arteries (Figure 2F/14), and the central retinal artery (Figure 2F/17).

Aa. Ciliares anteriors ventralis

The ventral anterior ciliary artery (Figure 2N/13) was derived from the medial long posterior ciliary artery. It moved between the ventral rectus muscle and the retractor bulbi muscle, then curved across the latter's lateral border to reach the ventral surface of the eyeball. From there, it moved rostrally till it punctured the anterior sclera to feed it with blood.

Aa. Ciliares anteriors dorsalis

The dorsal anterior ciliary artery (Figure 2K/6) emerged from the supraorbital artery. It located at the space between the dorsal rectus muscle and the retractor bulbi muscle, then it penetrated the sclera by bending across the medial border of the latter muscle and onto the orbit's dorsal side. It supplied the ciliary body, iris, sclera, conjunctiva, and anterior portion of the eyeball.

A. Retinae choroidae

The choroidoretinal artery (Figure 2F/18) derived from the medial and lateral long posterior ciliary arteries in the posterior portion of the orbit. It gave off the ventral posterior ciliary artery (Figure 2N/20) and divided into a few little points that go both caudally and rostrally through the optic nerve.

A. Ciliares posteriors ventralis

The ventral posterior ciliary artery (Figure 2N/20) supplied the posterior surface of the eyeball and was a tiny, fine artery that emerged from the choroidoretinal arteries.

Aa. Ciliares posteriors breves

The short posterior ciliary arteries (Figure 2F /14) were the result of two or three tiny, coiled fine branches that sprung from the medial and lateral long posterior ciliary arteries (Figure 2F/12,15 respectively). It traveled dorsally and formed many anastomoses with adjacent species. These networks supplied the majority of the choroid with thin episcleral arteries and several branches that pierced the sclera.

A. Centralis retinae

The slightly thicker and more convoluted central retinal artery (Figure 2F/17) was produced by the medial long posterior ciliary artery, which emerged at the medial aspect of the optic nerve beneath the medial aspect of the retractor oculi muscle. It proceeded through the optic nerve in a more atypical manner, serving the inner layers of the retina before coming to an end and splitting into several branches that supplied the choroids.

A. Infraorbitalis

The infraorbital artery (Figure 1, Figure 2A/27 and Figure 3/10) was a straight branch of the maxillary artery that extended into the infraorbital canal. It exited the infraorbital canal through the infraorbital foramen and supplied the medial angle of the eyeball with the malar artery.

A. Malaris

The malar artery (Figure 1, Figure 2M/24 and Figure 3/11) emerged from the infraorbital artery close to the maxillary foramen. It traveled cranio-medially to the ocular muscles before supplying the periorbita and penetrating the medial angle of the eye. During its course, it supplied the medial region of the eyelids and the lacrimal sac with a muscular branch of the ventral rectus muscle before bifurcating into the medial superior and inferior palpebral arteries (Figure 2I/24", 24', respectively).

A. Palpebralis superior medialis

The medial superior palpebral artery (Figure 1 and Figure 2I/24"), which anastomosed with the lateral one and proceeded rostrally to the superior eyelid, gave rise to the artery of the third eyelid (Figure 1 and Figure 2I/31).

A. Palpebralis inferior medialis

The medial inferior palpebral artery (Figure 1 and Figure 2I/24'), which emerged at the medial aspect of the ocular muscles and extended toward the inferior eye lid, provided the ventral oblique muscle.

The acquired data, which indicates that the external ocular artery is a branch of the maxillary artery and supplies the majority of the arterial blood flow to the eyeball in donkeys, supports the current research hypothesis. This result is similar to those reported in buffaloes (Beyrami *et al*., 2021), camels (Nickel *et al*., 1981; Wang 2002; (Noor and El-bably, 2018), yaks (Shao *et al*., 2008), mouse (Ninomiya and Inomata, 2006), sheep (Sisson and Grossman, 1975), and horses (Simoens *et al*., 1996). Nonetheless, in birds (Sisson and Grossman, 1975) and humans (Drake *et al*., 2014); it was reported that the internal carotid artery is the origin of the external ophthalmic artery, which is also known as the ophthalmic artery.

The current results revealed that the external ophthalmic artery gives rise to the supraorbital artery, lacrimal artery, external ethmoidal arteries, muscular branches, dorsal posterior ciliary artery, lateral long posterior ciliary artery,

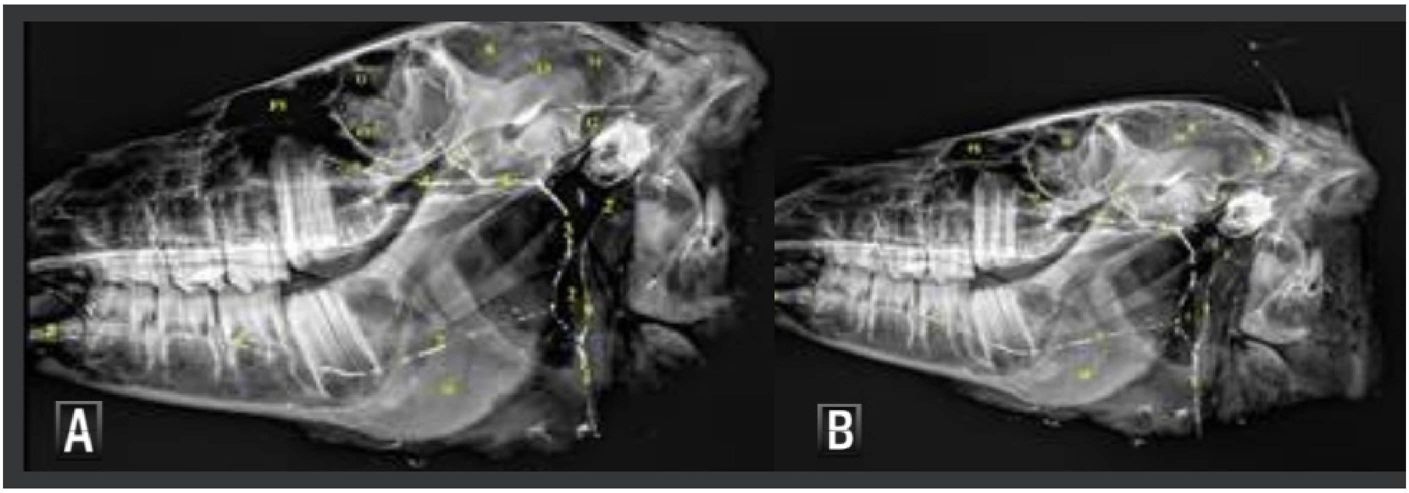

Figure 3: Radiograph showing the origin of the external ophthalmic artery, A. Ventro-dorsal view, B. Lateral view, FS. Frontal sinus, M. Mandible, O. orbit, B. cranial cavity, 1. Common carotid A., 2. Occipital A., 3. External carotid A. 4. Maxillary A., 5. Inferior alveolar A., 6. Caudal deep temporal A., 7. Lingo-facial A., 8. Inferior labial A., 9. Internal carotid A., 10. Infra-orbital A., 11. Malar A., 12. Superficial temporal A., 13. Transverse facial A., 14. Caudal auricular A.

and anastomosing branch of the internal ophthalmic artery. These results are similar to those recorded in buffaloes (Beyrami *et al*., 2021) and horses (Simoens *et al*.,1996), however, the later authors emphasized that it also gives off the orbital, bulbar, and choroidoretinal arteries. Wang (2002) showed in Bactrian camel that the external ocular artery supplies the dorsal oblique muscular branch, zygomaticotemporal, temporal muscular, 1-2 epidural rete mirabile, posterior short ciliary, lateral and medial posterior long ciliary, and central retinal artery. However, Kanan (1972) and Noor and El-bably (2018) in dromedary camels recorded that the external ophthalmic artery also releases the rostral epidural rete mirabile, external ethmoidal artery, ophthalmic rete mirabile, malar artery, and maxillary tubercular artery. The external ocular artery supplies the posterior long ciliary, posterior short ciliary, and central retina according to Sisson and Grossman (1975) in carnivores.

In the present study, the supraorbital artery originates from the external ophthalmic artery. Our finding concurs with those reported in camels (Smut and Bezuidenhout,1987; Noor and El-bably 2018), cattle (Frckowiak *et al*., 2016), saw (Sisson and Grossman, 1975, Nickel *et al*.,1981; Dyce *et al*., 2010), chinchilla (Kuchinka, 2015), horses (Simoens *et al*., 1996), and humans (Drake *et al*., 2014). Although the supraorbital artery was described as a branch of the zygomaticotemporal artery by Wang (2002) in Bactrian camel, Beyrami *et al*. (2021) in buffalo, and Shao *et al*. (2008) in yak, while Nickel *et al*. (1981) and Sisson and Grossman (1975) in ruminant observed that the supraorbital artery shares a trunk with the external ethmoidal. Based on the current study's findings, the supraorbital artery is divided into two branches near its termination: the superficial and the deep branches. The anastomosis with the external ethmoidal artery and the dorsal anterior ciliary artery is comparable to those found in buffaloes (Beyrami *et al*., 2021), and camels (Wang, 2002). On the other hand, Steven (1964) and Nickel *et al*. (1981) demonstrated that the supraorbital artery branches out into the superior eyelid in ox. Furthermore, Shao *et al*. (2008) stated that there are no branches of the supraorbital artery in yaks.

This study found that the lacrimal artery is a noticeable, large branch that enters the lacrimal gland from the external ocular artery, resembling the results of Wissdorf *et al*. (2021) and Ninomiya and Inomata (2014) in horses, El-Naseery *et al*. (2016) in dogs, Dyce *et al*. (2010) in domestic animals, Smut and Bezuidenhut (1987) in the camel, Sisson and Grossman (1975), Nickel *et al*. (1981) in pigs, and Drake *et al*. (2014) in humans. However, El-Naseery *et al*. (2016) and Park *et al*. (2015) in dogs determined that it originates from the muscular branch of the external ocular artery or the ventral branch of the external ethmoidal artery, while Nickel *et al*. (1981) cited that the lacrimal artery arose from the maxillary artery in cat and O'Brien *et al*. (2016) observed that it originates from the maxillary rete mirabile from the superficial temporal artery in giraffe. On the other hand, Noor and El-bably (2018) noted that there is no main lacrimal artery in one humped camels, but only 4-5 branches supplied the lacrimal gland. Moreover, Wang (2002) in camels, Beyrami *et al*. (2021) in buffaloes, and Shao *et al*. (2008) in yaks recorded that the lacrimal artery emerges from the zygomaticotemporal artery and from the external ophthalmic artery and its rete mirabile. However, Sisson and Grossman (1975) in ruminant stated that the lacrimal artery originates from the ophthalmic rete and gives off the anterior and posterior ciliaries arteries.

In relation to the external ethmoidal artery's origin, this research found that it is anastomosed with the supraorbital artery and a direct descendant of the external ophthalmic artery. This claim is made in simulation using the following animals: buffaloes (Beyrami *et al.*, 2021), camels (Smut and Bezuidenhut, 1987), yaks (Shao *et al.*, 2008), ox (Steven, 1964), domestic animals (Sisson and Grossman, 1975), sheep (Simoens *et al.*, 1981), and giraffes (Nickel *et al.*, 1981; O'Brien *et al.*, 2016). However, in the camels it originates from the maxillary artery and is not the continuation of the external ophthalmic artery (Wang, 2002; Noor and El-bably, 2018).

In the present work, the dorsal anterior ciliary artery emerges from the supraorbital artery. Unlike to this finding, Simoens *et al.*'s (1996) found that the supraorbital artery is not always the source of the dorsal anterior ciliary artery in horses. However, Sisson and Grossman (1975) and Nickel *et al.* (1981) in carnivores and horses, Simoens *et al.* (1981) in sheep and Brudnicki (2000) in goats noted that the anterior ciliary arteries originates from the muscular branch of the external ophthalmic artery. But Beyrami *et al.* (2021) in buffaloes, Drake *et al.* (2014) in humans, Shao *et al.* (2008) in yaks, Sisson and Grossman (1975) in ruminants, and Wang (2002) in camels stated that the anterior ciliary arteries originates from the ocular rete mirabile and the lacrimal artery, or the muscular branch of the external ophthalmic artery. There are no anterior ciliary arteries come from in rats (Janes and Bounds, 1955).

The current investigation revealed that the lateral superior and inferior palpebral arteries, the ciliary artery, the external ocular artery, and the medial superior and inferior palpebral arteries of the malar artery originate from musclular branches. These muscular branches emerge from the external ophthalmic artery. These findings are similar to those reported by Sisson and Grossman (1975) and Dyce *et al.* (2009) in horses, whereas they originate from the external ophthalmic artery and its rete mirabile in buffaloes (Beyrami *et al.*, 2021) and humans (Drake *et al.*, 2014).

The present findings verified that the ventral anterior ciliary artery arises from the medial long posterior ciliary artery. Conversely, Simoens *et al.* (1996) reported that the ventral anterior ciliary artery springs from the lateral long posterior ciliary artery or from the anastomotic branch to the internal ophthalmic artery in horses.

According to the current work, the ventral posterior ciliary artery originates from the choroidoretinal arteries, while the dorsal, lateral long posterior ciliary artery elicits from the external ophthalmic artery, and the medial long posterior ciliary artery arises from the internal ophthalmic artery that anastomoses with the external ophthalmic artery by anastomosis branch. These results are comparable to those recorded in equine by Simoens *et al.* (1996). Nevertheless, the posterior ciliary arteries originate directly from the external ophthalmic artery in carnivores, (Sisson and Grossman, 1975), humans (Drake *et al.*, 2014), and rats (Janes and Bounds, 1955). However, Simoens *et al.* (1981) in sheep and Brudnicki (2000) in goats stated that they arise from the muscular branch of the external ophthalmic artery.

According to the present observations, the medial and lateral long posterior ciliary arteries give rise to the short posterior ciliary arteries. These findings are similar to the findings of Beyrami *et al.* (2021) in buffaloes, Noor and El-bably (2018) and Wang (2002) in camels, Shao *et al.* (2008) in yaks, Kuchinka (2015) in chinchilla, and Simoens *et al.* (1996) in horses. In contrast, the external ophthalmic artery or its muscular branches are the origin of the short posterior ciliary arteries in humans (Drake *et al.*, 2014) and rats (Janes and Bound, 1955).

The current results demonstrated that the slightly thicker central retinal artery gives rise to a more convoluted branch that is derived from the medial long posterior ciliary artery. This finding is in line with the findings of Beyrami *et al.* (2021) in Buffalo, Sisson and Grossman (1975) in pigs, Simoens *et al.* (1996) in horses, and Shao *et al.* (2008) in yaks. Conversely, the external ocular artery is the source of the central retinal artery in carnivores (Sisson and Grossman, 1975) and rats (Janes and Bound, 1955). However, this artery originates from the short posterior ciliary arteries or the external ocular arteries in other situations in horses (Simoens *et al.*, 1996).

As for the malar artery, it develops from the infraorbital artery and subsequently splits into the medial superior and inferior palpebral arteries. These findings were recorded by Shao *et al.* (2008) in yaks, Smut and Bezuidenhut (1987) in dromedary camels, and Sisson and Grossman (1975) in carnivores and ruminants. However, the malar artery originates from the maxillary artery in camels Noor and El-bably (2018), giraffes (O'Brien *et al.*, 2016), and horses (Simoens *et al.*, 1996). Nonetheless, the inferior medial palpebral artery evolves in the ocular artery in pigs (Nickel *et al.*, 1981) and humans (Drake *et al.*, 2014). However, this artery is lacking in oxen (Sisson and Grossman, 1975) and giraffes (O'Brien *et al.*, 2016). The current results revealed that the medial superior palpebral artery of the malar artery is the source of the third eyelid. These findings are corroborated in ruminants, carnivores, and pigs. However, they originate from the muscular branch of the external ocular artery in horses (Sisson and Grossman, 1975; Nickel *et al.*, 1981).

In the present study, no ophthalmic rete mirabile was found in donkeys. This finding disagrees with the findings of Noor and El-bably (2018) and Wang (2002) in camels, O'Brien *et al.* (2016) in giraffes, Shao *et al.* (2008) in yaks, Sisson and Grossman (1975) in birds and Steven (1964) in ox. These studies noted that the ophthalmic rete mirabile is only observed in ruminants and birds, and that it plays a role in the formation of supraorbital, external ethmoidal, and lacrimal arteries, as well as the ocular muscles.

The relevance of the present findings is significant. These findings not only enhance the ability of veterinarians to care for donkeys more effectively but also contribute to broader advancements in veterinary science and animal welfare. Furthermore, these findings can improve the surgical interferences of cataract, cornea, eye lid, and glaucoma and the diagnostic techniques like ultrasound biomicroscopy (UBM) and electroretinography (ERG) for better management of ocular health in donkeys and for ensuring more successful outcomes.

The main limitations of the present study are the small sample size, technological limitations, ethical considerations, and the need for interdisciplinary approaches. Future studies regarding the use of Doppler ultrasonography are recommended to study the blood supply of the donkey's eye.

CONCLUSIONS AND RECOMMENDATIONS

The current work investigated the arterial blood supply of eye's donkey and its branches that nourish various areas of the eye. The anatomical information gathered from this study will be beneficial to veterinary surgeons doing interventional operations on donkeys with eye disorders.

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NOVELTY STATEMENT

This study is the first to investigate the arterial blood supply of the donkey's eye that will help in the therapeutic surgical interventions.

AUTHOR'S CONTRIBUTION

The author (Meray Nabil) designed the research work, dissected the eyes, revised the manuscript draft, and approved the last version of the manuscript.

Ethical Approval

All animals were treated and used after ethical approval from the Veterinary Medicine Cairo University Institutional Animal Care and Use Committee (Vet- CU- IA-CUC) with approval number (Vet-CU-18042024922)

Conflict of Interest

The author declares no conflict of interest.

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