

The Presence and Distribution of *Vasa vasorum* in the Media of the Aorta in the Goat (*Capra hircus*)

Presencia y Distribución de *Vasa vasorum* en la Parte Media de la Aorta en la Cabra (*Capra Hircus*)

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IRIMIE, A.; MARTONOS, C.; COTÎRLA, E.; CRET, C.R.; RATIU, C.; HÎRUTA, A. & VIOREL, M. The presence and distribution of *vasa vasorum* in the media of the aorta in the goat (*Capra hircus*). *Int. J. Morphol.*, 43(5):1498-1502, 2025.

SUMMARY: To highlight the *vasa vasorum* within the goat aorta media, sections of the ascending aorta, aortic arch, thoracic descending aorta, and abdominal descending aorta were obtained from eight goats. Histological analysis revealed the presence of *vasa vasorum* across all the studied segments, albeit with variations in both quantity and caliber depending on their proximity to the heart. Notably, the ascending aorta exhibited the greatest number and largest caliber of *vasa vasorum*, with a gradual decrease observed toward the abdominal descending aorta, where they were fewer and smaller in size. Spatially, *vasa vasorum* were predominantly located in the outer two-thirds of the media in the ascending aorta and aortic arch, in the outer half of the media in the thoracic descending aorta, and only in the outer third in the abdominal descending aorta. The abundance of *vasa vasorum* and their significant caliber, particularly in the initial segments, leads us to believe that the goat aorta undergoes more exertion than most mammalian species. A plausible explanation could be the additional metabolic demand imposed by the unique organs present in goats, such as the rumen, reticulum, and omasum, which are absent in many other mammals.

KEY WORDS: *Vasa vasorum*; Aorta; *Capra hircus*.

INTRODUCTION

The circulatory system delivers oxygen and nutrients to tissues and organs, while the walls of blood vessels also need their own blood supply to maintain vascular health and functionality (Billaud *et al.*, 2017). In smaller arteries, this supply comes from the diffusion of circulating blood and vessels in the adventitia, a process effective in vessels with walls not exceeding 0.5 mm in thickness and 29 elastic lamellae (Heistad *et al.*, 1978). However, larger vessels have too thick walls for nourishment by diffusion alone; they rely on specialized vessels known as *vasa vasorum* for their nutrition. *Vasa vasorum* form a vascular network made up of small vessels that supply blood to the walls of major blood vessels, such as the aorta and vena cava. Arterial *vasa vasorum* provide oxygen and nutrients to the vessel walls, while venous and lymphatic *vasa vasorum* remove waste and extracellular fluid to adjacent veins and lymphatic vessels (Phillippi, 2022). Through 3D micro-CT studies, researchers have identified three types of *vasa vasorum*: internal, external, and venous (Gössl *et al.*, 2003). Their origins vary based on the vessel. For instance, the external *vasa vasorum* of the ascending aorta stems from the brachiocephalic trunk and coronary arteries (Phillippi, 2022).

In contrast, those of the descending thoracic aorta arise from the intercostal arteries, and those of the descending abdominal aorta are connected to the mesenteric and lumbar arteries (Gössl *et al.*, 2003). External *vasa vasorum* penetrates the media thickness in large arteries like the thoracic aorta, carotid, femoral, and coronary arteries (Phillippi, 2022). On the other hand, internal *vasa vasorum* originates from the lumen of the parent vessel, as observed in studies on porcine coronary arteries (Kwon *et al.*, 1998). Some authors state that the *vasa vasorum* develops in humans during the first weeks of gestation and continues to expand during fetal growth from the 12th week onwards (Mulligan-Kehoe, 2010).

MATERIAL AND METHOD

Eight adult common breed goats were utilized in this study, all of which had suffered accidents resulting in injuries severe enough to necessitate euthanasia by their owners. The study obtained approval from the Bioethics Commission of USAMV Cluj-Napoca, under decision no. 403 dated 29.09.2023, and adhered to the recommendations outlined by the World Organization for Animal Health regarding animal

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slaughter. Following anatomical identification of the aorta, sections of the ascending aorta, aortic arch, thoracic descending aorta, and abdominal descending aorta were collected for histological analysis. These samples were fixed in 10 % formalin for 7 days, followed by dehydration with ethyl alcohol, clarification with 1-butanol, and embedding in paraffin. Sections with a thickness of 5 μm were obtained using a rotary microtome, mounted on slides, and stained using the Trichrome Goldner method. Histological examination of the prepared slides was conducted using an Olympus BX41 microscope equipped with an Olympus E-330 digital camera.

RESULTS

Within the ascending aorta, *vasa vasorum* of varying calibers were observed within the outer two-thirds of the media. Notably, differences were noted between the outer third and the middle third in terms of both quantity and caliber of vessels. In the outer third, *vasa vasorum* appeared significantly larger and more abundant. The largest vessels were found near the muscle islands in the middle, suggesting a direct support of their activity (Fig. 1).

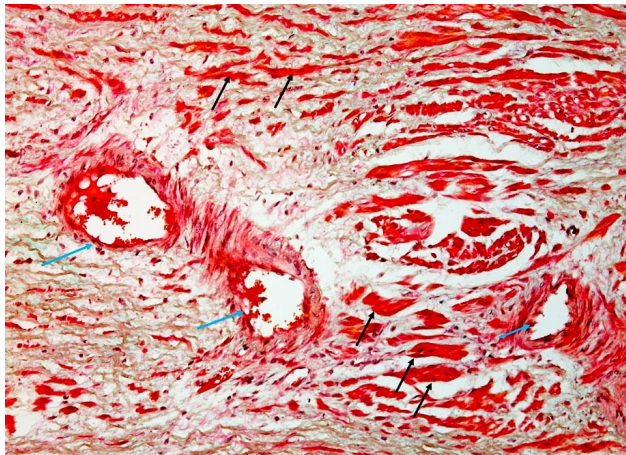


Fig. 1. Ascending aorta: blue arrows - *vasa vasorum*; black arrows - muscular islets Trichrome Goldner, 20X).

In the aortic arch, the distribution of *vasa vasorum* closely resembles that observed in the ascending aorta, especially regarding their presence in the outer two-thirds and the number of vessels. However, a slight disparity is noted in the caliber of the vessels, which appears somewhat diminished at the level of the aortic arch, particularly within the external middle third (Fig. 2).

In the descending thoracic aorta, *vasa vasorum* are found in the outer half, though there is a slight reduction in their number and a minor decrease in their caliber observed (Fig. 3).

In the descending abdominal aorta, *vasa vasorum* were identified on average, yet notably fewer than in the

preceding segments. Additionally, only *vasa vasorum* of small caliber were observed, situated exclusively within the external third of the media (Fig. 4).

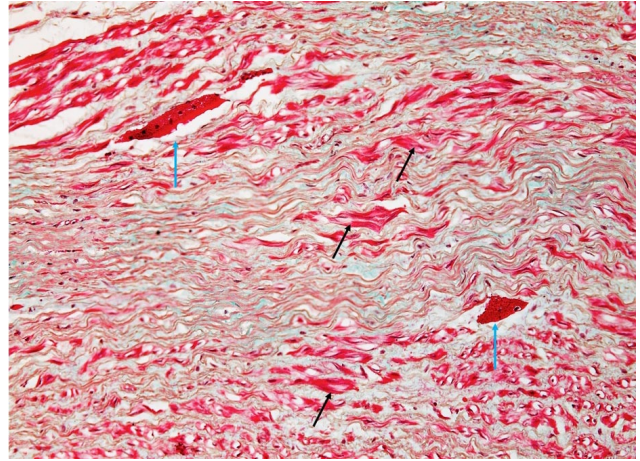


Fig. 2. Aortic arch: blue arrow - *vasa vasorum*; black arrow - muscular islets (Trichrome Goldner, 20X).

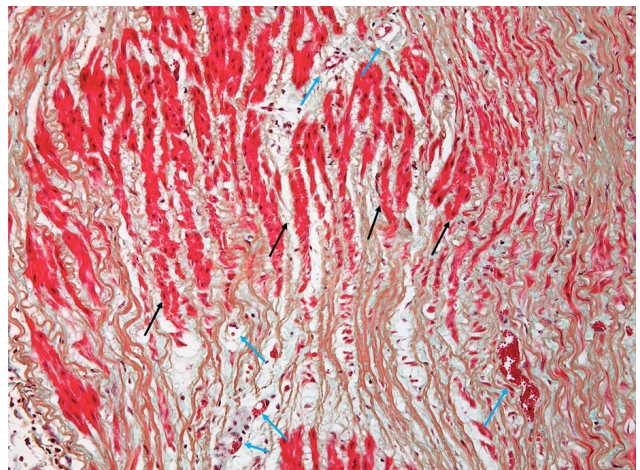


Fig. 3. Thoracic descending aorta: blue arrow - *vasa vasorum*; black arrow - muscular islets (Trichrome Goldner, 20X).

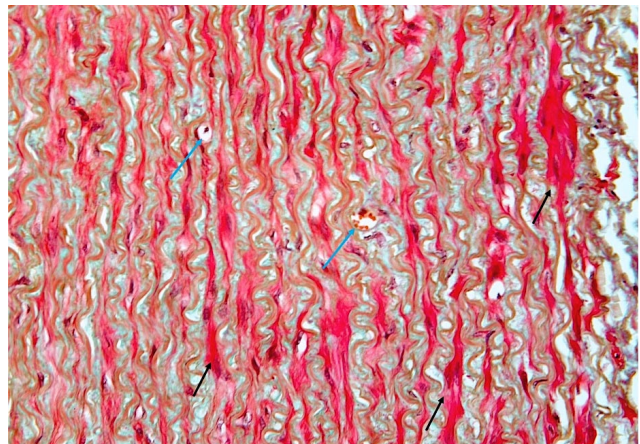


Fig. 4. Abdominal descending aorta: blue arrow - *vasa vasorum*; black arrow-muscle bands (Trichrome Goldner, 40X).

DISCUSSION

Based on our investigation into the presence, caliber, and distribution of *vasa vasorum* in various aortic segments of the goat, we observed their consistent presence across all segments studied, albeit with notable differences between each segment. The greatest abundance and caliber were observed in the ascending aorta, gradually decreasing in subsequent segments until becoming sparse and smaller in caliber at the level of the abdominal segment. Additionally, their disposition was predominantly within the outer two-thirds of the media in the ascending aorta and aortic arch, extending to the outer half in the thoracic descending aorta and confined to the outer third in the abdominal descending aorta. The significant number and size of *vasa vasorum*, particularly in the initial segments departing from the heart, suggest heightened physiological demands on this crucial vessel in goats compared to many other mammalian species. This increased demand is likely attributed to the presence of three additional organs unique to ruminants, namely the rumen, reticulum, and omasum, which are not typically found in most mammals.

Similar findings have been observed in other mammalian species. For instance, Sano *et al.* (2016), noted the density of arterial *vasa vasorum* in various regions of the human aorta, reporting a peak in the aortic arch followed by a gradual decrease that reaches a minimum in the abdominal region aorta. In a study by Ruxanda *et al.* (2015), that examined the presence and distribution of *vasa vasorum* in lambs, rabbits, and chinchillas, these vessels were identified in lambs but not in rabbits and chinchillas. Specifically, the authors found *vasa vasorum* to be present in relatively high numbers at the level of the aortic arch in lambs, with a significant decrease observed in the thoracic descending aorta and their absence highlighted in the abdominal descending aorta. In ruminants, these vessels reach the muscle islands located in the outer half of the media in the proximal segments of the aorta. In distal segments of the descending thoracic and abdominal aorta, *vasa vasorum* are still present in the tunica media. However, their distribution is restricted to the outer third of the media or its adventitial periphery (Angouras *et al.*, 2000). In this context, our results align with those reported by the aforementioned authors, as we also identified *vasa vasorum* in the descending abdominal aorta with comparable localization. Top of Form Bottom of Form

The type and density of *vasa vasorum* are influenced by factors such as wall thickness (Kachlik *et al.*, 2007), the luminal blood's oxygen content, and the vascular wall's role in regulating blood flow to organs (Chuncher & Somana, 2005). Their presence and density within the vascular wall

can vary across animal species. Some authors suggest that these vessels penetrate only into the tunica media of vessels with a wall thickness exceeding 0.5 mm and comprising more than 29 elastic lamellae, leading to the assertion that there are no *vasa vasorum* in the abdominal aorta (Heistad *et al.*, 1978). However, other authors argue that *vasa vasorum* are present in goats even when the wall thickness is less than 0.5 mm, and there are fewer than 29 lamellar units. Examination of the number of elastic lamellae in the thoracic aorta of adult Deccani sheep and Bidri goats revealed comparable situations between the two species, ranging between 20-22 (Sharanagouda *et al.*, 2016). This differs from findings in other species. Consequently, it was deduced that the abdominal aorta in goats is more metabolically active than initially presumed (Ogengo *et al.*, 2011).

Variations are evident in the expansion of *vasa vasorum* within the walls of large vessels across different animal species. Some authors have observed *vasa vasorum* extending from the media to the intima in dogs (Stefanadis *et al.*, 1993) and pigs (Angouras *et al.*, 2000).

Under normal circumstances, the number of *vasa vasorum* remains stable throughout life, but it can increase in response to acute arterial injury (Scotland *et al.*, 2000). Being small-caliber vessels, *vasa vasorum* are highly susceptible to external mechanical compression (Moore *et al.*, 2010), potentially contributing to vascular disease pathology. Both oxygen tension and wall thickness are crucial factors determining the presence of *vasa vasorum*, and diseases causing wall thickening or hypoxia can have significant implications for the host vessel. For instance, alterations in the number and density of vessels occur in certain cardiovascular conditions such as atherosclerosis, closely associated with changes in the vascular wall's blood supply (Scotland *et al.*, 2000; Baikoussis *et al.*, 2011). These vessels play vital roles in aortic diseases like atherosclerosis (Ritman & Lerman, 2007) and aneurysm (Mulaudzi, 2009). By examining the density of *vasa vasorum* in stenotic and calcified human coronary arteries, some researchers concluded that there is a higher density of *vasa vasorum* in arteries prone to atherosclerosis compared to non-stenotic vessels (Gössl *et al.*, 2010), suggesting neovascularization of arteries in atherosclerosis-prone regions. Within the walls of arteries affected by atherosclerosis, complex biological processes occur, including angiogenesis and inflammation, in which adventitial *vasa vasorum* play significant roles (Mulligan-Kehoe, 2010).

Some authors have reported that inflammation and atherosclerosis can induce extensive vascularization in mouse arteries despite the arterial wall not exceeding the diffusion limit of 0.5 mm (Drinane *et al.*, 2009). In studies regarding atherosclerosis in pigs, it was observed that the proliferation of *vasa vasorum* in coronary arteries precedes vessel wall thickening and plaque development (Herrmann *et al.*, 2001), with proliferation being preceded by infiltration of inflammatory cells into the adventitia. These observations suggest that inflammatory cells infiltrating the adventitia secrete various angiogenic growth factors, including vascular endothelial growth factor.

Rupture of the *vasa vasorum* within the aortic wall can initiate a series of pathological events, including intramural hematoma (Nakamura *et al.*, 2006) or acute aortic dissection (Baikoussis *et al.*, 2011).

The remodeling of *vasa vasorum* under both normal and pathological conditions involves intricate mechanisms influenced by hemodynamics, vessel architecture, and the developmental origin of local cells (Phillippi, 2022). To prevent excessive growth of *vasa vasorum* in specific scenarios, it is conceivable that future interventions may involve the local administration of agents capable of inhibiting this phenomenon (Phillippi, 2022). Perfusion pressure through *vasa vasorum* can be modulated by the administration of vasodilators such as acetylcholine, histamine, allopurinol, adenosine triphosphate (ATP), adenosine diphosphate (ADP), adenosine, or sodium nitroprusside (Ohhira & Ohhashi, 1992).

CONCLUSIONS

All segments of the goat aorta exhibit the presence of *vasa vasorum*, with the largest caliber and highest abundance observed in the initial segments departing from the heart. Gradually, their caliber and quantity diminish, resulting in fewer and smaller vessels in the abdominal aorta. The total number of the *vasa vasorum* observed by us in the tunica media of the aorta of *Capra hircus*, exceeds the reported data for most mammalian species. This heightened demand can primarily be attributed to the presence of three additional organs unique to ruminants, specifically goats in this study - namely, the rumen, reticulum, and omasum - which are absent in other mammals.

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IRIMIE, A.; MARTONOS, C.; COTÎRLA, E.; CRET, C. R.; RATIU, C.; HÎRUTA, A. & VIOREL, M. Presencia y distribución de *vasa vasorum* en la media de la aorta en la cabra (*Capra hircus*). *Int. J. Morphol.*, 43(5):1498-1502, 2025.

RESUMEN: Con el objetivo de identificar los *vasa vasorum* en la media de la aorta de la cabra, se obtuvieron secciones de la aorta ascendente, el arco aórtico, la aorta descendente torácica y la aorta descendente abdominal de ocho cabras. El análisis histológico reveló la presencia de *vasa vasorum* en todos los segmentos estudiados, aunque con variaciones tanto en cantidad como en calibre según su proximidad al corazón. Cabe destacar que la aorta ascendente presentó la mayor cantidad y calibre de *vasa vasorum*, con una disminución gradual observada hacia la aorta descendente abdominal, donde fueron menos numerosos y de menor tamaño. Espacialmente, los *vasa vasorum* se localizaron predominantemente en los dos tercios externos de la media en la aorta ascendente y el arco aórtico, en la mitad externa de la media en la aorta descendente torácica y solo en el tercio externo en la aorta descendente abdominal. La abundancia de *vasa vasorum* y su significativo calibre, particularmente en los segmentos iniciales, nos lleva a creer que la aorta de la cabra se somete a un mayor esfuerzo que la mayoría de las especies de mamíferos. Una explicación plausible podría ser la demanda metabólica adicional impuesta por los órganos únicos presentes en las cabras, como el rumen, el retículo y el omaso, ausentes en muchos otros mamíferos.

PALABRAS CLAVE: *Vasa vasorum*; Aorta; *Capra hircus*.

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