

Histological evaluation of the common carotid arteries in the goat (*Capra Hircus*)

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Abstract: Fragments of the common carotid arteries were collected from 8 goats that had succumbed to accidents. These samples underwent histological processing, involving fixation and embedding in paraffin. Sections, 5 μ in thickness, were then stained using the Trichrome Goldner method for overall assessment and Verhoeff staining for elastic tissue analysis. Upon using Trichrome Goldner staining, it was observed that goat carotid arteries exhibited a typical appearance of muscular arteries, with the thickest layer being the media, primarily composed of muscular components. Verhoeff staining further revealed a well-represented elastic tissue presence within the adventitia, exhibiting a distinct arrangement. Both staining methods indicated that goat common carotid arteries possess tunics comparable in thickness to muscular arteries, with a predominantly muscular media. However, the adventitia was notably distinguished by a significantly higher concentration of elastic tissue compared to typical muscular arteries. Consequently, with these findings, we propose classifying goat common carotid arteries as musculoelastic transitional arteries.

Keywords: common carotid arteries, muscular component, elastic component

1. Introduction

Arteries are broadly categorized into two types: elastic and muscular. Large-diameter arteries, such as the aorta and its primary branches, are classified as elastic arteries due to their predominant elastic media composition, despite also containing muscle and connective tissue [1]. In these arteries, the elastic component not only prevails but also exhibits a distinctive arrangement. Specifically, the elastic component of large arteries comprises multiple concentric elastic lamellae, interspersed with muscle and connective tissue. Examples of elastic arteries include the aorta, brachiocephalic trunk, common carotid artery, subclavian artery, and common iliac artery [2].

Arteries play a crucial role in supplying organs with blood and essential nutrients. The initial arteries emerging from the heart invariably experience high pressure. To withstand this stress, they are rich in elastic tissue and have a lower concentration of smooth muscle. Elastin, a key component of the arterial wall, provides elasticity, allowing arteries to expand and contract, thereby adjusting their diameter. The elasticity of the walls of large arteries enables them to maintain a relatively steady pressure gradient, even as the heart functions as a pump. Specifically, arterial wall elasticity facilitates the dampening of pulsations and the equalization of blood flow through passive expansion and elastic recoil. As arteries extend away from the heart, they progressively branch into smaller vessels characterized by a greater proportion of smooth muscle and reduced elastic tissue [3].

All vertebrates and invertebrates possess closed circulatory systems, though the properties of their components vary to accommodate species-specific physiological

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pressure ranges. In each instance, the elasticity of vessels arises from the parallel arrangement of elastic and rigid connective tissue elements within their walls.

In ruminants, the common carotid arteries originate from the bicarotid trunk at an acute angle and ascend along the tracheal margins to the cranial end of the cervical region. There, they bifurcate into two branches: the external carotid artery, which supplies structures in the head, and the internal carotid artery, responsible for supplying the brain and its derivatives [4]. In contrast, other species such as equines and carnivores have common carotid arteries that terminate in three branches: the internal carotid, external carotid, and occipital artery [5]. These differences in arterial branching patterns seem to be influenced by various factors, including the animals' dietary habits and locomotion requirements. Animals adopt different postures for feeding based on their locomotion needs and specific feeding habits. Some animals feed with their heads raised to reach elevated branches, while others feed with their heads lowered to access food at ground level. Ruminants present a unique scenario, as they spend several hours daily in rumination, during which they typically hold their heads up [6]. To accommodate the hemodynamic needs associated with locomotion and feeding habits, animals have adapted through specific arrangements of vessels serving various anatomical regions. The goat, for instance, engages in extensive movement while foraging, gathering food with both upward and downward head movements, and dedicating significant time to rumination compared to monogastric animals.

Considering these factors, we deemed it appropriate to conduct morphological investigations on the common carotid arteries supplying the head and neck of goats. Our aim was to identify any adaptive structures that may have developed in response to the unique characteristics of this animal with distinctive feeding habits.

2. Materials and Methods

The biological material used consisted of 8 common breed goats, deceased from various causes. The study was conducted based on the approval of the Bioethics Committee of the USAMV Cluj-Napoca, under decision no. 403 dated 29.09.2023, adhering to the recommendations of the World Organization for Animal Health. An anatomical dissection was performed to gain access to the carotid arteries, after which arterial fragments were collected for histological investigations. The collected pieces were fixed in 10% formalin solution, dehydrated in increasing concentrations of ethyl alcohol (70%, 95%, absolute), clarified with 1-Butanol, and embedded in paraffin. Sections with a thickness of 5 μm were prepared, which were stained using the Trichrome Goldner method for general topographic aspects and Verhoeff staining to highlight elastic structures. The histological preparations were examined under an OlympusBX41 microscope, equipped with a digital camera.

3. Results

Structurally, the common carotid arteries exhibit a prominent media layer, constituting 65-70% of the total thickness of the arterial wall. The intima consists primarily of endothelium and a relatively thin endothelial layer. At the boundary between the intima and media, a thick and undulating internal elastic lamina is observed. The media is composed of smooth muscle cells predominantly arranged in a circular fashion (Figures 1 and 3), interspersed with discontinuous elastic lamellae that are relatively thin and spaced apart. Within the broad interstices between these lamellae lie delicate elastic fibers oriented obliquely and transversely, creating an impression of an elastic network anchoring the components together. The internal elastic lamina is thick and undulating, while the external lamina comprises 2-3 thin elastic lamellae. Overall, the structural characteristics of goat common carotid arteries closely resemble those of typical muscular arteries. However, a notable difference lies in the adventitia, which constitutes approximately 25% of the arterial wall thickness and contains numerous elastic lamellae. These lamellae exhibit a distinctive circular arrangement, reminiscent of the arrangement observed in the middle layers of elastic arteries (Figures 2 and 4).

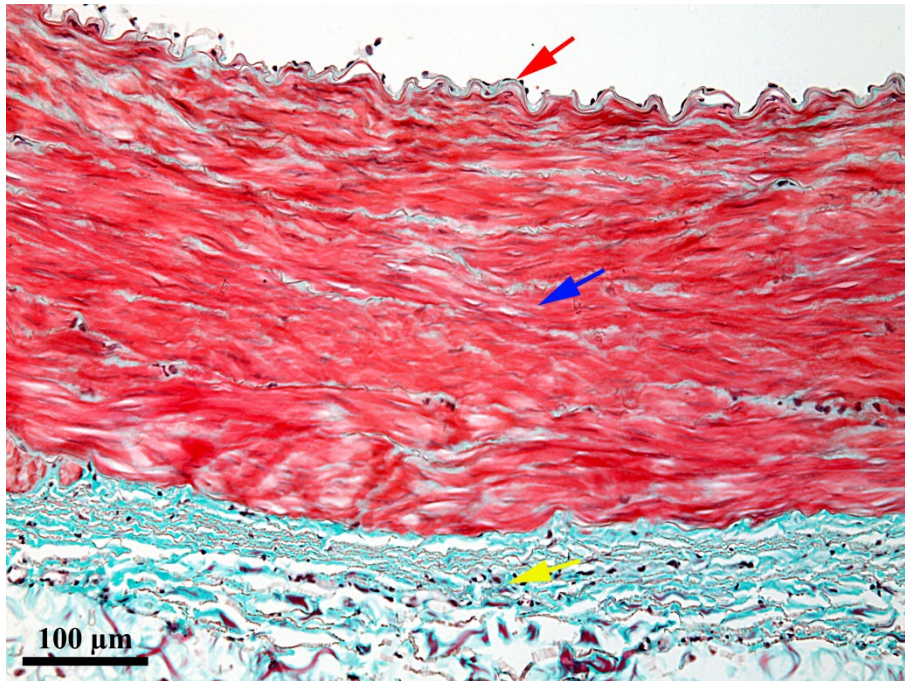


Figure 1. Right Carotid Artery (Goldner's Trichrome staining); red arrow - intima; blue arrow - media; yellow arrow – adventitia.

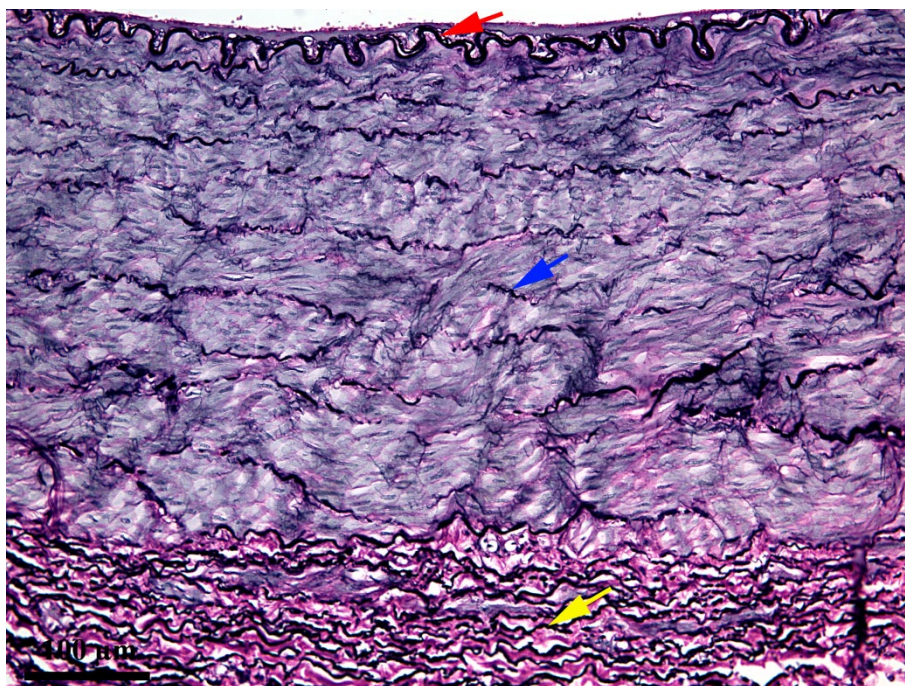


Figure 2. Right carotid (Verhoeff staining); red arrow – internal elastic limiter; blue arrow – elastic fibers on average; yellow arrow - elastic fibers in the adventitia.

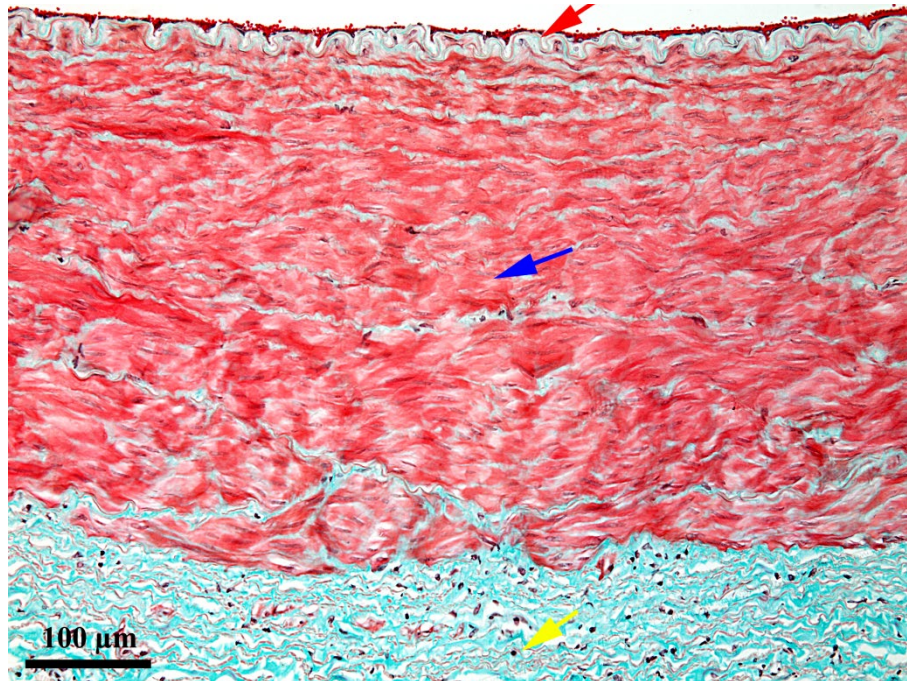


Figure 3. Left carotid (Goldner's Trichrome staining); red arrow – intima; blue arrow - media; yellow arrow – adventitia.

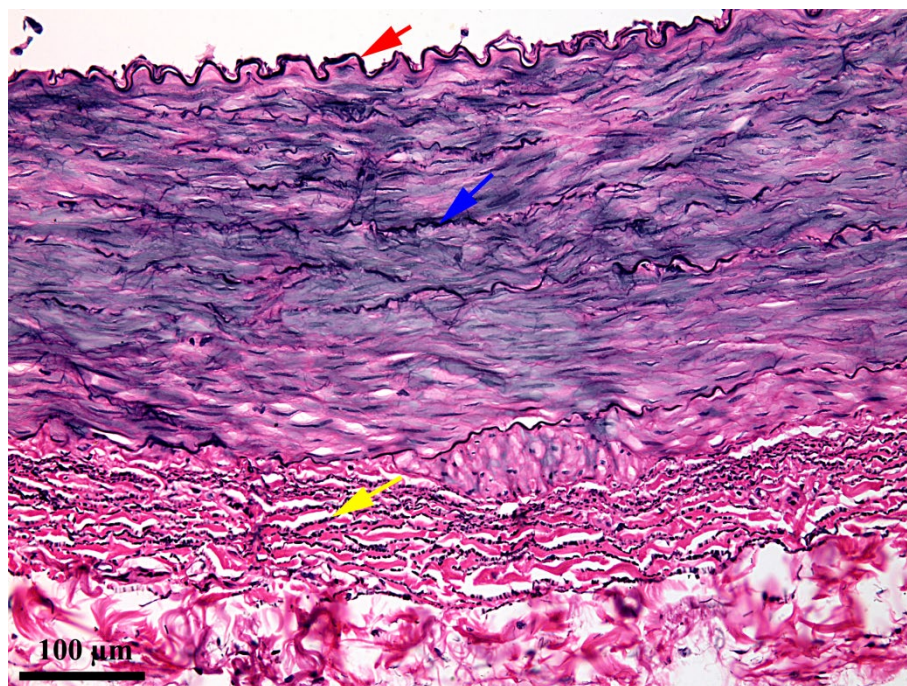


Figure 4. Left carotid (Verhoeff staining); red arrow – internal elastic limiter; blue arrow – elastic fibers on average; yellow arrow - elastic fibers in the adventitia.

4. Discussion

The common carotid arteries, crucial for supplying blood to the head and neck regions, are large elastic arteries [7, 8, 9]. They bifurcate at the carotid sinus into the internal carotid artery, serving the brain, and the external carotid artery, supplying the neck and face [10, 11].

The anatomical positioning of the goat's common carotid arteries is notably unique, situated within a highly mobile region and in close proximity to the external environment. This anatomical context demands continuous blood flow despite external stresses, particularly the significant movements of the head and neck during food collection, whether upward or downward from branches. Adaptations in the structural

composition of goat common carotid arteries have occurred to meet these demands for both quantitative and qualitative blood supply.

To optimize blood flow, the average goat common carotid artery possesses a relatively thick media primarily comprised of smooth muscle cells arranged predominantly in a circular pattern. Unlike typical elastic arteries characterized by a predominantly elastic media, goat common carotid arteries exhibit a media where smooth muscle cells are the predominant feature. While elastic lamellae are present, they are fewer in number, discontinuous, and spaced apart compared to elastic arteries. The media is demarcated from the intima by a thick, undulating elastic lamina, akin to typical muscular arteries, alongside a thin outer elastic lamina.

Overall, the structural characteristics of goat common carotid arteries resemble those of muscular arteries, despite a slightly greater representation of elastic lamellae. However, they differ significantly from elastic arteries in terms of the number and arrangement of elastic lamellae. Based solely on media structure, these arteries could be classified as muscular arteries.

A noteworthy observation pertains to the adventitia, which shares a comparable thickness with muscular arteries but differs slightly in structure. The distinct appearance of the adventitia in goat common carotid arteries stems from a substantial presence of elastic tissue, manifested by elastic lamellae arranged approximately concentrically. These lamellae exhibit relative polymorphism in thickness, and their arrangement partially mirrors that of elastic arteries, albeit with greater and uneven spacing between them. This conjunctive-elastic composition of the adventitia in goat common carotid arteries stands apart from the thin, predominantly collagenous structure of elastic arteries and the thicker but structurally distinct adventitia of muscular arteries. The notable disparity lies in the significantly greater abundance of elastic tissue.

In our assessment, this unique adventitial structure in goat common carotid arteries does not seem to arise solely from adaptation to internal stresses imposed by the blood column traversing their lumen. Instead, adaptations primarily occur at the structural level within the intima and media to address internal demands. We believe that the development of a well-defined adventitia with abundant elastic tissue arranged in a specific pattern could stem from adaptation to external stresses, likely due to the anatomical positioning within a highly mobile region.

In response to external stresses, the adventitia of goat common carotid arteries has adapted by significantly increasing the elastic component, thereby primarily providing elasticity to these arteries. Consequently, the adventitia acts as an elastic buffer, ensuring the integrity of the arterial wall despite exposure to external stresses.

Considering both the structure of the media and the adventitia, goat common carotid arteries cannot be classified as typical muscular arteries or typical elastic arteries. Instead, they exhibit characteristics of transition arteries, combining features of both muscle and elastic arteries.

Similar findings, albeit not identical, have been reported in related species such as sheep. Martonos et al. [12] observed that in the average carotid artery of Țurcană breed sheep, the internal elastic lamina is wavy and easily distinguishable compared to the deeper elastic lamellae. Additionally, there is a slightly increased number of elastic lamellae, likely influenced by the gradual change in vessel caliber and anatomical-topographical distance from the heart [13]. Interlamellar bridges, consisting of elastic fibers crossing the interlamellar space and anchoring the elastic lamellae together, have also been identified [12]. These bridges are hypothesized to play a significant role in maintaining interlamellar spaces against the pressure of blood flow in the vascular bed [12], a phenomenon previously observed in human aortic segments [14]. Martonos et al. [12] classify the common carotid artery of sheep as elastic arteries, albeit with certain distinct aspects. However, this classification does not align with our recommendation for goat common carotid arteries, despite the high similarities observed between the two species. Differences in interpretation may account for these discrepancies.

Differences in arterial elasticity are also evident in animals living in unique environmental and feeding conditions. Large whales provide a striking example, with their aortic arch exhibiting exceptional elasticity while the descending aorta displays minimal elasticity [2]. The aortic arch in these animals possesses an extraordinary capacity for expansion, effectively ensuring elastic compliance throughout the arterial tree, whereas the descending aortic segments have thinner walls and are approximately 30 times stiffer than the aortic arch [15]. The remarkable expansion capability of the aortic arch in large whales enhances the aorta's volume capacity and likely aids in maintaining blood flow during diving bradycardia [16, 17].

To estimate elastic, viscous, and inertial moduli, Bia et al. [18] developed various methodologies, through which they discovered that carotid arteries exhibit higher relative levels of collagen and smooth muscle compared to the ascending and descending aorta. Moreover, over time, the relative value of elastin was found to be significantly lower ($P < 0.05$).

5. Conclusions

Considering the thickness of their tunics comparable to muscular arteries, a predominantly muscular media, and a distinctive presence of elastic tissue within the adventitia, we classify goat common carotid arteries as transitional, musculoelastic arteries. We believe that this unique structure reflects adaptation to the hemodynamic demands specific to goats, influenced by their anatomical disposition and the functions they serve.

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