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Elastic and muscular organization of the tunica media in human arteries

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Abstract. According to the classical classification, the large arteries located close to the heart are considered elastic, whereas the arteries surrounding and residing within the organs are categorized as muscular. The analysis of longitudinal arterial sections demonstrates a gradual transition from elastic to muscular vessels as the distance from the heart increases. Nonetheless, the available evidence regarding the locations at which structural changes in the human arterial media occur is limited and, in some cases, contradictory. Additionally, the morphological criteria for identifying and classifying hybrid arteries have not yet been established. This review summarizes current morphological findings on the structural changes in the human arterial media throughout the systemic and pulmonary circulation.

Keywords: arteries, tunica media, histology, elastin, smooth muscle cells

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Эластический и мышечный компонент средней оболочки артерий человека

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Резюме. Согласно классическому представлению, крупные артерии вблизи сердца относятся к эластическому типу, а околоорганные и внутриорганные к мышечному. Исследование продольных срезов артерий свидетельствует о плавном переходе сосудов эластического типа в мышечный по мере удаления от сердца. Вместе с тем сведения о том, на каком уровне происходит изменение строения средней оболочки артерий человека, немногочисленны и часто противоречивы. Отдельной проблемой морфологии является критерий отнесения артерии к смешанному типу. В обзоре суммированы морфологические данные об изменении строения средней оболочки артерий человека большого и малого кругов кровообращения.

Ключевые слова: артерии, средняя оболочка, гистология, эластин, гладкие миоциты

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Introduction

The structure of the arterial wall is determined by the hemodynamic conditions in which it functions [1]. Based on the features of the tunica media, arteries are classified into three types: elastic, muscular, and hybrid, each one having distinct mechanical properties and vulnerability to pathological changes [2–5].

The overall architecture of the arterial wall remains consistent across all the types, with the key distinguishing feature being the extent to which the muscular and elastic components are developed within the tunica media of the arterial wall. The muscular component consists of vascular smooth muscle cells (SMCs), whereas the elastic one is composed of elastic fibers capable of forming fenestrated elastic membranes, including the internal (IEM), external (EEM), and medial (intermediate) elastic membranes that are interposed among IEM and EEM. The IEM and EEM are fenestrated elastic membranes, with IEM demarcating the boundaries between the tunica intima and media and EEM, between the tunica media and adventitia. In this review, the authors categorize both IEM and EEM as components of the tunica media. Apart from providing elasticity, they act as barriers that limit the movement of substances and cells between adjacent layers of the vessel wall [2]. The fenestrae of the IEM are smaller than those of the medial elastic membranes. In addition to elastic and muscular components, the tunica media contains fibroblasts, mast cells, macrophages, lymphocytes, dendritic cells, adventitial cells, mesenchymal stem cells, collagen fibers, nerve endings, and an amorphous ground substance [6, 7].

Elastic arteries are characterized by a highly developed elastic component within the tunica media (Fig. 1 A), which is composed of numerous concentrically arranged fenestrated elastic membranes interconnected by elastic fibers. Together with the elastic fibers found in other layers of the arterial wall, the fenestrated elastic membranes and elastic fibers of the tunica media establish a unified elastic structure of the vessel. In the elastic arteries, the IEM and EEM are poorly demarcated, and their density and thickness increase with distance from the heart. In both the innermost and outermost layers of the tunica media, the elastic fibers are primarily oriented longitudinally, whereas in its central layer, they are arranged transversely (circumferentially). Longitudinal elastic fibers prevent arterial tortuosity, whereas transversal elastic fibers provide the elasticity required for reversible radial expansion in response to varying hemodynamic pressures. SMCs and fibroblasts are located between the fenestrated elastic membranes and organized either in a circular pattern or at an angle relative to the longitudinal axis of the vessel. A single layer of SMCs separates adjacent fenestrated elastic membranes. The fenestrated elastic laminas, along with elastic and collagen fibers, as well as SMCs and fibroblasts, are immersed in an amorphous ground substance.

A hybrid type represents a transitional artery type (Fig. 1 B). As arteries become more distant from the heart, the proportion of fenestrated elastic membranes and elastic fibers within the tunica media gradually decreases, while that of SMCs steadily increases. In hybrid arteries, the IEM and EEM are well defined, although the EEM is thinner than the IEM. The tunica media of hybrid type arteries contains fibroblasts, collagen fibers, and an amorphous ground substance.

Muscular arteries are characterized by a highly developed muscular component in the tunica media (Fig. 1 C). The SMCs in the tunica media of muscular arteries are oriented circumferentially, obliquely, or, less commonly, longitudinally. In some muscular arteries, longitudinally oriented SMCs are also present in the tunica intima and adventitia. The elastic component consists of several elas-

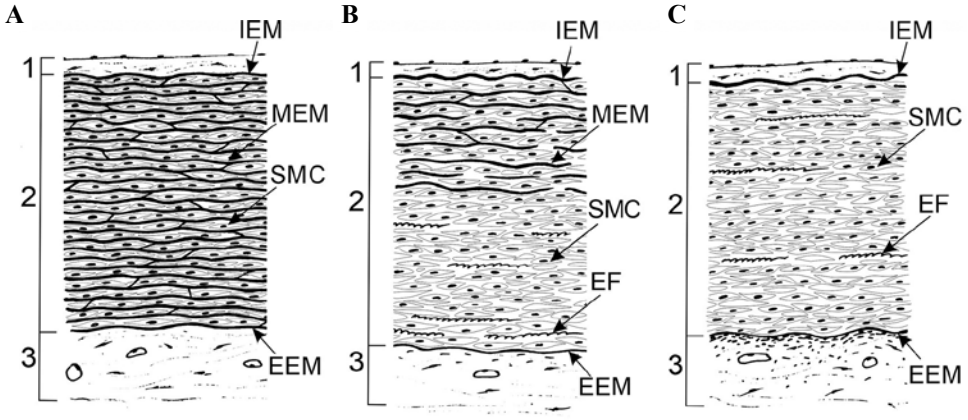


Fig. 1. Microstructure of the arterial wall.
A – elastic artery, B – hybrid artery, C – muscular artery
1 – tunica intima, 2 – tunica media, 3 – tunica adventitia. IEM – internal elastic membrane, EEM – external elastic membrane, MEM – medial elastic membrane, EF – elastic fibers, SMCs – smooth muscle cells

Рис. 1. Микроморфология стенки артерии.
А – артерия эластического типа, В – артерия смешанного типа, С – артерия мышечного типа
1 – внутренняя оболочка, 2 – средняя оболочка, 3 – адвентициальная оболочка артерии. IEM – внутренняя эластическая мембрана, EEM – наружная эластическая мембрана, MEM – эластическая мембрана средней оболочки, EF – эластические волокна, SMC – гладкие миоциты

tic fibers, the IEM, and EEM. The IEM is particularly well developed in muscular arteries; with decreasing arterial diameter, both the size and the number of pores within the IEM increase, whereas their density decreases. In contrast, the EEM is usually less prominent than the IEM and tends to disappear as the arterial diameter decreases; it is also absent in the intracranial and intraosseous arteries [8]. The SMCs, fibroblasts, collagen, and elastic fibers found within the arterial media are situated within the amorphous ground substance.

For educational purposes, hybrid type arteries may be subdivided into two categories: elastic-muscular and muscular-elastic. Elastic-muscular arteries are characterized by a predominance of the elastic component over the muscular one within the tunica media, whereas the opposite pattern is observed in muscular-elastic arteries. At the transition between these subcategories, the elastic and muscular components are present in approximately equal proportions.

In the human body, the tunica media of arteries undergoes gradual morphological changes with increasing distance from the heart, making it difficult to distinct arterial types and the boundaries between elastic, hybrid, and muscular arteries [9, 10]. As a result, the classification of individual arteries remains inconsistent across the scientific literature [11, 12]. Traditionally, arteries have been classified according to the number of elastic membranes or fibers within the tunica media. However, Y. Kato et al. argued that classification should consider not only their quantity but also their relative volume [13].

Given the subjective and often arbitrary delineation of hybrid arteries, examining the structure of the arterial media is crucial for understanding the functional properties of individual vessels and the pathological processes that affect them. Accordingly, this literature review aimed to summarize current knowledge of the structure of the tunica media in arteries of the human systemic and pulmonary circulation. Despite substantial advances in our understanding of arterial structure in experimental animals, comparable data for humans remain limited [14–16]. Furthermore, human anatomy textbooks occasionally describe the structure of analogous animal vessels, which may be confusing.

The literature search was conducted between October 2025 and January 2026 using four electronic databases: eLIBRARY, PubMed, Google Scholar, and ScienceDirect. The search included the following keywords: “human,” “artery,” “anatomy and histology,” “elastin,” and “smooth muscle cells,” without restrictions on publication date or language.

Human arteries of pulmonary circulation

The pulmonary trunk is traditionally classified as an elastic artery. During fetal development, the pressure in the pulmonary artery is comparable to that in the aorta, and the tunica media of these vessels therefore exhibits similar structural characteristics. At this stage and early postnatal stages, the tunica media of the pulmonary trunk contains densely packed concentric fenestrated elastic membranes. During the first month of life, pulmonary arterial pressure declines markedly and subsequently remains relatively stable. Over the next two years, the elastic structure of the pulmonary trunk undergoes involution, so that in adults, the tunica media of the pulmonary trunk contains fragmented elastic membranes with numerous ruptures [17]. According to D.B. Antipas et al., the volume fraction of SMCs in the adult pulmonary trunk exceeds that of collagen and elastic fibers. Consequently, they suggest that the human pulmonary trunk during this phase of postnatal ontogenesis can be classified as a hybrid type artery [11].

The right and left pulmonary arteries are classified as elastic arteries. Their tunica media contains numerous fenestrated elastic membranes, which may occasionally be discontinuous, and a thin IEM [17]. Pulmonary arteries with a diameter of approximately 2 mm are categorized as hybrid type arteries: their tunica media includes four or more fenestrated elastic membranes, while the proportion of SMCs progressively increases with decreasing arterial diameter [17]. With further reduction in vessel size, fenestrated elastic membranes within the tunica media disappear, and in arteries smaller than 1 mm in diameter, only the EEM and IEM remain identifiable [18]. Intra-acinar pulmonary arteries are primarily classified as muscular arteries [17].

Human arteries of systemic circulation

The aorta is classified as an elastic artery. Being the longest vessel in the body, it exhibits regional variations in the structure of its tunica media [19, 20]. The tunica media gradually becomes thinner along the length of the aorta, from the arch to the bifurcation. The quantity of fenestrated elastic membranes decreases from 50–60 in the ascending aorta, aortic arch, and descending thoracic aorta to 25–30 in the descending abdominal aorta [21], with a significant reduction in their number below the origin of the renal arteries. Their thickness also decreases with increasing distance from the heart [5]. Notably, various sections of the aortic wall at the bifurcation experience different hemodynamic stresses, which results in distinct structural characteristics. The aortic bifurcation is characterized by a high concentration of elastic fibers [22].

Studies on the human descending abdominal aorta have shown that maturation is accompanied by an increase in the number of fenestrated elastic membranes, a reduction in their thickness, and an expansion of the interlamellar spaces. The composition of the tunica media remains stable between 30 and 45–55 years of age, after which both the quantity and thickness of the fenestrated elastic membranes decline. Throughout the postnatal ontogenesis, the number of SMCs in the tunica media of the wall of the human descending abdominal aorta remains relatively unchanged [23].

All branches of the aorta are classified as elastic arteries at their origin, yet their wall structure gradually changes with increasing distance from the aorta.

The coronary arteries acquire the characteristics of muscular arteries within the first centimeter after their origin

from the aorta. Accordingly, they exhibit well-defined IEM and EEM [8, 19].

The common carotid artery gradually transitions from an elastic type in its proximal segment to a hybrid type at the bifurcation. Proximally, elastic laminae and fibers are evenly distributed throughout the tunica media [13]. In contrast, the carotid sinus contains a higher proportion of SMCs, while the elastic membranes and fibers are concentrated predominantly in the inner half of the tunica media adjacent to the IEM, becoming progressively less abundant toward the EEM.

The internal and external carotid arteries are classified as muscular arteries [24]. The transitions from the elastic wall structure of the common carotid artery to the muscular one of the internal and external carotid arteries is gradual, with the extent of this transition zone differing among individuals. In some cases, the internal and external carotid arteries exhibit muscular characteristics 5 mm distal to the common carotid bifurcation, whereas in others, the transitional segment extends up to 15 mm. Moreover, the length of this segment can differ considerably between the right and left sides of the same individual [25]. In the extracranial part of the internal carotid artery, both the IEM and EEM are present, and a small number of longitudinally oriented elastic fibers are found in the tunica media adjacent to the IEM. A similar organization is observed in the external carotid artery, which is characterized by well-developed IEM and EEM and a limited number of elastic fibers within the tunica media [26]. In contrast, the EEM is absent in the horizontal segment of the cavernous internal carotid artery and its intracranial section.

The EEM is absent in all intracranial arteries. The anterior, middle, and posterior cerebral arteries, together with the anterior and posterior communicating arteries, the basilar artery, and the anterior and posterior inferior cerebellar arteries, are classified as muscular arteries. They are characterized by a well-defined IEM and only a few elastic fibers within the tunica media. The IEM is thinner in the posterior arteries of the cerebral arterial circle than in the anterior arteries [19, 27].

Although the basilar artery is generally classified as a muscular artery, some researchers consider it a hybrid artery. This discrepancy in the classification reflects the considerable morphologic variability of the vessel and the difficulties in distinguishing between hybrid and muscular arteries. Elastic fibers are present within the tunica media, but their distribution varies along the course of the vessel: in the distal (caudal) segment they are primarily concentrated in the inner portion, whereas in the proximal (cranial) segment, they are evenly distributed throughout the tunica media [28].

The subclavian artery is classified as an elastic artery, with elastic membranes and fibers evenly distributed throughout the tunica media [29].

The vertebral artery, the first branch of the subclavian artery, exhibits structural changes along its course. Its proximal (prevertebral) section is characterized as a hybrid type artery, whereas the remaining segments are muscular. In the proximal segment, both IEM and EEM are present; elastic fibers are predominantly located in the inner half of the tunica media. In the middle segment, the IEM and EEM are retained, although the elastic component of the tunica media is less developed. In the distal segment, which penetrates the meninges and joins the basilar artery, EEM may be inconsistent, thinned, or entirely absent [10].

At its origin from the subclavian artery, the internal thoracic artery is classified as an elastic artery. Its tunica media typically contains approximately 10 fenestrated elastic membranes and both IEM and EEM. In 18% of cases, the vessel maintains its elastic nature throughout its entire length. In the remaining cases, the proximal and distal 20–30% of the artery exhibit a hybrid structure, characterized by 5–7 fenestrated elastic membranes and a predominance of SMCs over the elastic component. In the terminal segment, the wall structure undergoes a gradual or abrupt transition from the hybrid to the muscular type. Therefore, the proximal 1–2 cm of the musculophrenic artery is of the hybrid type, whereas the remainder of the vessel is muscular. The superior epigastric artery is also categorized as muscular [30, 31].

The axillary artery is classified as an elastic artery, but gradually changes to a hybrid structure over a length of up to 3 cm [8]. The brachial artery is, in contrast, a muscular artery [32]; 5 cm proximal to the elbow, it contains a well-defined IEM and a poorly defined EEM. Short elastic fibers are found in the tunica media among the SMCs, with the highest density adjacent to the IEM [33]. The radial and ulnar arteries are likewise muscular arteries and are marked by a well-developed IEM, thin and fragmented EEM, and scattered elastic fibers within the tunica media. In the radial artery, elastic fibers account for up to 18% of the tunica media volume [30, 34].

The wall structure of intercostal arteries varies along their length. Examination of the 4th to 9th intercostal arteries identified three morphological patterns: (1) a transition from the elastic type to the hybrid and subsequently to the muscular type; (2) a transition from the hybrid type to the muscular; (3) a muscular structure maintained throughout almost the entire arterial length. The second pattern is the most common [30].

Bronchial arteries are muscular arteries characterized by a well-defined IEM and a poorly defined EEM. At the level of the large bronchi, histological analysis demonstrates the structural differences between the walls of bronchial and pulmonary arteries, reflecting their muscular and elastic organization, respectively [8].

The celiac trunk is of the muscular type, characterized by a well-developed IEM and a poorly developed EEM [29]. However, within the first centimeter from its origin from the aorta, the tunica media transitions to the hybrid and muscular vessel type [8]. The branches of the celiac trunk are also classified as muscular arteries. For instance, the splenic artery is characterized by a well-developed IEM and a less developed EEM [19, 29, 35].

The histological composition of certain arteries within the common hepatic artery basin has been studied in detail. The common hepatic artery and the gastroduodenal artery are classified as muscular arteries, with well-defined IEM and EEM [30, 35]. The right gastroepiploic artery is also of the muscular type; however, its elastic components vary along its course. The proximal segment contains a well-developed IEM and lacks EEM that appears in the middle segment and becomes well-developed distally [30, 36].

At its origin from the aorta, the superior mesenteric artery has a wall rich in elastic fibers. Over the proximal 1.5–3 cm, however, its structure transitions to the muscular type. This transition is accompanied by a notable reduction in elastin, an increase in the number of SMCs, and the appearance of distinct IEM and EEM. These features become more pronounced towards the curvature and distal regions of the vessel [37]. The jejunal and ileal arteries, together with the arterial arches and the vasa recta originating from them, are muscular arteries [38, 39].

The wall structure of the renal artery changes along its course, transitioning from elastic pattern in the proximal section to the muscular pattern in its distal section. According to J. Janzen et al., this transition occurs within 1 cm of the artery from its origin from the aorta [40]. As a result, the number of elastic membranes and fibers within the tunica media decreases from the proximal to the middle and distal segments. The IEM is present throughout the entire length of the artery, whereas the EEM is only weakly developed in the proximal segment and becomes more prominent in the middle and distal segments. In approximately one-third of cases, longitudinally oriented SMCs are present in the tunica adventitia of the middle and distal segments [41].

The inferior mesenteric artery is classified as a muscular artery [42]. However, detailed histological data on the wall of the inferior mesenteric artery are scarce. Based on the available evidence, its wall is likely to undergo a rapid transition from an elastic to a muscular pattern near its origin from the aorta, similar to the other visceral branches of the abdominal aorta.

The common iliac artery is an elastic artery that transitions into a hybrid one over the first 1–3 cm of its course [8]. During the transition, the IEM and EEM become well-defined [5, 19, 43]. Within the inner two-thirds of the tunica media, thin elastic fibers that are arranged both longitudinally and circumferentially and partially coalesce to form concentric fenestrated elastic membranes, between which longitudinally oriented SMCs are interposed. In contrast, circumferentially oriented SMCs are confined to the outer third of the tunica media [44].

The internal iliac artery is a hybrid artery characterized by a well-developed IEM and a less prominent EEM [5, 43]. Along its course, the vessel gradually acquires the characteristics of a muscular artery, a pattern that is also observed in its branches, which are muscular in type.

In fetuses and newborns, the common iliac artery and the internal iliac artery are classified as elastic arteries, which is associated with the unique characteristics of fetal circulation [44]. In cases of a single umbilical artery, only the common iliac artery and internal iliac artery giving rise to that vessel exhibit elastic properties; on the contralateral side, they are muscular [1]. In fetuses, the elastic component is distributed unevenly within the vessel wall. A continuous and thick IEM together with multiple fenestrated elastic membranes within the tunica media is present in the lateral wall of the common iliac artery and the dorsomedial wall of the internal iliac artery. In the remaining regions, instead of a well-defined IEM, only a few thin, longitudinally arranged elastic fibers are present; the elastic component of the tunica media contains a thin network of elastic fibers [44]. As maturation progresses, the composition of the tunica media undergoes progressive remodeling: the interlamellar spaces expand, and the number of SMCs increases [1].

The umbilical arteries are muscular arteries with fragmented or completely absent IEM and no EEM [45].

The external iliac artery is a muscular artery with well-developed IEM and EEM [5, 43, 44]. In children aged 3–4.5 years, the tunica media contains only circumferentially arranged SMCs; thereafter, longitudinally oriented SMCs begin to appear in its inner third. The branches stemming from the external iliac artery are classified as muscular arteries. For instance, the inferior epigastric artery is a muscular artery that exhibits prominent IEM and EEM along with a limited quantity of elastic fibers in its tunica media [30, 36, 46].

The femoral, popliteal, peroneal, and posterior tibial arteries are muscular, having well-defined IEM and EEM and a small number of elastic fibers in the tunica media [47].

Clinical significance

The structural organization of the wall and hemodynamic conditions determine the predisposition of different artery types to specific pathological processes. For example, elastic arteries are most susceptible to aneurysms, which is associated with age-related or pathological fragmentation of the elastic frame, including that associated with genetic syndromes [3]. Although aneurysms also occur in muscular arteries, they typically develop at sites of IEM disruption [2, 27]. Atherosclerotic lesions are more common in muscular arteries, especially in areas with increased mechanical stress caused by elevated pressure and disturbed blood flow, such as the coronary arteries and cerebral arteries. Mechanical stress causes damage to the IEM, the integrity of which is important for the separation of substances from the intima to the media, as well as for optimal interaction between endothelial cells and vascular SMCs [2]. The structural features of the arterial wall are taken into account when selecting an autograft for coronary artery bypass grafting [30, 36].

Human arteries exhibit considerable individual variability in their wall structure that undergoes alterations throughout the postnatal phase, enhancing our comprehension of hemodynamic transformations during development.

With aging, arterial elasticity declines following the damage to elastic membranes and the accumulation of collagen fibers [4]. These age-related alterations contribute to the development of vascular diseases and provide important insights into the mechanisms underlying their progression. In addition, growing attention has been directed towards anatomical variations of the arterial system [48–50]. Such variations may lead to unique hemodynamic characteristics and are often accompanied by differences in arterial wall structure [1, 37]. Therefore, detailed knowledge of arterial wall structure is crucial in understanding both normal vascular function and pathological changes.

Conclusion

Human arteries can be subdivided into two distinct types: elastic-muscular arteries, in which the elastic component predominates, and muscular-elastic arteries, in which the muscular component is more prominent. This subclassification facilitates the identification of transitional segments between elastic and muscular arteries and recognition of hybrid type arteries.

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References/Литература

1. *Meyer WW, Lind J*. Iliac arteries in children with a single umbilical artery. Structure, calcifications, and early atherosclerotic lesions. Arch Dis Child. 1974;49(9):671–9. DOI: 10.1136/adc.49.9.671.
2. *Sims FH, Chen X, Gavin JB*. The importance of a substantial elastic lamina subjacent to the endothelium in limiting the progression of atherosclerotic changes. Histopathology.1993;23(4):307–17. DOI: 10.1111/j.1365-2559.1993.tb01213.x.
3. *Halabi CM, Kozel BA.* Vascular elastic fiber heterogeneity in health and disease. Curr Opin Hematol. 2020;27(3):190–6. DOI: 10.1097/MOH.0000000000000578.
4. *Jadidi M, Razian SA, Habibnezhad M, Anttila E, Kamenskiy A.* Mechanical, structural, and physiologic differences in human elastic and muscular arteries of different ages: comparison of the descending thoracic aorta to the superficial femoral artery. Acta Biomater. 2021;119:268–83. DOI: 10.1016/j.actbio.2020.10.035.
5. *Liyanage L, Musto L, Budgeon C, Rutty G, Biggs M, Saratzis A et al.* Multimodal structural analysis of the human aorta: from valve to bifurcation. Eur J Vasc Endovasc Surg. 2022;63(5): 721–30. DOI: 10.1016/j.ejvs.2022.02.005.
6. *Aschacher T, Schmidt K, Aschacher O, Eichmair E, Baranyi U, Winkler B et al.* Telocytes in the human ascending aorta: characterization and exosome-related KLF-4/VEGF-A expression. J Cell Mol Med. 2021;25(20):9697–709. DOI: 10.1111/jcmm.16919.
7. *Dolbnya A, Ivanova V, Serebryakova O, Pleshko R, Milto I.* Telocytes: history, origin, identification, structure, distribution, and functions. Histochem Cell Biol. 2025;163(1):86. DOI: 10.1007/s00418-025-02413-1.
8. *Vuong PN, Berry C.* Histology of vessels. In: The Pathology of Vessels. Paris: Springer, 2002. P. 1–23. DOI: 10.1007/978-2-8178-0786-7_1.
9. *Kamenskiy AV, Pipinos II, Carson JS, MacTaggart JN, Baxter BT.* Age and disease-related geometric and structural remodeling of the carotid artery. J Vasc Surg. 2015;62(6):1521–8. DOI: 10.1016/j.jvs.2014.10.041.
10. *Desai AR, Chavan SK*. Histo-morphometric study of various segments of vertebral artery in human cadavers. Int J Anat Res. 2019;7(1.1):6102–7. DOI: 10.16965/ijar.2018.415.
11. *Antipas DB, Milovanova ZP, Zavalishin NN.* The structure and mechanical properties of the human pulmonary trunk and its valves. Morfologiia. 1993;104(3-4):73–80. PMID: 7889164.
12. *de Sa M, Moshkovitz Y, Butany J, David TE.* Histologic abnormalities of the ascending aorta and pulmonary trunk in patients with bicuspid aortic valve disease: clinical relevance to the ross procedure. J Thorac Cardiovasc Surg. 1999;118(4):588–94. DOI: 10.1016/S0022-5223(99)70002-4.
13. *Kato Y, Mizutani T, Otsuka N, Ezure H, Inoue Y*. Quantitative analysis of the elastic fiber in the tunica media at the carotid bifurcation. Okajimas Folia Anat Jpn. 2018;95(2):23–27. DOI: 10.2535/ofaj.95.23.
14. *Tomášek P, Tonar Z, Grajciarová M, Kural T, Turek D, Horáková J et al.* Histological mapping of porcine carotid arteries – an animal model for the assessment of artificial conduits suitable for coronary bypass grafting in humans. Ann Anat. 2020;228:151434. DOI: 10.1016/j.aanat.2019.151434.
15. *McCreary DD, Skirtich NF, Andraska EA, Tzeng E, McEnaney RM*. Survey of the extracellular matrix architecture across the rat arterial tree. JVS Vasc Sci. 2021;3:1–14. DOI: 10.1016/j.jvssci.2021.08.001.
16. *Serebryakova ON, Ivanova VV, Milto IV.* Structural features of the wall of the ascending aorta of premature rats. Cell Tiss Biol. 2024;18(2):221–8. DOI: 10.1134/S1990519X23700098.
17. *Townsley MI.* Structure and composition of pulmonary arteries, capillaries, and veins. Compr Physiol. 2012;2(1):675–709. DOI: 10.1002/cphy.c100081.
18. *Aiello VD, Gutierrez PS, Chaves MJ, Lopes AA, Higuchi ML, Ramires JA.* Morphology of the internal elastic lamina in arteries from pulmonary hypertensive patients: a confocal laser microscopy study. Mod Pathol. 2003;16(5):411–6. DOI: 10.1097/01.MP.0000067685.57858.D7.
19. *Nakashima Y, Chen YX, Kinukawa N, Sueishi K.* Distributions of diffuse intimal thickening in human arteries: preferential expression in atherosclerosis-prone arteries from an early age. Virchows Arch. 2002;441(3):279–88. DOI: 10.1007/s00428-002-0605-1.
20. *Concannon J, Dockery P, Black A, Sultan S, Hynes N, McHugh PE et al.* Quantification of the regional bioarchitecture in the human aorta. J Anat. 2020;236(1):142–55. DOI: 10.1111/joa.13076.
21. *Thiene G, Basso C, Della Barbera M*. Pathology of the aorta and aorta as homograft. J Cardiovasc Dev Dis. 2021;8(7):76. DOI: 10.3390/jcdd8070076.
22. *Meyer WW, Kauffman SL, Hardy-Stashin J.* Studies on human aortic bifurcation. Part 1. Histo-architecture of the bifurcation. Atherosclerosis. 1980;37(3):377–88. DOI: 10.1016/0021-9150(80)90142-2.
23. *Yuzefovich NA, Studenikina TM, Melnikov IA*. Age features of the structural changes in elastic membranes of the abdominal aorta. Proceedings of the National Academy of Sciences of Belarus,

Medical series. 2017;(3):45–55 (In Russ.). Available from: https://www.elibrary.ru/item.asp?id=18965846 (accessed 06.03.2026).
24. *Gomes CR, Chopard RP*. A morphometric study of age-related changes in the elastic systems of the common carotid artery and internal carotid artery in humans. Eur J Morphol. 2003;41(3-4): 131–7. PMID: 16225264.
25. *Janzen J, Lanzer P, Rothenberger-Janzen K, Vuong PN.* Variable extension of the transitional zone in the medial structure of carotid artery tripod. Vasa. 2001;30(2):101–6. DOI: 10.1024/0301-1526.30.2.101.
26. *Kinoshita H, Umezawa T, Omine Y, Kasahara M, Rodríguez-Vázquez JF, Murakami G et al.* Distribution of elastic fibers in the head and neck: a histological study using late-stage human fetuses. Anat Cell Biol. 2013;46(1):39–48. DOI: 10.5115/acb.2013.46.1.39.
27. *Trushel NA, Pivchenko PG, Melnikov IA.* Structural peculiarities of the wall of the vessels of the cerebral arterial circle in the area of bifurcations in people of different age. Morfologiia. 2012;142(5):39–43 (In Russ.). Available from: https://www.elibrary.ru/item.asp?id=17951511 (accessed 06.03.2026).
28. *Gudiene D, Baltrusaitis K, Rackauskas M*. Features of elastic tissue staining and its arrangement in the wall of human basilar artery. Medicina (Kaunas). 2003;39(10):946–50. PMID: 14578635.
29. *Federici D, Torii S, Ciuffreda M, Galletti L, Lorini L, Bonanomi E et al.* Coronary pathology of inherited generalized arterial calcification of infancy: a case report. Cardiovasc Pathol. 2018;36:15–9. DOI: 10.1016/j.carpath.2018.05.001.
30. *van Son JAM, Smedts FMM, Yang CQ, He GW.* Histology and comparison of arterial grafts used for coronary surgery. In: GW He (ed.). Arterial grafting for coronary artery bypass surgery. Berlin, Heidelberg: Springer, 2006. P. 3–16. DOI: 10.1007/3-540-30084-8_1.
31. *Muradov MM, Molochkov AV, Ivanova AG, Fedorov DN, Sidorov RV, Zhbanov IV et al*. Morphology internal thoracic artery in patients with coronary artery disease in different age groups. Bulletin of Pirogov National medical & surgical center. 2015;10(4):11–18 (In Russ.). Available from: https://www.elibrary.ru/item.asp?id=26506834 (accessed 06.03.2026).
32. *Hartman PC, Xhakaza NK.* The prevalence of the tortuous upper limb arteries and its effects on the histological structure of the arterial walls. Int J Morphol. 2025;43(3):908–13. Available from: https://intjmorphol.com/wp-content/uploads/2025/06/Art_27_433_2025.pdf (accessed 06.03.2026).
33. *Sorensen KE, Kristensen IB, Celermajer DS*. Atherosclerosis in the human brachial artery. J Am Coll Cardiol. 1997;29(2):318–22. DOI: 10.1016/s0735-1097(96)00474-3.
34. *Gaudino M, Crea F, Cammertoni F, Mazza A, Toesca A, Massetti M*. Morpho-functional features of the radial artery: implications for use as a coronary bypass conduit. Ann Thorac Surg. 2014;98(5): 1875–9. DOI: 10.1016/j.athoracsur.2014.06.101.
35. *Kimani SM, Ogeng'o JA, Saidi H, Ndung'u B.* Comparative intimal-media morphology of the human splenic and common hepatic arteries. J Morphol Sci. 2011;28(1):52–6. Available from: https://www.researchgate.net/publication/236159357_Comparative_intimal-media_morphology_of_the_human_splenic_and_common_hepatic_arteries (accessed 06.03.2026).
36. *van Son JA, Smedts F, Vincent JG, van Lier HJ, Kubat K.* Comparative anatomic studies of various arterial conduits for myocardial revascularization. J Thorac Cardiovasc Surg. 1990;99(4):703–7. PMID: 2319794.
37. *Mei J, Yu H, Qin L, Zhang J, Xu H, Xue T et al.* Multimodal study of the superior mesenteric artery wall. Ann Vasc Surg. 2024;102:92–100. DOI: 10.1016/j.avsg.2023.11.031.
38. *Conley D, Hurst PR, Stringer MD.* An investigation of human jejunal and ileal arteries. Anat Sci Int. 2010;85(1):23–30. DOI: 10.1007/s12565-009-0047-9.
39. *Jia Z, Mei J, Ding W, Zhao X, Gong W, Yu H et al.* The pathogenesis of superior mesenteric artery dissection: an in-depth study based on fluid-structure interaction and histology analysis. Comput Methods Programs Biomed. 2022;226:107187. DOI: 10.1016/j.cmpb.2022.107187.
40. *Janzen J, Lanzer P, Rothenberger-Janzen K, Vuong PN*. The transitional zone in the tunica media of renal arteries has a maximal length of 10 millimetres. Vasa. 2000;29(3):168–72. DOI: 10.1024/0301-1526.29.3.168.
41. *Mompeó-Corredera B, Hernández-Morera P, Castaño-González I, Quintana-Montesdeoca MDP, Mederos-Real N.* Regions of the human renal artery: histomorphometric analysis. Anat Cell Biol. 2022;55(3):330–40. DOI: 10.5115/acb.22.072.
42. *Sakamoto W, Yamada L, Suzuki O, Kikuchi T, Okayama H, Endo H et al.* Microanatomy of inferior mesenteric artery sheath in colorectal cancer surgery. J Anus Rectum Colon. 2019;3(4): 167–74. DOI: 10.23922/jarc.2019-016.
43. *Kazim M, Razian SA, Zamani E, Varandani D, Shahbad R, Zolfaghari Sichani A et al*. Mechanical, structural, and morphological differences in the iliac arteries. J Mech Behav Biomed Mater. 2024;155:106535. DOI: 10.1016/j.jmbbm.2024.106535.
44. *Meyer WW, Lind J*. Calcifications of iliac arteries in newborns and infants. Arch Dis Child. 1972;47(253):364–72. DOI: 10.1136/adc.47.253.364.
45. *Stehbens WE, Wakefield JS, Gilbert-Barness E, Zuccollo JM.* Histopathology and ultrastructure of human umbilical blood vessels. Fetal Pediatr Pathol. 2005;24(6):297–315. DOI: 10.1080/15227950500503660.
46. *Barner HB, Naunheim KS, Fiore AC, Fischer VW, Harris HH*. Use of the inferior epigastric artery as a free graft for myocardial revascularization. Ann Thorac Surg. 1991;52(3):429–37. DOI: 10.1016/0003-4975(91)90902-3.
47. *Struczewska P, Razian SA, Townsend K, Jadidi M, Shahbad R, Zamani E et al.* Mechanical, structural, and physiologic differences between above and below-knee human arteries. Acta Biomater. 2024;177:278–99. DOI: 10.1016/j.actbio.2024.01.040.
48. *Pandey SK, Bhattacharya S, Mishra RN, Shukla VK*. Anatomical variations of the splenic artery and its clinical implications. Clin Anat. 2004;17(6):497–502. DOI: 10.1002/ca.10220.
49. *Rybakov AG, Loshkarev IA, Machinsky PA, Plotnikova NA*. Variant anatomy of aortic arch branches. Russian Journal of Operative Surgery and Clinical Anatomy. 2018;2(2):35–36 (In Russ.). DOI: 10.17116/operhirurg20182235.
50. *Gayvoronsky IV, Bykov PM, Gayvoronskaya MG, Sinenchenko GI, Semenova AA*. The variant anatomy of the celiac trunk and its branches in adult men and women with various body shape. Morphological newsletter. 2020;28(2):32–40 (In Russ.). DOI: 10.20340/mv-mn.2020.28(2):32-40.

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