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APPLIED MORPHOLOGY OF THE AORTA

ПРИКЛАДНА МОРФОЛОГІЯ АОРТИ

Резюме. Це дослідження має на меті описати особливості кровопостачання жирової подушки аорти та дослідити мінливість кореляції між лівим блукаючим нервом та лівим поворотним гортанним нервом стосовно дуги аорти. Крім того, дослідження аналізує вплив форми аорти на схильність до атеросклерозу.
Матеріал і методи. Дослідження було проведено на 185 суб'єктах, яким було проведено розтин упродовж 24 годин після смерті. Вибірка включала осіб віком від 16-тижневих плодів до 96 років. Були використані різні методи дослідження, включаючи спостереження за зразками розтину аорти, морфометричний аналіз, тонку анатомічну дисекцію, фарбування реактивом Шиффа, гістологічне дослідження та ін'єкцію кольорового желатину.
Результати. Дослідження визначило vasa vasorum internee як основне джерело васкуляризації висхідної аорти, що має значні клінічні наслідки. Анатомічний зв'язок між лівим блукаючим нервом, лівим поворотним гортанним нервом та дугою аорти відхиляється від класичних описів і залежить від конституційного типу людського тіла. Крім того, було виявлено, що схильність аорти до атеросклерозу корелює з торакоабдомінальним індексом просвіту аорти.
Висновки. Враховуючи нові дані, представлені в цій статті, щодо характеристик кровопостачання висхідної аорти та варіацій розташування лівого блукаючого нерва та лівого поворотного гортанного нерва, ці результати відіграють вирішальну роль у зменшенні післяопераційних ускладнень.
Ключові слова: висхідна аорта, дуга аорти, жирова подушка висхідної аорти, лівий поворотний гортанний нерв, анатомічні варіанти.

Few blood vessels in the human body have been the focus of as many scientific studies as the aorta. It may appear that every aspect of it has already been explored, including its ontogenesis, morphogenesis, macro- and microstructures, wall properties, and sources of nerve and blood supply. However, a review of over 800 scientific papers on the morphology and physiology of the aorta indicates that significant uncertainties persist in this field.

Two aspects might attract attention:

– A multitude of articles published by clinicians, particularly cardiothoracic surgeons, from various countries, deal with the issue of lacking morphological evidence explaining certain postoperative complications and explores ways to prevent them.

– At the same time articles on the morphology of the aorta have been rarely published during the last two decades.

The following items remained unclear:

- Functional anatomy of the fat pads;
- Paraganglia and glomic structures;
- Regional specific features of the blood and nerve supply;
- Location of the reflexogenic regions of the aorta;
- Dependence of the aorta morphology on the body constitutional type;
- Some specific features of aortic syntopy
- Confused terminology preventing rapid implementation.

Clinicians have reported high mortality rates, loss of work capacity, and disability among the population, alongside a high prevalence of heart and aortic diseases, particularly in patients of working age. Cardiac surgeons are concerned about the frequency of postoperative complications, such as atrial fibrillation, bleeding, and phonetic issues. The economic impact is also significant, as Jonathan S. Steinberg highlights in his article, «Postoperative Atrial Fibrillation: A Billion-Dollar Problem» (J. Am. Coll. Cardiol. 2004;43:1001-1003). A thorough knowledge of the anatomy of the heart and aorta is a prerequisitefor the successful completion of the myriad procedures performedby the cardiothoracic surgeons.

Material and methods. A total of 257 fresh human aortas and 120 embalmed aortas were collected from the dissection room. Examination of autopsied specimens, detailed anatomical dissection, staining with Schiff reagent, histological analysis, injection of colored gelatin, and statistical analysis.

Research results and their discussion. Nowadays, it has become clear that overlooking periaortic and heart fat pads may lead in some cases to errors of diagnosis, in others can cause postoperative complications. The fat pad located on the anterior surface (Fig. 1) of the ascending aorta has increased clinicians' interest in recent years.

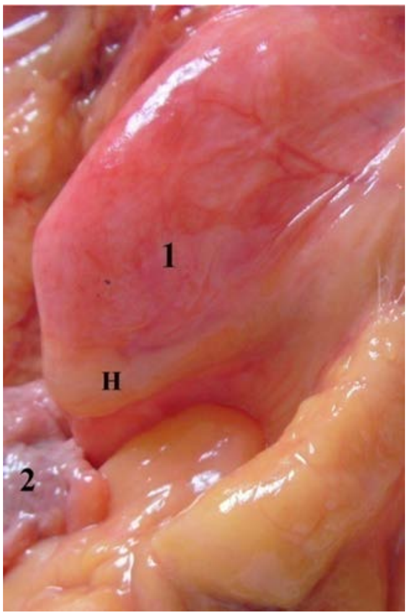

Fig. 1. Fat pad (H) of the ascending aorta (1); 2 – auricle of the right atrium

There is a place where many surgical manipulations are performed, such as: access and application of haemostatic forceps; aortic cannulation and aortic cross-clamping (proximally), this fat pad itself is often the cannulation site for the administration of antegrade cardioplegia. In coronary bypass procedures, the proximal anastomoses are usually performed with partial cross-clamping of the ascending aorta, and the fat in this region is removed to facilitate the construction of these anastomoses.

If it is the result of repetitive contact with the right atrial appendage then perhaps one would expect it to be absent in children and become more apparent with age. It does not increase in size with aging. Moreover, it is particularly noticeable in fetuses and little children (Fig. 2). An explanation might be, that in a developing heart, the relative size of the atrial appendage is greater and thus its contact with the aorta is more forceful. Epicardial fat pad of ascending aorta in the fetus can be seen with the naked eye. The amount of periaortic fat bears no constant relation to the quantity of general body fat. In several obese persons and a few undernourished ones, fat pad thickness was increased, in others the opposite was found. Atrophic hearts nearly always possess a thickened layer of fat, regardless of other pathological changes.

It would not make sense to mention these obvious facts without considering the clinical importance of fat accumulation and its close relationship with the vascular network's structure. Many scientific papers indicate the following sources of blood supply to the ascending aorta: coronary arteries, bronchial arteries, mediastinal arteries, and the arterial vessels branching from the aorta to other organs.

Besides the sources of blood supply to the RFP area described by other authors, we identified the vasa vasorum internae by injecting colored gelatin into the ascending aorta and staining with Schiff reagent. These vessels do not leave the aortic wall. Their number ranges from 1 to 7, with the largest supplying blood to the RFP. When adipose tissue is poorly developed, blood vessels originating from the upper part of the concave surface of the intrapericardial aorta can be seen with the naked eye. These vessels descend and move to the right, toward the fat pad of the ascending aorta (Fig. 3).

We found data on the vascularization of the chemoreceptor area of the aorta in I. Comroe (1939). It is accepted that the carotid bodies, along with the aortic ones, make up a chemosensitive system. The author describes a constant vessel in dogs that starts from the dorsal side of the aortic arch at the level of the brachiocephalic trunk. In some cases, in the absence of the indicated vessel, a branch starting from the initial portion of the brachiocephalic trunk is detected. Since the chemoreceptor zone is located between the aorta and the pulmonary artery, the possibility of its vascularization from the pulmonary artery was tested. The answer was negative.

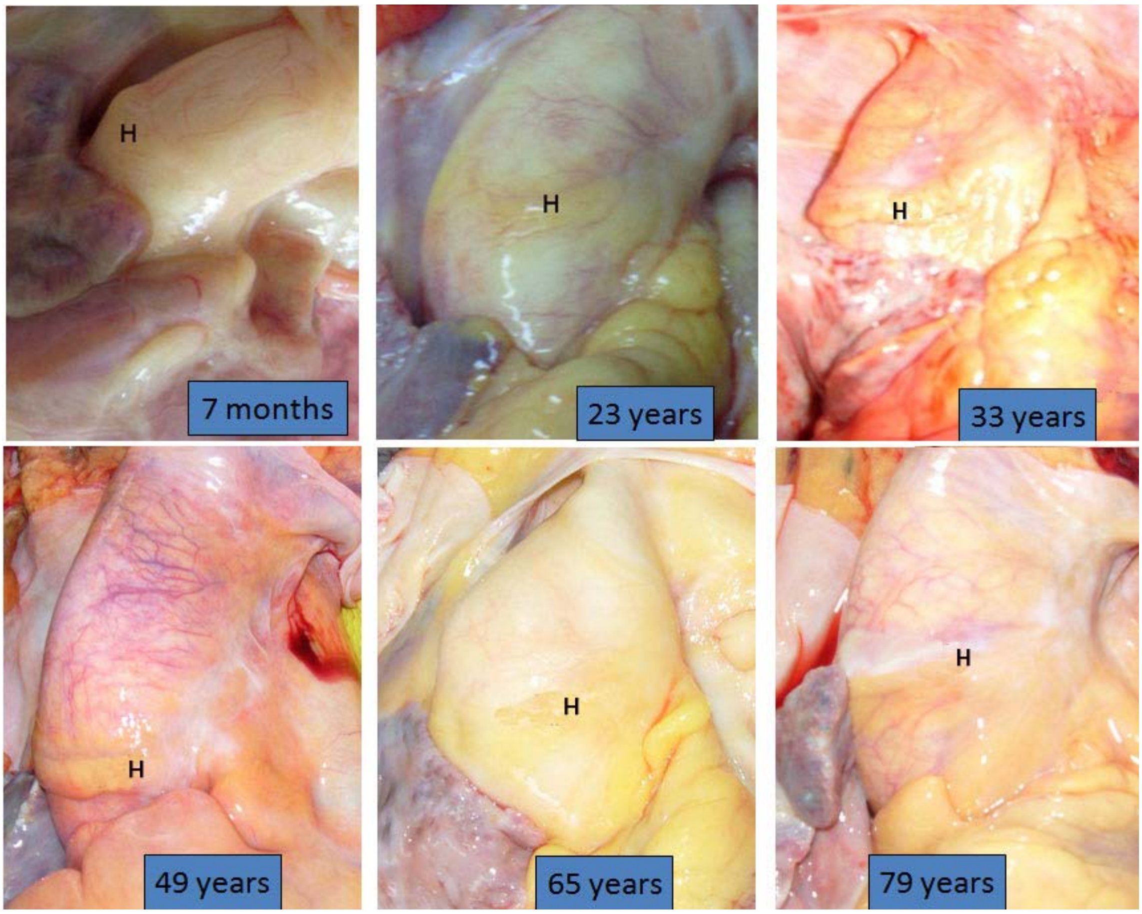

Fig. 2. Fat pad of ascending aorta at different ages

Our studies revealed that branches of the ascending aorta directed toward the fat pad of the ascending aorta were always visible, either with the naked eye or through Schiff's reagent staining (Fig. 3, 4). All they pierce the glomic structures.

In vascular surgery, in auto -, in homo – and in heterotransplantations, a special role is played by the vascularization and innervation of the transplant wall, as well as the surrounding tissues. Naturally, the result of transplantation depends not only on the protein compatibility of tissues, but also on the vasa vasorum of the transplant with its innervation apparatus, its age features and the ability to regenerate. Aortic fat pad is removed before resorting to the indicated procedures, to facilitate access. Blood pressure in vasa vasorum internae with genesis from AAs is high, their damage is complicated by abundant bleeding. This fact contributes to the appearance in the postoperative period (in cardiac surgery) of hemorrhages that require re-sternotomy.

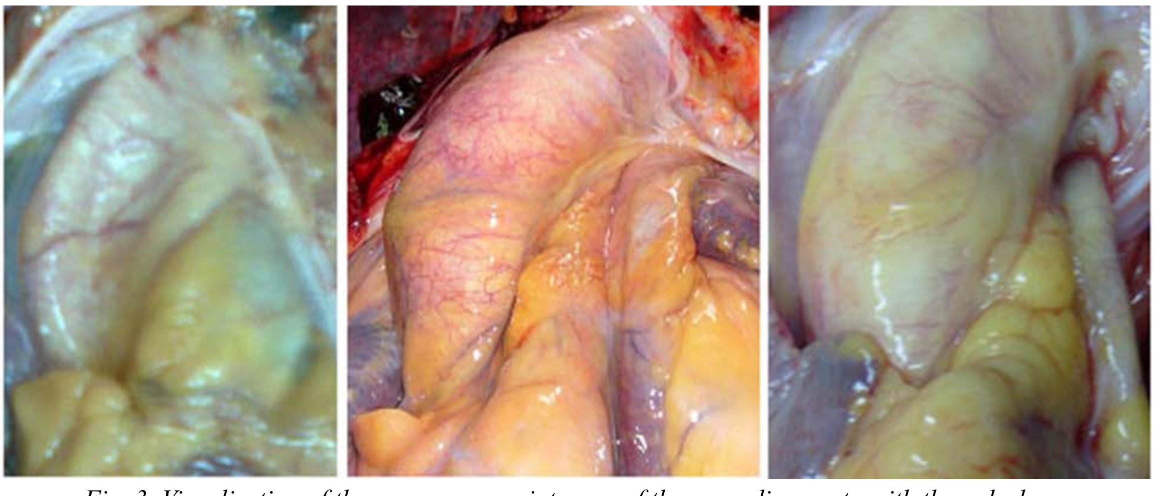

Fig. 3. Visualization of the vasa vasorum internae of the ascending aorta with the naked eye

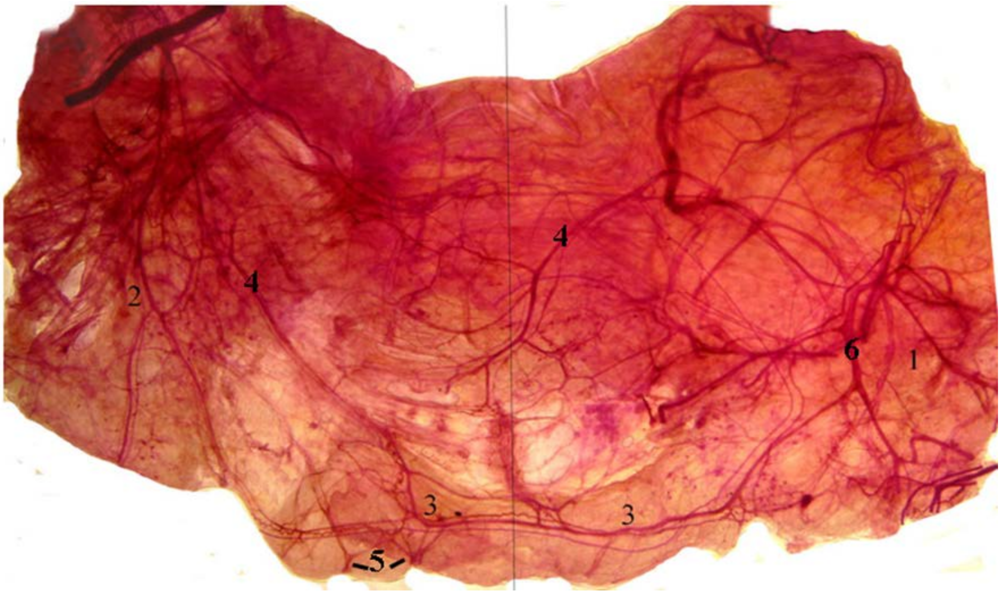

Fig. 4. Sources of blood supply of simple oblique fat pad of ascending aorta. Mesoscopic view of the fat pad of aorta: 1 – external layer of the anterior semicircular part of the ascending aorta; 2 – external layer of the posterior semicircular part of the ascending aorta; 3 – vasa vasorum internae inside of RFP; 4 – branches of the arteries of adjacent organs; 5 – branches of the coronary areries; 6 – vasa vasorum internae

Our opinion on the clinical significance of the vasa vasorum internae is as follows: their intraoperative damage and insufficient density of the applied sutures are the causes of profuse bleeding requiring reoperation.

We also focused on another important aspect: the near absence of anastomoses between the blood supply sources of the aortic arch and the adjacent ascending and descending aortic segments (Fig. 5). Particular attention was given to the fact that aortic dissections and aneurysms most commonly develop at the junction of these regions. It is believed that, in the near future, advances in technology, such as stem cell therapy, may enable the reinforcement of aortic walls by promoting the growth of blood vessels.

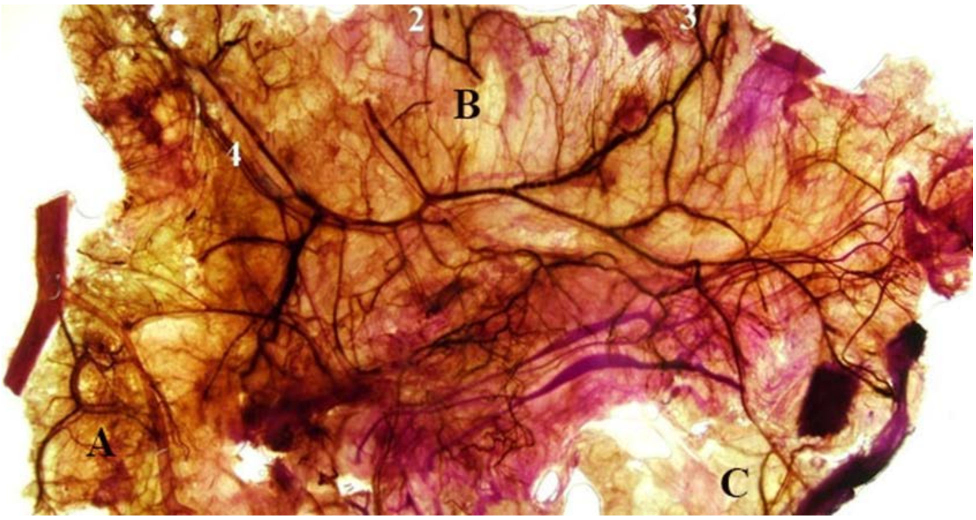

Fig. 5. Relationship of the sources of blood supply to different parts of the thoracic aorta: A – ascending aorta; B – arch of aorta; C – descending aorta; 1, 2, 3 – sources of vascularization of the arch of aorta

During surgeries on the aortic arch, there is a risk of postoperative phonetic issues due to the variability in the syntopy of the left vagus and left recurrent laryngeal nerves. Our study identified certain syntopic patterns associated with different constitutional body types. According to our data, deviations in the number of aortic arch branches from the norm occured in 3% of cases. In some cases, the branches were clustered closely together, while in others, they are spaced farther apart.

The present study showed that the number of branches varied from 2 to 6. Consequently, the syntopy of the aortic arch was altered, affecting the localization of the left vagus nerve and the left recurrent laryngeal nerve, which deviated from classical descriptions (Fig. 6). These variations must be considered during surgical interventions involving the aortic arch and adjacent structures, such as the esophagus and trachea. Recognizing these intraoperative anatomical variations can help reduce the incidence of complications.

Fig. 6. Variation of branching of the arch of aorta and relationship to the left vagus and recurrent laryngeal nerve

A high branching of the recurrent nerve, including its bifurcation and trifurcation, has been observed, along with various positional variations in relation to the anterior aortopulmonary groove.

Despite advances in the prevention of aortic atherosclerosis the problem of affection of this vessel remains unsolved. Observation of more than 200 cases with the definition of the thoracoabdominal index of the aorta (diameter ratio of the proximal and distal areas of the descending aorta) showed that the severity of pathological process depends directly on its index, i.e. a sharp narrowing of the aorta develops hemodynamic conditions contributing to a faster development of disease than a smooth one (Fig. 7).

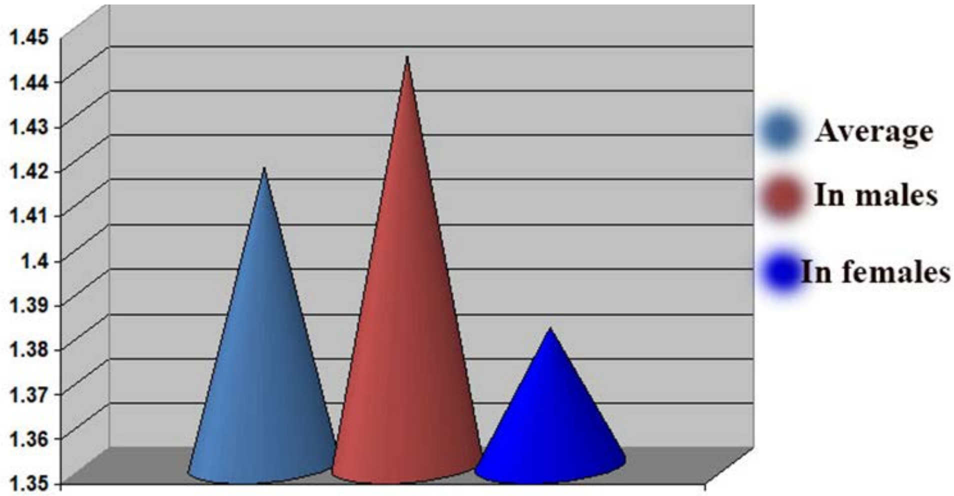

Fig. 7. Lumen coefficients of the descending aorta

Our ongoing study on aortic morphology indicates that the data collected thus far suggest the potential to reduce certain postoperative complications and prevent others through the implementation of new technologies.

This article examines several structural features of the human aorta that have recently gained significant interest among clinicians [1], including the functional anatomy of fat pads, the impact of aortic structural characteristics on its pathologies, and specific aspects of aortic syntopy. Special emphasis was placed on the applied clinical significance of the ascending aorta and aortic arch. The macroscopic and mesoscopic structural features of the aorta were analyzed from a practical perspective. Modern cardiovascular surgeons focus on preventing complications, one of the most critical being post-surgical bleeding, which often necessitates re-sternotomy. However, limited research has addressed the prevention of blood vessel and nerve injuries during aortic and cardiac surgeries. Advancements in surgical techniques for heart diseases have underscored the need for a precise understanding of the distribution patterns and modes of anastomosis formation in the arteries supplying the ascending aorta. Consequently, this study presents certain regional morphological peculiarities of the blood supply sources to the ascending aorta, knowledge of which can help prevent vascular injuries. According to existing data [2], some vascular sources of the ascending aorta include the bronchial and mediastinal arteries, the accompanying artery of the vagus nerve, and the right coronary artery. By integrating multiple research methods, this study expands the list of vascular sources, providing a more comprehensive understanding of their anatomical variations. Thus, sources of vascularization not yet described in the specialty literature have been found. Among the sources of the ascending aorta blood supply, the vasa vasorum internae has been reported. Vasa vasorum internae have their origin on the left side of the ascending aorta, above the level of the adipose plica location. Originating in the aorta and having a high blood pressure, they present a risk factor for haemorrhage in case of their damage. So far, the technique of cannula insertion and extracorporal circulation installation in bypass performing has stipulated the removal of the plica in order to ensure access. Anatomic peculiarities involving arterial supply of the ascending aorta are of clinical significance. Variations range from the pattern of origin, branching and anastomoses formation.

Conclusion. 1. Among the constant sources of vascularization of the ascending aorta (coronary, mediastinal, bronchial arteries, the artery associated with the right vagus nerve), those originating on the concave surface of the extrapericardial portion of the AAs – vasa vasorum internae – were detected. The latter are constant, form numerous anastomoses with other sources of blood irrigation of the AAs, and should be taken into account during surgical interventions on the ascending aorta. 2. Typical interorganic relationships were attested to the left vagus nerve in 54%, to the recurrent nerve – in 58% of cases studied, thus requiring maximum caution during operations on the arch of aorta. 3. Morphological sciences should, ideally, progress ahead of the evolving demands of medical practice. Addressing this issue effectively requires close collaboration between morphologists and clinicians.

Prospects for further research. The above refers to the clinical morphology of only one of more than a dozen permanent epicardial pads. Several of them are involved in surgical procedures in cardiac surgery. Nothing is known about the effects of injuring or removing them. For example, the fat pad of the pulmonary trunk is involved in:

1. Open-heart and great vessel surgeries:

- during sternotomy and exposure of the heart;
- the fat body is often divided or partially removed to expose the pulmonary artery trunk.

2. Surgery for congenital heart defects (in correction of Tetralogy of Fallot, transposition of the great arteries, common arterial trunk (*truncus arteriosus communis*), or pulmonary artery atresia).

3. Reconstructive surgery on the pulmonary trunk and its valve (pulmonary valve plasty, aneurysmectomy of the pulmonary trunk, or pulmonary valve replacement).

4. Pericardiectomy and anterior mediastinal surgeries (during total or partial pericardiectomy, the fat pad is often within the resection zone).

5. Resection of anterior mediastinal tumors. In some cases, when harvesting and anastomosing venous or arterial grafts, the surgeon dissects tissues anterior to the pulmonary artery trunk, partially involving the fat body.

Thus, this area of morphological research is the beginning of a large-scale clinically significant scientific work.

The second clinically important aspect of this article is the description of the variants of the left laryngeal nerve. Variations in the path of the left recurrent nerve are not common, but to mitigate potential postoperative complications, cardiothoracic surgeons must be aware of the possible variations. Cases of this nerve passing medially through the ligamentum arteriosum have been documented [3]. Recurrent laryngeal nerve (RLN) injury during thoracic surgery may result in life-threatening postoperative complications including recurrent aspiration and pneumonia. Anatomical details of the intrathoracic course are scarce [4]. The left-sided recurrent laryngeal nerve can be associated with a myriad of cardiothoracic conditions such as lung cancer, thoracic surgery, tumors, neck, chest, or cardiovascular lesions and edema [5-8]. Injury of the RLN during thoracic surgery has a considerable impact on the early postoperative course and on long-term outcome. Nerve injury usually occurs during lymph node dissection.

In 12% of cases, the left recurrent nerve starts from the ventromedial surface of the vagus nerve, in 88% – from the dorsomedial one. Inside the thorax, the left recurrent nerve is in close contact with the aorta, the trachea, the left atrium, the left main bronchus and the esophagus. Below the aortic arch, posterior to the Gross triangle (the space bounded anteriorly by the phrenic nerve, posteriorly by the vagus nerve and inferiorly by the left pulmonary artery), the recurrent nerve contacts 3-5 lymph nodes, which have parameters of 0.5-1.0 cm. In the case of an increase in their dimensions, the nerve flattens substantially, becoming 2-3 times thinner (at the same time, much wider) compared to the normal state, causing phonetic disorders, which are difficult to diagnose.

According to our observations, the typical location of the left recurrent nerve in the left tracheoesophageal groove occurs only in 61% of cases. In 39%, it passes 3-10 mm anterior to the aforementioned groove, on the left portion of the anterior surface of the trachea. In some of the anatomical specimens examined, the recurrent nerve was represented by two or three trunks. In asthenic individuals, accessory recurrent nerves were not observed. Their occurrence was noted in 4.5% of normosthenic cases and 37.5% of hypersthenic cases. The nerve trunks were consistently distributed in the frontal plane. In the posterior region of the aortic arch, at the level of its concave portion, the distance between the trunks ranged from 2 mm to 5 mm, while at the level of the convex surface, it increased to 10-14 mm.

Some sources describe the bifurcation of the recurrent laryngeal nerve into medial and lateral branches at the level of the inferior border of the larynx. Its lower division likely accounts for the presence of multiple recurrent nerve trunks. When supernumerary trunks are present, one is situated in the left tracheoesophageal groove, while others are located on the left portion of the anterior surface of the trachea. From a practical perspective, it is important to note that more often supernumerary trunks have been observed in individuals with a brachymorphic body constitution.

A consistent pattern has been observed: supernumerary trunks of the left recurrent laryngeal nerve were detected in most cases where the left vagus nerve intersects the convex edge of the aortic arch, either near its origin or at the level of the brachiocephalic trunk (Fig. 6). Therefore, intraoperative visualization of the vagus nerve allows for the prediction of the topographic location of the left recurrent laryngeal nerve and the presence of an accessory recurrent laryngeal nerve. This insight might help minimize the risk of nerve trauma, thereby contributing to the prevention of vocal fold paresis and paralysis [9, 10].

References

1. John LC. Crista aortae ascendentis, ascending aortic fold or Rindfleisch's fold-an enigma. Clin Anat. 2004 Mar;17(2):159-60; author reply 161-2. doi: 10.1002/ca.10221.

2. Parke WW. The vasa vasorum of the ascending aorta and pulmonary trunk and their coronary-extracardiac relationships. Am Heart J. 1970 Dec;80(6):802-10. doi: 10.1016/0002-8703(70)90142-0.

3. Khaki AA, Tubbs RS, Shoja MM, Zarrintan S. An unusual course of the left recurrent laryngeal nerve. Clin Anat. 2007 Apr;20(3):344-6. doi: 10.1002/ca.20341.

4. Behkam R, Roberts KE, Bierhals AJ, Jacobs ME, Edgar JD, Paniello RC, et al. Aortic arch compliance and idiopathic unilateral vocal fold paralysis. J Appl Physiol (1985). 2017 Aug 1;123(2):303-9. doi: 10.1152/japplphysiol.00239.2017.

5. Ng C, Woess C, Maier H, Schmidt VM, Lucciarini P, Öfner D, et al. Nerve at risk: anatomical variations of the left recurrent laryngeal nerve and implications for thoracic surgeons. Eur J Cardiothorac Surg. 2020 Dec 1;58(6):1201-5. doi: 10.1093/ejcts/ezaa258.

6. Mulpuru SK, Vasavada BC, Punukollu GK, Patel AG. Cardiovocal syndrome: a systematic review. Heart Lung Circ. 2008 Feb;17(1):1-4. doi: 10.1016/j.hlc.2007.04.007.

7. Spataro EA, Grindler DJ, Paniello RC. Etiology and Time to Presentation of Unilateral Vocal Fold Paralysis. Otolaryngol Head Neck Surg. 2014 Aug;151(2):286-93. doi: 10.1177/0194599814531733.

8. Tewari P, Aggarwal SK. Combined left-sided recurrent laryngeal and phrenic nerve palsy after coronary artery operation. Ann Thorac Surg. 1996 Jun;61(6):1721-2; discussion 1722-3. doi: 10.1016/0003-4975(96)00185-3.

9. Hacina T. Structural peculiarities of the ascending aorta and their role in cardiovascular surgery: morphological and immunohistochemical study. MJHS. 2016;7(1):7-15.

10. Hacina T, Cebotaru A, Cebotaru S. Morphological aspects regarding the postoperative events mitigation in heart surgery. Intellectus. 2013;3:80-7.

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Abstract. This study aims to describe the peculiarities of the blood supply to the aortic fat pad and examine the variability in the correlation between the left vagus nerve and the left recurrent laryngeal nerve in relation to the aortic arch. Additionally, the research analyzes the impact of aortic shape on susceptibility to atherosclerosis.

Material amd method. The study was conducted on 185 subjects who underwent autopsy within 24 hours postmortem. The sample included individuals ranging in age from 16-week-old fetuses to 96 years. Various research methods were employed, including observation of aortic autopsy specimens, morphometric analysis, fine anatomical dissection, Schiff reagent staining, histological examination, and injection of colored gelatin.

Results. The study identified the vasa vasorum internee as the primary source of vascularization for the ascending aorta, with significant clinical implications. The anatomical relationship between the left vagus nerve, the left recurrent laryngeal nerve, and the aortic arch deviates from classical descriptions and depends on the constitutional type of human body. Additionally, the susceptibility of the aorta to atherosclerosis was found to correlate with the thoracoabdominal lumen index of the aorta.

Conclusions. Considering the new data presented in this article regarding the characteristics of blood supply to the ascending aorta and the variations in the positioning of the left vagus nerve and the left recurrent laryngeal nerve, these findings play a crucial role in reducing postoperative complications.

Key words: ascending aorta, aortic arch, fat pad of ascending aorta, left recurrent laryngeal nerve, anatomical variations.

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