DOI: 10.17816/KMJ2021-678

Morphometrical observation on the left atrium in human adults

A.A. Gaponov[1], M.E. Noskova[1], A.A. Iakimov[1,2]*

[1]Ural State Medical University, Ekaterinburg, Russia;
[2]Ural Federal University, Ekaterinburg, Russia

Abstract

Aim. To determine the left atrial dimensions, their ratios and relationships that characterize anatomy for left atrium structure in the normal human adult using the model of the atrial end-diastolic phase.

Methods. We studied 54 heart specimens of subjects aged 35–88 years who died from non-cardiac causes. The atrial end-diastolic phase was modeled by filling a specimen fixed in 1% formalin with liquid silicone. After silicone hardened, we performed morphometric measurements by a caliper. The data were processed by using a cluster, correlation and variance analysis. For pairwise comparison, we used the Mann–Whitney U-test or a two-sided t-test.

Results. The article presents mean, standard deviation, median, 25th percentile and 75th percentile and coefficients of variation for the length, width and sagittal size of the left atrium, as well as the values of the distances between the pulmonary vein orifices, which characterize the dimensions of the left atrium posterior wall. Based on the left atrial size differences and their ratios, the specimens were divided into three clusters. The first (n_1=23) and second clusters (n_2=10) were represented by hearts with a cubic atrium; the second group differed from the first in the larger size of the left atrium. The third cluster (n_3=21) included the hearts in which the largest left atrium size was the width, so the shape of the atria resembled a parallelepiped. The typical number of the pulmonary vein ostia we found in 91% of the specimens. The posterior wall of the left atrium, with a common number and topography of the ostia, were rectangle or an unequal trapezium in shape. We analyzed correlations between the sizes of the heart, left atrium and its posterior wall. We concretized the conceptual apparatus concerning the nomenclature and terminology of the left atrium anatomical structures.

Conclusion. Based on the size ratio, two shape variations of the left atrium body can be identified: cubic or parallelepiped; cubic atria can be divided into large and small; the co-directional dimensions of the left atrial body and its posterior wall showed the strongest correlations.

Keywords: human anatomy, anatomical variants, heart, atria, left atrium, pulmonary veins.

For citation: Gaponov A.A., Noskova M.E., Iakimov A.A. Morphometrical observation on the left atrium in human adults. *Kazan Medical Journal.* 2021; 102 (5): 678–686. DOI: 10.17816/KMJ2021-678.

Background. Information about the reference (normative and conditionally normal) dimensions of the heart chambers is necessary for an accurate differential diagnosis of a cardiac pathology. An increase in the size of the left atrium (LA) is associated with valvular defects, atrial fibrillation, and cardiomyopathies [1–3].

In recent years, many studies have presented reference values of the LA parameters obtained by ultrasonography and radiation diagnostic methods, and the main focus was the overall dimensions and volumetric characteristics of the LA [1–5]. Following our literature search in the eLibrary, PubMed, Scopus, and Web of Science, among the anatomical structures of the LA, most of the publications focused on the left auricle, while the LA itself (its "body") was less investigated.

In the last decade, several review articles on the anatomy of the LA have been published [5–9]. In particular, Dudkiewicz et al. (2021) provided information on the length of the line connecting the entry of the superior pulmonary veins (PVs) (roof line) [9]. However, no study has provided detailed information on the reference morphometric parameters of the LA and the variants of its shape.

Meanwhile, quantitative data on the LA size are important in X-ray endovascular cardiac surgery and will be needed by specialists in interventional cardiology and arrhythmology when planning for radiofrequency ablation. Determining the quantita-

For correspondence: ayakimov07@mail.ru Received 12.07.2021; accepted 14.09.2021; published 15.10.2021.

tive boundaries of variabilities of these parameters and their relationships with the overall dimensions of the LA "body" concretizes and complements the idea of the conventional norm in cardiomorphology.

This study aimed to determine the overall dimensions of the LA, their ratios and interrelationships, which characterize the variants of the normal anatomical structure of the LA in an adult, using a model of the end-diastolic phase of the atria.

Materials and methods of research. This descriptive, non-randomized study was performed on 54 anatomical specimens of an adult heart at the Department of Human Anatomy of the Ural State Medical University from January to April 2021. Heart specimens belonged to deceased patients whose bodies were not requested for burial, and there was no possibility of obtaining informed consent. When working with the autopsy material, the requirements of Article 5 of the Federal Law No. 8 "On burial and funeral business" (on January 12, 1996, as amended and supplemented on January 01, 2017) were considered.

The study protocol was approved by the local ethics committee of the Ural State Medical University of the Ministry of Health of Russia (Protocol No. 8 dated November 20, 2020).

The criteria for the inclusion of materials were as follows:

1) Death from causes not related to heart disease.
2) A typical left-sided position of the heart.
3) Apparent typically formed heart.
4) Concordant ratio of the chambers of the heart and near-cardiac vessels.
5) Heart weight of 250–400 g.

The exclusion criteria were as follows:

1) Age <18 and >90 years.
2) Macroscopic signs of complications of ischemic heart disease, deforming diseases of the atrioventricular valves, and history of heart surgery.
3) Opening the left auricle in case of suspected thromboembolism due to cryptogenic stroke.
4) Damage or deformity of the LA.

Morphometry was performed on wet specimens, on which, by filling the LA cavity with silicone, the LA diastole phase was modeled. Thus, the specimens after evisceration were thoroughly washed from clots and stored in 1% formalin solution for up to 5 days. Then, the specimens were completely washed of formalin, and the left ventricle and right atrium were tamponed with cotton wool. The LA cavity through the entry of the right superior PV was filled with Super Mold 10 liquid silicone with a hardener in a ratio of 100:2. During silicone curing, the specimens were suspended so that the lower wall of the LA was raised above the table plane by 10°–15°, which is as close as possible to the natural position of the heart in an orthograde position. After hardening of the silicone, the remnants of the mediastinal tissue were removed from the LA walls by preparation.

Morphometry was performed with an electronic caliper ShTsTs-1-250 0.01 (Chelyabinsk, ChIZ; accuracy 0.03 mm). The length of the heart was measured from its apex to the entry of the superior vena cava, and the width and anteroposterior dimension of the heart were measured at the level of the coronary sulcus in mutually perpendicular directions. The length and width of the LA were measured on the inferior (diaphragmatic) wall of the LA perpendicular to each other. The LA length was measured from the middle of the line of transition of the LA posterior wall ("roof") to the lower wall to the middle of the left half of the coronary sulcus. The LA width was measured from the most lateral point of the LA parallel to the coronary sulcus to the projection of the inter-atrial septum in the posterior inter-atrial sulcus (Waterstone groove). The sagittal LA size was measured as the distance between the points most remote from each other of the inferior (diaphragmatic) LA wall and the wall facing the transverse pericardial sinus (Fig. 1).

We also measured the distances between the points of the entry of each PV, the closest to the center of the posterior wall ("roof") of the LA (internal distances) and the furthermost from this wall (external distances). The external and internal perimeters of the posterior wall of the LA were determined by summing the corresponding distances.

Using the Statistica 10.0 program (StatSoft Inc., USA), the nature of the distribution of signs was assessed using the Shapiro–Wilk W-test. If the distribution deviated from the normal, the results were presented only as median (Me), 25th and 75th percentiles (p_{25}, p_{75}), and extreme values. If the distribution was normal, in addition to the above parameters, the values were presented as the mean and its standard deviation (M ± SD). The coefficient of variation was calculated. For the analysis of variance, the Kruskal–Wallis H test was used, and for pairwise comparison, depending on the nature of the distribution, a two-sided *t*-test or Mann–Whitney *U*-test was used. To determine the LA shape variants, the multivariate cluster analysis (method of k-means) was used. For correlation analysis, Spearman's test (Rs) was used. Differences were considered significant at $\alpha = 0.05$.

Definition of terms

– *LA:* a chamber of the heart, into which arterial blood enters through the PV and from which it then enters the left ventricle. It consists of the LA body, left auricle, and mitral valve vestibule.

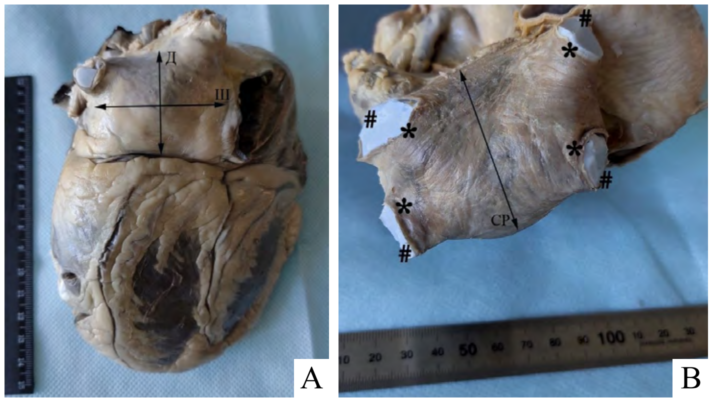

Fig. 1. Landmarks for the morphometry of the left atrium (LA). View from the side of the diaphragmatic surface (A) and from the side of the posterior wall of the LA. The LA is filled with silicone. (B) The myocardium was prepared. Д, length; Ш, width; CP, sagittal size of the LA. Symbols * and # mark the areas of the pulmonary vein entries, between which the internal and external dimensions of the posterior wall of the LA were measured, respectively.

– LA "*roof*": the posterior LA wall, bounded by conventional lines that can be drawn through the most distant from each area of the PV orifice at places where these veins enter the LA. In the heart of a living person *in situ*, the "roof" is turned not upward, but backward; therefore, the term is used in quotation marks.

– *LA body:* the major part of the LA, which includes its entire cavity, with the exception of the left auricle, and mitral valve vestibule.

– *Mitral valve vestibule:* the most distal (in blood flow) part of the LA cavity, separated from its body by a conventional plane passing along the lowest point of the entry of the left auricle parallel to the plane of the left atrioventricular (mitral) opening.

– *Opening of the left auricle*: an opening on the border of the anterior and lateral walls of the LA body, through which blood enters this auricle from the LA body and returns back. The opening is absent at the right auricle and is one of the anatomical markers of the LA.

Results. The heart length varied from 99 to 153 mm (Me = 125 mm). The width ranged from 70 to 145 mm (Me = 102 mm), and the anteroposterior size varied from 46 to 79 mm (Me = 65 mm). The length, width, and sagittal size of the LA body in the entire sample set were significantly different (H = 2; $p = 0.0001$) from each other (Fig. 2).

Based on the LA dimensions and their ratios, the specimens were divided into three groups using cluster analysis by the k-means method. Group 1 ($n_1 = 23$) and group 2 ($n_2 = 10$) included hearts with a cube-shaped LA. In each group, the overall dimensions of the LA were practically equal to each other, while the sizes in group 2 were significantly different from those in group 1 considering only larger LA. Group 3 ($n_3 = 21$) included hearts with

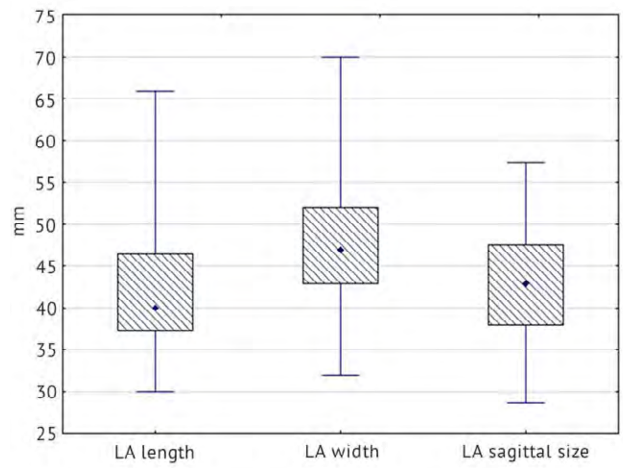

Fig. 2. Overall dimensions of the body of the cardiac left atrium (LA). Data are presented as medians (points in rectangles), 25th and 75th percentiles (lower and upper boundaries of the rectangles, respectively), and extreme values (segments).

the largest LA width; thus, the LA shape was close to a parallelepiped (Table 1, Fig. 3).

Four PV orifices were present in 91% (49 of 54) of the cardiac specimens. In the remaining five specimens, the left PVs entered the LA with a common entry. Table 2 presents the statistical parameters of the external and internal distances between the orifices of the PV.

The external distance between the right PVs was greater than that between the left PVs (t = 2.68; $p = 0.008$). The external distance between the superior PVs was significantly greater than the same distance between the inferior PVs (t = 2.68; $p = 0.008$). The internal distance between the superior PVs exceeded the internal distance between the inferior PVs (U = 879; $p = 0.046$).

The minimum distance from the left superior PV to the right inferior PV was 38 mm, which

Table 1. Morphometric characteristics of the anatomical variants of the left atrial body.

Overall dimension, mm	Statistical parameter	Anatomical variant		
		Cube		Parallelepiped (cluster 3)
		Small (cluster 1)	Large (cluster 2)	
Length	M ± SD	36.7±4.7	52±6.3	41.7±4.1
	Me ($p_{25;}$ p_{75})	37 (32.4; 39.6)	51 (48; 52.6)	41 (38.6; 45.2)
	Vx	13	12	10
Width	M ± SD	41.6±4.8	56.3±6.7	50.4±4.1
	Me ($p_{25;}$ p_{75})	43 (37; 45.2)	56 (52; 60)	50 (47.2; 53.3)
	Vx	12	12	8
Sagittal dimension	M ± SD	38.7±5.0	51.7±4.4	43.1±5.2
	Me ($p_{25;}$ p_{75})	39 (35.9; 42)	53 (48; 56)	44 (38.8; 45.8)
	Vx	13	8	12

Note: M ± SD, mean value and its standard deviation; Me (p_{25}; p_{75}), median (25th and 75th percentiles); Vx, coefficient of variation.

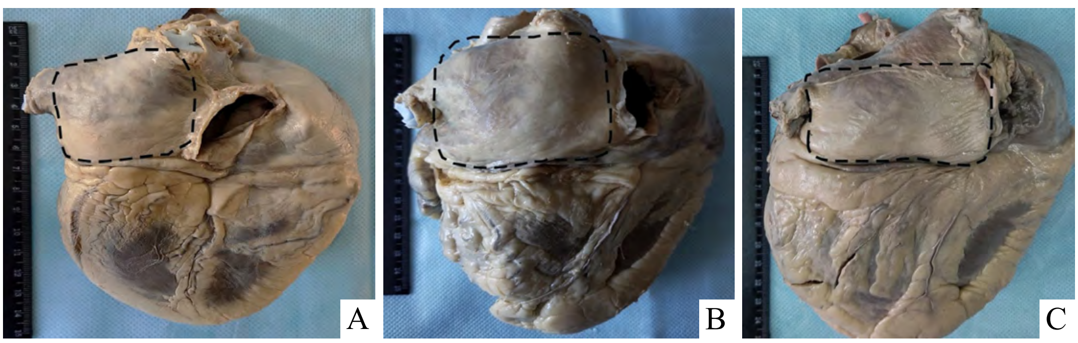

Fig. 3. Variants of the shape and size of the left atrium: A, small cube; B, large cube; C, parallelepiped shape. The left atrium is filled with solidified silicone. View from the side of the diaphragmatic surface of the heart.

varied from 25 to 57.7 mm. The distance from the right superior to the left inferior PV was 40 mm, which varied from 21.9 to 71.7 mm. Differences in the lengths of the diagonals of the LA posterior wall were on the verge of statistical significance (U = 850; p = 0.055). The size of the external perimeter of this wall was 172.4 mm (107.1–226.5 mm) and exceeded significantly (U = 15; p = 0.0001), and that of the inner perimeter was 84.7 mm (57.8–146.4 mm). When comparing the internal and external perimeters of the posterior LA wall within the three cluster groups, group 2 differed from the other two groups, as it had the highest values of these parameters (H = 2; p < 0.005).

The LA width indicator formed correlation pairs with both external distances between the superior (Rs = 0.62) and inferior (Rs = 0.6) PVs and with internal distances between the superior (Rs = 0.47) and inferior (Rs = 0.41) PVs. Moreover, the distance between the superior PVs was dependent on the LA length (Rs = 0.5). The sagittal LA size correlated with the external distance between the homolateral PVs on the left (Rs = 0.64) and on the right (Rs = 0.57). To a lesser extent, these distances were dependent on the width of the heart and, to a lesser extent, on its length.

The external and internal distances between the superior PVs were weakly dependent on the width of the heart. Distances similar between the inferior PVs were not dependent on the heart width. Correlations were noted between the external distances measured between the left and between the right PVs (Rs = 0.63), as well as between the superior and between the inferior PVs (Rs = 0.58). The external perimeter of the posterior LA wall was dependent on the LA length (Rs = 0.5), width (Rs = 0.6), and sagittal size (Rs = 0.6). The internal perimeter formed less strong correlation pairs with the overall dimensions of the LA body.

Discussion. *LA walls in the spatial coordinate system*. As regards the anatomical terminology of the heart, the approach based on the examination of the heart removed from the body in the so-called "valentine" position was preferred [10]. With this orientation, the ventricles were at the bottom, the atria were at the top, and the sites where the PVs

Table 2. Distances between the orifices of the pulmonary veins.

Distance, mm	Statistical parameter	Between the left veins	Between the right veins	Between the superior veins	Between the inferior veins
Internal	M ± SD	7.7±3.17	8.7±5.3	36.6±8.6	33.3±6.70
	Me (p_{25}; p_{75})	6.8 (5.4; 9.6)	7.9 (5.5; 10.3)	35.9 (31; 42.3)	33.0 (29.6; 37.2)
	Vx	41	61	24	20
External	M ± SD	31±4.8	34±6.5	55±10.6	49.6±8.7
	Me (p_{25}; p_{75})	31.5 (28; 34.5)	32.8 (29.8; 38.2)	54.5 (47.9; 60.5)	50 (45.5; 53.2)
	Vx	15	19	19	17

Note: M ± SD, mean value and its standard deviation; Me (p_{25}; p_{75}), median (25th and 75th percentiles), Vx, coefficient of variation.

entered the LA were in the uppermost position. Thus, it appeared reasonable to call this LA wall as the upper (or "roof") wall of the LA [6].

Another clinically oriented approach is based on viewing the heart in the human body when standing upright (in an orthograde position). With this approach, the PV ostia occupy the most posterior position, the anterior LA wall faces the transverse sinus of the pericardium, and the superior wall is located near the pulmonary trunk [5]. Heart examination in this coordinate system will correlate correctly the data of anatomical studies obtained on cadaveric material and in intravital studies using different methods [11, 12]. Thus, considering the heart *in situ* in an orthograde body position, the anterior, posterior, superior (near-auricle), septal (right, medial), and left (lateral) walls can be distinguished in the LA, as was conducted in this study.

What departments are detected in the LA? In cardiomorphology, there is no single point of view on how the LA should be divided into sections. Both atria have a venous part, an auricle, and a vestibule of the atrioventricular valve [7, 12]. In 2015, Chaplygin et al. divided the LA into three segments, namely, "sinus of the PV, the atrium itself, and the left auricle" [6]. In 2014, Falkovsky identified in the LA cavity into "two segments: the superior (posterior) with the area of the PV entry and the opening of the left auricle and the inferior (anterior) which is the supravalvular" and noted the absence of clear boundaries of the transition from one segment to another [13].

These areas of the cavity were also different clinically, as knowledge of the features of the near-auricle zone is important for correct clipping of the orifice and placement of occluders. The anatomy of the PV entry is very important for radiofrequency ablation in the localization of ectopic pacemakers in the myocardial PV "arms." Therefore, it is advisable to distinguish these parts of the LA.

In 2019, Whiteman et al. conducted a review article on the LA anatomy and designated all LA, except for the auricle, as the LA body and noted that the LA body is "between the vestibule of the [mitral valve] and the pulmonary venous components" [5]. This approach to the separation of the LA cavity is used in the present investigation. We believe that it is most justified from clinical, functional, and ontogenetic positions.

LA shape. Generally, the LA has a cube [5] or cylindrical [14] shape. This study has established the existence of two variants of the LA shape. Given the predominance of the width, the LA body in 38.9% of cases has a parallelepiped shape; in other cases, it has a cube shape. Conversely, the cube-shaped atria has significantly different size; thus, it can be divided into two subgroups (Fig. 3).

Our data on the LA shape and size are largely consistent with the data of Kozlov et al. (1996), who studied the atria on casts, as we did. They found that the shape of the casts of the atrial cavities in different age groups were not significantly different, while the linear dimensions and volume of the cavities were more variable. In most cases, the shape of the LA cavity cast resembled an ellipsoid on rotation; less often, it could approximately resemble a cylinder or a truncated cone, directed with its apex toward the left ventricle. The projection of the LA cavity casts in the sagittal and frontal planes could have an oval shape [4].

We believe that the ellipsoidal and cylindrical shapes described by the authors, as well as the oval shape of the cast projection, corresponded to group 3 of specimens in our study, which included the LA with a nearly parallelepiped shape. According to Kozlov et al. (1996), the ratio of the width and length of the LA in the sagittal and frontal planes were not significantly different and ranged from 1.1 to 1.7 [4]. The wider range of variation of these ratios (0.76–1.68), established in the present study, is a quantitative expression of the greater variability of the LA body shape.

Ratio of the LA sizes. To the best of our knowledge, for the first time in the study of anatomical specimens, this study is an attempt to determine the variants of the LA body shape, not subjectively but on the basis of the differences in sizes and their ratios. The posterior LA wall bounded by the PV orifices, with a typical number and position of these orifices, had the shape of an unequal trapezoid. The greater lateral side of the trapezium was facing the inter-atrial septum, and the wide base was facing forward and upward, toward the pulmonary trunk, and transverse pericardial sinus. Less often, with equal external dimensions between PVs, this LA wall resembled a rectangle elongated from top to bottom.

Comparative analysis of our data is problematic due to insufficient literature data. Review articles [5, 8] have provided data on wall thickness and left auricle size; however, there is no data on the size of the LA body. The length of one of the sides of the LA roof line, corresponding to the distance between the orifices of the superior PVs, was 33.3 ± 5.3 mm [9], which is close to our data on the internal distance between these orifices (36.6 ± 8.6 mm). However, there is no information on other dimensions of this LA wall in as previous study [9].

In 2019, Gupta et al. performed morphometric analysis of the distances between the PV orifices on 30 heart specimens of people aged 23–95 years and found that the distances between the superior (32.1 ± 8.3 mm) and between the inferior (35.4 ± 5.4 mm) PVs were significantly greater than the distance between the right (9.1 ± 3.0 mm) and between the left (7.3 ± 2.9 mm) PVs [15].

Their data are consistent with our data; i.e., the distance between the superior PVs is the largest among the four sizes, and the distance between the left PVs is the smallest. The entry of the PV into the LA often has a funnel shape; therefore, the boundary between the PV and the LA wall is indistinct [7]. Essentially, the discrepancies in the results can be partly explained by the inaccuracy of landmarks during morphometry.

In 2019, Gupta et al. obtained data from the morphometry of fixed specimens without control over the retention of the LA shape. Another study [15] did not assess the significance of data differences, which reduces their significance.

In the analysis of studies reporting the results of LA measurements, no study has focused on the complex characteristics of the LA body dimensions. To assess the LA body shape based on its size, values of at least three parameters are required, measured in mutually perpendicular directions. However, in studies reporting such data [6, 14], objects and measurement techniques were not described, which complicated the interpretation of the results.

In an adult at different age periods, Kozlov et al. (1996) reported that the mean LA length varied from 36 to 49 mm, and the mean anteroposterior size ranged from 32 to 42 mm. In addition, the LA width was measured in two planes, namely, the sagittal (34–44 mm) and frontal (33–42 mm) planes [4]. In those studies where measurements were performed in the diastole phase, the LA width usually varied from 30 to 42 mm [1, 4, 16, 17], which is consistent with our results obtained on the specimens of groups 1 and 3 (Table 1).

As established in the study by Starchik (2016), in heart specimens of women with hypersthenic body type, the LA width reached 52 mm [16]. The smaller LA size in other studies could be due to the fact that morphometry was performed without taking into account the degree of LA filling [6, 14].

According to Cho et al. (2012), the overall dimensions of the LA were larger in c with atrial fibrillation than in patients with sinus rhythm. Specifically, in patients with arrhythmia, the lateral and superior–inferior LA sizes were 64.1 ± 9.3 and 63.8 ± 7.9 mm, respectively, which exceeded those in patients with sinus rhythm ($p = 0.002$) [3].

Gendlin et al. (2019) examined the intravital anatomy of the LA in patients with and without aortic valve stenosis. They revealed an LA diameter of 45.7 mm (40.8–49.1 mm) in patients with aortic valve stenosis and 35.7 mm (33.2–42 mm) in the control group and noted that the LA diameter did not depend on gender and age [1].

With transthoracic echocardioscopy, Martirosyan and Balandina (2020) performed LA morphometry in 128 healthy people of mesomorphic body type, determined the superior–inferior LA size, and using this size, calculated the LA volume using the Simpson equation. They concluded the comparable values of these parameters in adult men and women [2].

The sizes of the heart and, in particular, the LA are associated with the somatotype. Thus, Starchik (2016) revealed that the lateral size of the LA in women with a normosthenic physique was 1.18 times greater ($p < 0.05$) than in those with an asthenic physique and 1.10 times less ($p < 0.05$) than in those with a hypersthenic physique. Moreover, the author found significant differences in the superior–inferior LA size associated with body type and concluded that the LA morphology, similar to several other heart structures, is constitutionally determined [16].

In the present study, a correlation analysis was performed to determine the aspects and reveal the regularities of the local constitution of the LA body. The strongest correlations were characteristic of the co-directional dimensions of the LA body and its posterior wall. This can be considered a sign of the general biological principle of the coordinated growth and development of structurally and topographically subordinate morphological formations and can be used to assess the harmony of organ development.

CONCLUSIONS

1. The values of morphometric indicators characterizing the overall dimensions of the LA body in the end-diastolic phase of the cardiac cycle are different, and their ratios are represented by three cluster groups that determine the shape and size of this heart chamber.

2. The LA body can have a cube or parallelepiped shape, which has the largest width.

3. A cube-shaped LA, based on significant differences in size, can be divided into large and small.

4. The posterior LA wall with a typical number and position of the openings of the PVs has a rectangle or an unequal trapezium shape, and the larger side of which faces the inter-atrial septum, and the wide base faces forward and upward.

5. The strongest correlations are characteristic of the co-directional dimensions of the LA body and its posterior wall.

Author contributions. A.A.G. developed the concept and design of the study, prepared the specimens, performed measurements and data analysis, and wrote the text of the article. M.E.N. prepared the specimens and performed measurements and data analysis; A.A.Ya. was the work supervisor, developed the concept and design of the study, analyzed the data, and wrote the text of the article.

Funding. The study had no external funding

Conflict of interest. The authors declare no conflict of interest.

REFERENCES

1. Gendlin G.E., Kovaleva A.I., Emelina E.I., Nikitin I.G. Linear and volumetric parameters of left atrium in patients with isolated aortic stenosis. *Rossiyskiy kardiologicheskiy zhurnal*. 2019; 24 (11): 16–21. (In Russ.) DOI: 10.15829/1560-4071-2019-11-16-21.

2. Martirosyan L.P., Balandina I.A. Parameters of volume of the atria and left ventricle in men and women of the mesomorphic body type according to the results of performing echocardiography. *Volgogradskiy nauchno-meditsinskiy zhurnal*. 2020; (2): 58–61. (In Russ.)

3. Cho Y., Lee W., Park E.-A., Oh I.-Y., Choi E.-K., Seo J.-W., Oh S. The anatomical characteristics of three different endocardial lines in the left atrium: evaluation by computed tomography prior to mitral isthmus block attempt. *Europace*. 2012; 14 (8): 1104–1111. DOI: 10.1093/europace/eus051.

4. Kozlov V.A., Stebel'skiy S.E., Makovetskiy V.D., Yurchenko I.V. Topography and shape of heart cavities in ontogenesis. In: *Prikladnaya anatomiya serdtsa*. (Applied anatomy of the heart.) Ed. by V.A. Kozlov. Dnepropetrovsk. 1996; 6–32. (In Russ.)]

5. Whiteman S., Saker E., Courant V., Salandy S., Gielecki J., Zurada A., Loukas M. An anatomical review of the left atrium. *Translational Res. Anat*. 2019; 17: 100052. DOI: 10.1016/j.tria.2019.100052.

6. Chaplygina E.V., Kaplunova O.A., Evtushenko A.V., Karakozova E.A., Markevich A.V., Shvyrev A.A., Sankova I.V. Applied aspects of the anatomical structure of the human's heart left atrium. *Sovremennye problemy nauki i obrazovaniya*. 2015; (5): 146–155. (In Russ.)

7. Ho S.Y., Sánchez-Quintana D. The importance of atrial structure and fibers. *Clin. Anat*. 2009; 22 (1): 52–63. DOI: 10.1002/ca.20634.

8. Ho S.Y., Cabrera J.A., Sanchez-Quintana D. Left atrial anatomy revisited. *Circ. Arrhythm. Electrophys*. 2012; 5 (1): 220–228. DOI: 10.1161/CIRCEP.111.962720.

9. Dudkiewicz D., Słodowska K., Jasińska K.A., Dobrzynski H., Hołda M.K. The clinical anatomy of the left atrial structures used as landmarks in ablation of arrhythmogenic substrates and cardiac invasive procedures. *Translational Res. Anat*. 2021; 23 (3): 100102. DOI: 10.1016/j.tria.2020.100102.

10. Anderson R.H., Loukas M. The importance of attitudinally appropriate description of cardiac anatomy. *Clin. Anat*. 2009; 22 (1): 47–51. DOI: 10.1002/ca.20741.

11. Mori Sh., Tretter J., Spicer D., Bolender D., Anderson R.H. What is the real cardiac anatomy? *Clin. Anat*. 2019; 32 (3): 288–309. DOI: 10.1002/ca.23340.

12. Kausar A., Razzak I., Shapiai M.I., Beheshti A. 3D shallow deep neural network for fast and precise segmentation of left atrium. *Multimedia Syst*. 2021. DOI: 10.1007/s00530-021-00776-8.

13. Fal'kovskiĭ G.E. *Stroenie serdtsa i anatomicheskie osnovy ego funktsii*. (Structure of the heart and anatomical bases of its function.) M.: Nauchnyy tsentr serdechno-sosudistoy khirurgii im. A.N. Bakuleva. 2014; 136–143. (In Russ.)

14. Mikhaylov S.S. *Klinicheskaya anatomiya serdtsa*. (Clinical anatomy of the heart.) M.: Meditsina. 1987; 59–71. (In Russ.)

15. Gupta T., Cheema N., Randhawa A., Sahni D. Translational anatomy of the left atrium and esophagus as relevant to the pulmonary vein antral isolation for atrial fibrillation. *Surg. Radiol. Anat*. 2020; 42 (4): 367–376. DOI: 10.1007/s00276-019-02327-3.

16. Starchik D.A. Constitutional and structural features of right and left atriums of mature women. *Vestnik Natsional'nogo mediko-khirurgicheskogo Tsentra im. N.I. Pirogova*. 2016; 11 (1): 101–103. (In Russ.)

17. Ikiz Z.A.A., Üçerler H., Özgür T. Anatomic characteristics of left atrium and openings of pulmonary veins. *Anadolu. Kardiyol. Derg*. 2014; 14 (8): 674–678. DOI: 10.5152/akd.2014.4968.