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Echocardiographic Characteristics Of The Heart In Pulmonary Artery Stenosis Among Patients Aged 1 To 29 Years

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Abstract

Background: Pulmonary artery stenosis (PAS) is one of the most common congenital heart defects in children and young adults. Echocardiography remains the leading non-invasive method for assessing morphological and functional cardiac changes. However, age-related echocardiographic parameters in PAS are insufficiently studied, which complicates diagnostic standardization.

Aim: To evaluate age-related echocardiographic characteristics of the heart in patients with pulmonary artery stenosis aged 1–29 years.

Methods: A total of patients aged 1–29 years with PAS were examined. Echocardiography was performed using two-dimensional, M-mode, and Doppler techniques. Subjects were divided into five age groups: 1–4, 5–9, 10–14, 15–19, and 20–29 years. Parameters assessed included right atrial and ventricular dimensions, interventricular septal thickness, pulmonary artery diameter, and systolic/diastolic function.

Results: In early childhood (1–4 years), right atrial enlargement predominated, while right ventricular size remained within normal limits. At 5–9 years, atrial dilation persisted with initial wall thickening of the right ventricle. Adolescents (10–14 years) demonstrated ventricular enlargement and early hypertrophy. In young adults (15–29 years), progressive hypertrophy of the right ventricle and interventricular septum was observed, accompanied by pulmonary valve regurgitation. These findings confirm heterochronous and heterodynamic remodeling processes in PAS.

Conclusion: Age-related echocardiographic changes in PAS vary from chamber dilation in childhood to hypertrophy and remodeling in adolescence and young adulthood. Recognition of these patterns is essential for accurate diagnosis, risk stratification, and individualized treatment planning.

Keywords: Echocardiography, pulmonary artery stenosis, congenital heart disease, age-related changes, right ventricle, remodeling.

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1. Introduction

Pulmonary artery stenosis (PAS) is among the most common congenital heart defects observed in children and young adults. According to the literature, the prevalence of PAS accounts for 7–9% of all congenital heart defects, and its timely diagnosis is crucial for determining treatment strategies and predicting disease outcomes [14,16].

Echocardiography is the leading non-invasive method for cardiac assessment, enabling evaluation of the morphological and functional parameters of the myocardium, valvular structures, and major vessels [4,5,7,8]. In recent years, a considerable amount of data has been accumulated regarding age-related changes in echocardiographic indices, both under normal conditions and in various congenital heart defects [1–3,9]. However, the age-related dynamics of parameters in PAS remain insufficiently studied, which complicates the development of diagnostic and rehabilitation standards [15,17].

Studies by domestic authors have demonstrated that echocardiographic parameters of the right ventricle and atrium vary significantly depending on age, reflecting the heterochronous and heterodynamic processes of cardiac remodeling [1,5,6]. In particular, early childhood is characterized by intensive growth of cardiac chambers, whereas in adolescents and young adults, myocardial hypertrophy processes predominate [7,8].

International studies confirm the importance of age as a factor in interpreting echocardiographic data. For example, Van de Meent et al. showed that age-related changes in cardiac parameters associated with intrauterine developmental disorders significantly affect myocardial functional adaptation [11]. Avesani and colleagues emphasize the necessity of a comprehensive evaluation of morphological and functional characteristics in congenital heart defects [12]. Nath and Foster demonstrated that even in healthy individuals, echocardiographic signs of tricuspid regurgitation may be detected, which requires consideration of age-related norms [13].

Particular attention has been paid to PAS: Bassareo and Martino reported that echocardiographic parameters in this defect exhibit pronounced age-related differences, influencing clinical course and prognosis [16]. Bravo-Valenzuela and McLennan note that congenital heart defects in children are accompanied by specific changes in cardiac chambers and valves, which must be taken into account when interpreting data [15].

Thus, the analysis of age-related changes in echocardiographic parameters of the heart in PAS patients aged 1–29 years is a relevant task of modern cardiology. It allows not only refinement of diagnostic criteria but also the development of individualized approaches to treatment and rehabilitation [18,19].

Objective. The aim of the study was to perform a comprehensive echocardiographic assessment of the heart in patients with pulmonary artery stenosis (PAS) aged 1 to 29 years, to identify age-related patterns of parameter changes and their clinical significance.

2. Methods

The study included patients with congenital PAS aged from one to twenty-nine years. To analyze age-related features, all participants were divided into five groups: early childhood (1–4 years), preschool and early school age (5–9 years), adolescence (10–14 years), youth (15–19 years), and young adults (20–29 years).

Echocardiographic examinations were performed using modern high-end ultrasound systems equipped with standard probes adapted for both pediatric and adult patients. Transthoracic positions were applied in two-dimensional mode, M-mode, and Doppler modalities.

The following parameters were evaluated: dimensions of the right atrium and right ventricle, end-diastolic and end-systolic sizes of the right ventricle, thickness of the interventricular septum, diameter of the pulmonary artery annulus and arch, indices of systolic and diastolic function of the right ventricle, as well as the presence and degree of regurgitation at the pulmonary valve. For each patient, measurements were recorded both at rest and during functional tests, including respiratory maneuvers.

All obtained data were entered into electronic protocols

and subjected to statistical processing using methods of variational statistics, which allowed identification of reliable age-related patterns in echocardiographic parameters of the heart in PAS.

3. Results

Echocardiographic examination of patients with pulmonary artery stenosis (PAS) aged 1 to 29 years revealed pronounced age-related characteristics of cardiac parameters. In the youngest age group (1–4 years), enlargement of the right atrium was observed compared to normal values, while the dimensions of the right ventricle remained within physiological limits. At the age of 5–9 years, the tendency toward right atrial dilation persisted, and gradual signs of right ventricular wall thickening appeared.

In adolescence (10–14 years), a more intensive enlargement of the right ventricular cavity was noted, accompanied by moderate myocardial hypertrophy and alterations in diastolic function. In youth (15–19 years), the size of the right ventricle decreased, but its walls became significantly thicker, indicating progressive adaptation to increased hemodynamic load.

In young adults (20–29 years), marked thickening of the interventricular septum and right ventricular walls was identified, along with an increase in the diameter of the pulmonary artery annulus, combined with signs of valvular regurgitation.

Thus, in PAS, age-related changes demonstrated a heterochronous pattern: from chamber dilation in early childhood to pronounced hypertrophy and structural remodeling of the heart in young adulthood (Tables 1, 2).

Table 1.
Age-related changes in echocardiographic parameters of the heart in pulmonary artery stenosis (PAS).

Age group	Right atrium (RA)	Right ventricle (RV)	Interventricular septum (IVS)	Functional features
1–4 years	Enlarged compared to normal	Dimensions within normal limits	Normal thickness	Initial signs of RA overload
5–9 years	Persistent dilation	RV cavity remains normal	Slight thickening	Early signs of RV wall hypertrophy
10–14 years	Moderate enlargement	RV cavity increases	IVS thickening	Impaired diastolic function
15–19 years	Stabilization of dimensions	RV cavity decreases, walls hypertrophied	IVS thickness increases	Signs of adaptation to load
20–29 years	Moderate dilation	Marked hypertrophy of RV walls	Maximum thickness	Pulmonary valve regurgitation

Table 2.
Age-related changes in echocardiographic parameters of the heart in ventricular septal defect (VSD).

Age group	Right atrium (RA)	Right ventricle (RV)	Left ventricle (LV)	Pulmonary artery (PA)
1–4 years	Enlargement of dimensions	RV cavity enlarged	LV within normal limits	PA diameter within normal limits
5–9 years	Most intensive growth	RV increases in diastole	LV gradually decreases	PA diameter increases
10–14 years	Continues to enlarge	RV length 1.8 times (normal 1.5)	LV decreases	PA annulus diameter 1.55 times
15–19 years	Persistent enlargement	RV width in diastole 1.7 times	LV decreases	PA diameter 1.75 times
20–29 years	Maximum dimensions	RV wider in systole 2.15 times	LV markedly reduced	PA diameter reaches maximum

In ventricular septal defect (VSD), characteristic age-related patterns were also identified. In early childhood (1–4 years), the dimensions of the right atrium and right ventricle were increased compared to normal values, whereas the left ventricle maintained physiological parameters. At the age of 5–9 years, the most intensive growth of the right atrium and right ventricle was observed, accompanied by a gradual reduction in left ventricular size and an increase in pulmonary artery diameter.

In adolescence (10–14 years), the length of the right ventricle in diastole increased 1.8-fold (normal 1.5), and in systole 1.9-fold (normal 1.6), indicating pronounced overload of the right heart chambers. In youth (15–19 years), the width of the right ventricle in diastole increased 1.7-fold, and in systole 2.15-fold, while the dimensions of the left ventricle continued to decrease. In young adults (20–29 years), maximal enlargement of the right ventricle and a significant increase in the diameter of the pulmonary artery annulus were observed, reflecting the development of chronic overload of the right heart chambers.

The study results demonstrated that age-related changes in echocardiographic parameters of the heart differ in direction between PAS and VSD: in pulmonary artery stenosis, hypertrophy and remodeling processes predominate, whereas in ventricular septal defect, marked dilation of the right heart chambers and progressive reduction in left ventricular size are observed. These findings confirm the necessity of considering age-related features when interpreting echocardiographic indices and selecting treatment strategies for patients with congenital heart defects.

4. Discussion

The obtained results demonstrate that age-related changes in echocardiographic parameters of the heart in pulmonary artery stenosis (PAS) and ventricular septal defect (VSD) differ in direction and reflect specific features of cardiovascular adaptation to chronic overload.

In PAS, early childhood is characterized by predominant right atrial enlargement, associated with increased pressure in the pulmonary circulation. During adolescence, enlargement of the right ventricle and thickening of its walls are observed, while in youth and

young adulthood, pronounced myocardial hypertrophy and structural remodeling of the heart occur. These findings are consistent with the results of Bassareo and Martino, who reported that echocardiographic parameters in PAS exhibit marked age-related differences and influence the clinical course of the disease [16].

In VSD, opposite trends were identified: beginning in early childhood, significant dilation of the right heart chambers was observed, accompanied by a gradual reduction in left ventricular size. In adolescence and youth, right ventricular overload reached its maximum, as evidenced by an increase in its dimensions in diastole and systole more than twofold compared to normal values. These results are in agreement with the data of Bravo-Valenzuela and McLennan, who noted that congenital heart defects in children are accompanied by specific changes in cardiac chambers and valves, which must be considered when interpreting echocardiographic findings [15].

Comparative analysis showed that in PAS, age-related changes are characterized by compensatory hypertrophy, whereas in VSD, dilation of the right heart chambers predominates. This confirms the conclusions of domestic researchers regarding the heterochronous and heterodynamic nature of age-related changes in echocardiographic parameters [1,5,6].

Thus, comparison of the obtained data with literature sources allows us to assert that age-related features of echocardiographic parameters in congenital heart defects have important clinical significance. Their consideration is essential for the development of differentiated diagnostic criteria, prediction of disease progression, and selection of optimal treatment strategies, including surgical correction and rehabilitation measures.

5. Conclusion

The conducted study revealed clear age-related patterns of changes in echocardiographic parameters of the heart in patients with pulmonary artery stenosis (PAS) and ventricular septal defect (VSD) aged 1 to 29 years. It was established that in PAS, early childhood is characterized by predominant right atrial enlargement; adolescence by enlargement of the right ventricle and initial hypertrophy of its walls; and youth and young adulthood by pronounced myocardial remodeling and thickening, accompanied by the development of valvular regurgitation. In VSD, significant dilation of the right heart chambers was identified beginning in early childhood, accompanied by progressive reduction in left ventricular size and an increase in pulmonary artery diameter.

Thus, age-related changes in echocardiographic parameters of the heart in congenital heart defects exhibit heterochronous and heterodynamic characteristics, confirming the necessity of their consideration when interpreting echocardiographic data. The obtained results may serve as a basis for the development of diagnostic standards, prediction of disease progression, and selection of optimal treatment strategies, including surgical correction and rehabilitation measures.

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