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CHANGES IN AORTIC HEMODYNAMICS IN CONGENITAL HEART DISEASES

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Abstract: Congenital heart diseases are among the most common cardiovascular pathologies in children and are frequently associated with significant hemodynamic disturbances in the aorta. Structural abnormalities of the heart and great vessels lead to altered blood flow, pressure overload, turbulent circulation, and vascular remodeling. This article reviews the pathophysiological mechanisms of aortic hemodynamic changes in congenital heart diseases based on modern scientific literature. Special attention is paid to aortic coarctation, bicuspid aortic valve, Tetralogy of Fallot, and patent ductus arteriosus. Hemodynamic overload in these conditions contributes to endothelial dysfunction, decreased vascular elasticity, left ventricular hypertrophy, and progressive aortic wall remodeling. Modern diagnostic methods including echocardiography, Doppler ultrasonography, computed tomography angiography, and magnetic resonance imaging play an essential role in early detection and monitoring of aortic abnormalities. Early diagnosis and timely surgical correction are critical for preventing irreversible cardiovascular complications in pediatric patients.

Keywords: congenital heart disease, aorta, hemodynamics, aortic coarctation, bicuspid aortic valve, pediatric cardiology, vascular remodeling.

Introduction

Congenital heart diseases (CHDs) represent one of the leading causes of morbidity and mortality in pediatric cardiology. According to international epidemiological data, CHDs occur in approximately 8–10 per 1000 live births worldwide. Many congenital cardiac anomalies directly affect the anatomy and physiology of the aorta, leading to major disturbances in systemic circulation and cardiovascular adaptation.

The aorta is the largest elastic artery in the human body and plays a central role in maintaining stable systemic blood flow. Under physiological conditions, the elastic properties of the aortic wall allow it to absorb systolic pressure and maintain continuous blood circulation during diastole. In congenital heart defects, however, abnormal intracardiac shunts, pressure overload, and altered blood flow patterns disrupt normal aortic hemodynamics.

Persistent hemodynamic stress causes structural and functional changes in the aortic wall, including endothelial dysfunction, increased collagen deposition, elastic fiber degeneration, and vascular stiffness. These pathological processes may progress over time and contribute to hypertension, ventricular hypertrophy, aneurysm formation, and heart failure.

The aim of this article is to analyze the main hemodynamic alterations of the aorta in congenital heart diseases and discuss their clinical significance based on current scientific evidence.

Materials and Methods

This review article was prepared using scientific literature obtained from PubMed, Scopus, Web of Science, and Google Scholar databases. Scientific publications related to congenital heart diseases, pediatric cardiology, aortic physiology, and vascular hemodynamics published between 2010 and 2025 were analyzed. Priority was given to systematic reviews, clinical studies, pediatric cardiology guidelines, and experimental investigations.

Results and Discussion

Aortic Coarctation and Hemodynamic Disturbances

Coarctation of the aorta is one of the most common congenital aortic abnormalities in children. Narrowing of the aortic lumen increases resistance to blood flow and significantly elevates left ventricular afterload. As a result, arterial hypertension develops in the upper part of the body, while perfusion of the lower extremities decreases.

Long-term pressure overload leads to left ventricular hypertrophy and progressive vascular remodeling. Chronic hemodynamic stress also reduces aortic elasticity and promotes fibrosis of the vascular wall. If untreated, severe complications such as heart failure, aortic rupture, and cerebrovascular events may occur.

Bicuspid Aortic Valve and Aortic Remodeling

Bicuspid aortic valve is the most frequent congenital valvular defect in children. In this condition, abnormal valve morphology produces turbulent blood flow within the ascending aorta. Continuous turbulent circulation increases mechanical stress on the aortic wall and contributes to progressive dilation.

Studies demonstrate that children with bicuspid aortic valves often develop enlargement of the ascending aorta at an early age. Endothelial dysfunction and altered extracellular matrix metabolism are considered important mechanisms underlying vascular remodeling. Over time, these changes may lead to aneurysm formation and decreased aortic compliance.

Tetralogy of Fallot and Hypoxic Vascular Changes

Tetralogy of Fallot is a complex congenital heart disease characterized by ventricular septal defect, pulmonary stenosis, right ventricular hypertrophy, and overriding aorta. Due to abnormal blood mixing, partially deoxygenated blood enters the systemic circulation through the aorta.

Chronic hypoxemia negatively affects endothelial cell function and promotes vascular injury. Long-standing hypoxia may reduce the elasticity of the aortic wall and impair vascular adaptation. Hemodynamic instability in Tetralogy of Fallot also contributes to abnormal aortic dilation and altered blood flow dynamics.

Patent Ductus Arteriosus and Volume Overload

In children with patent ductus arteriosus, blood abnormally flows from the aorta into the pulmonary artery. This left-to-right shunt causes increased pulmonary circulation and volume overload of the left heart chambers.

Persistent hemodynamic overload alters aortic flow velocity and may eventually lead to ventricular dysfunction and heart failure. Early diagnosis and surgical or interventional closure are essential for preventing progressive cardiovascular complications.

Importance of Diagnostic Methods

Modern imaging techniques play a major role in evaluating aortic hemodynamics in congenital heart diseases. Echocardiography is the primary diagnostic tool for assessing aortic diameter, blood flow velocity, pressure gradients, and ventricular function.

Doppler ultrasonography allows detection of turbulent blood flow and abnormal pressure differences. Computed tomography angiography and magnetic resonance imaging provide detailed

visualization of aortic anatomy and vascular abnormalities. Early identification of hemodynamic disturbances is essential for treatment planning and long-term prognosis.

Conclusion

Congenital heart diseases significantly affect aortic hemodynamics and may lead to severe cardiovascular complications in children. Structural abnormalities of the heart and great vessels alter blood flow patterns, increase vascular stress, and promote progressive remodeling of the aortic wall.

Conditions such as aortic coarctation, bicuspid aortic valve, Tetralogy of Fallot, and patent ductus arteriosus are associated with major disturbances in systemic circulation and vascular function. Persistent hemodynamic overload contributes to endothelial dysfunction, vascular stiffness, ventricular hypertrophy, and decreased aortic elasticity.

Modern diagnostic methods enable early assessment of hemodynamic changes and improve clinical management. Timely diagnosis, continuous monitoring, and appropriate surgical correction are essential for preventing irreversible cardiovascular damage and improving the quality of life in pediatric patients with congenital heart diseases.

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