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CHANGES IN VASCULAR AGE IN PATIENTS WITH HEART FAILURE

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Annotation: Chronic heart failure (ChHF) is a complex syndrome accompanied by a decrease in the pumping function of the heart, causing long-term loading and structural-functional changes in the cardiovascular system. In recent years, the concept of" vascular age " — the level of biological aging of the vessels — has emerged as an important biomarker that determines the prognosis of the disease in patients with SYY. Faster aging of the vessels compared to the passport age leads to an increase in cardiac load, a deepening of diastolic dysfunction and a risk of cardiac remodeling. This narrative analytical article highlights the essence of vascular age, methods for its assessment, (pulse wave rate, arterial stiffness) and its clinical significance on the topic of heart failure on the basis of recent scientific literature.

Keywords: heart failure, vascular age, arterial stiffness pulse wave rate, cardiac remodeling, biological aging

Introduction. Heart failure is a syndrome characterized by the inability of the heart to release blood to the extent that the body needs, and is one of the leading causes of death among cardiovascular disease. The development of ChHF is closely related not only to changes in the heart muscle, but also to aging and stiffness processes in vessels, especially large arteries. In this regard, the concept of" vascular age " is gaining relevance in clinical practice.

Vascular age is an indicator that reflects the biological aging level of a patient's arteries independently of their actual (chronological) age. Arterial stiffness, endothelial dysfunction, disruption of the collagen/elastin ratio, inflammation, and oxidative stress factors reduce the elasticity of the vascular wall and increase vascular age. In patients with heart failure, the increase in vascular age intensifies the systolic load on the heart, accelerates myocardial hypertrophy and remodeling, which leads to disease progression and worsens response to therapy.

Pulse wave velocity (PWV) is the primary and most widely used marker for assessing vascular age. It allows evaluation of arterial wall elasticity by measuring the speed of the heart's pulse wave propagation along the aorta. This article is devoted to a detailed analysis of the significance of vascular age in patients with heart failure, the criteria for its determination, and its diagnostic value.

Vascular age is an integrative biomarker that reflects the biological aging status of the human vascular system—primarily the aorta and large elastic arteries—and it does not always correspond to the patient's chronological age. This indicator depends on the structural and functional condition of the arterial wall, namely elasticity, the collagen/elastin ratio, endothelial function, and arterial stiffness. In particular, vascular stiffness measured by pulse wave velocity is considered the most reliable method for assessing vascular age.

When analyzing the clinical types of vascular age, it is generally compared to the patient's chronological (passport) age and corresponds to one of the following three categories:

The **first** is normal vascular age — in this case, the patient's vascular system ages proportionally to their chronological age. In other words, the arteries biologically retain elasticity consistent with those of individuals of the same chronological age. Such individuals typically have an average risk of cardiovascular diseases.

The **second** is supernormal vascular age — here, the arteries appear significantly "younger" relative to the chronological age, meaning they remain elastic, healthy, and functionally active. This condition is commonly observed in individuals who engage in regular physical activity, athletes, or those who adhere to a healthy lifestyle. These individuals have a substantially reduced risk of heart failure and atherosclerotic cardiovascular diseases.

The **third** is premature vascular aging (PVA) — in this scenario, the arteries age considerably faster than the patient's actual age; that is, the biological vascular age exceeds the chronological age by 5 to 10 years. PVA is primarily associated with hypertension, diabetes mellitus, metabolic syndrome, dyslipidemia, and chronic inflammatory processes. This condition markedly increases the risk of heart failure development, especially playing a pivotal role in diastolic dysfunction and heart failure with preserved ejection fraction (HFpEF).

Therefore, these three clinical patterns of vascular age serve as critical indicators for evaluating cardiovascular health, guiding preventive strategies, and monitoring therapeutic outcomes.

This approach is supported by numerous reputable studies. For example, Ben-Shlomo et al. (JACC, 2014), in their meta-analysis, demonstrated that patients with a pulse wave velocity (PWV) above 10 m/s have a twofold increased risk of cardiovascular diseases. Boutouyrie and Laurent (Nat Rev Cardiol, 2021) identified a close association between vascular age and biological stress, metabolic syndrome, and hypertension. Additionally, Cecelja and Chowienczyk (J R Soc Med Cardiovasc Dis, 2012) confirmed that the "functional aging" of arteries strongly influences the prognosis of heart failure.

The main factors influencing vascular age are as follows:

Changes in biological age — during the natural aging process, elastin degrades while collagen content increases.

Arterial hypertension — chronic high blood pressure causes stiffening of the vascular walls.

Dyslipidemia — leads to loss of arterial elasticity due to the development of atherosclerotic plaques.

Inflammatory factors (CRP, IL-6) — damage the endothelium and activate fibrotic processes.

Oxidative stress — free radicals disrupt elastic structures.

Diabetes mellitus — glycated proteins exacerbate endothelial dysfunction. Metabolic syndrome — abdominal obesity and insulin resistance accelerate vascular aging.

Smoking and physical inactivity — promote a pro-inflammatory and oxidative environment in the vessels.

Genetic factors — premature vascular aging is observed in certain families.

Increased vascular age is accompanied by the following pathobiochemical changes in the structure and function of the arterial wall:

- Elastin degradation and replacement by collagen tissue → leads to arterial wall stiffening.
- Endothelial dysfunction → decreased production of nitric oxide (NO) → impaired vasodilation.
- Inflammation → IL-1, IL-6, TNF-α → promotes stiffness and fibrosis.
- Oxidative stress → superoxide and peroxide radicals damage elastic structures.
- Atherosclerosis → disturbed laminar flow and arterial wall injury at plaque sites.

These changes reduce the elasticity of the aorta and large arteries, increase the systolic pressure load on the heart, and cause an earlier return of reflected pulse waves.

Clinical significance:

Increased cardiac load
The increase in vascular age leads to an earlier return of reflected pulse waves to the heart, which results in:

- Elevated systolic blood pressure
- Myocardial hypertrophy
- Diastolic dysfunction

Cardiac remodeling
Elevated vascular age alters the geometry of the myocardium, leading to concentric hypertrophy, which is associated with heart failure with preserved ejection fraction (HFpEF).

Cardiovascular disease prognosis
Numerous studies (e.g., Ben-Shlomo et al., JACC, 2014) have shown that patients with a pulse wave velocity (PWV) greater than 10 m/s have up to a twofold increased risk of cardiovascular complications such as myocardial infarction, stroke, and worsening heart failure.

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Association between aging and metabolic syndrome

In patients with metabolic syndrome, vascular age invariably increases more rapidly. This accelerates the progression of heart failure and reduces the effectiveness of treatment.

Vascular age is a modifiable biomarker. It can be rejuvenated through physical activity, nutrition, antihypertensive therapy, SGLT2 inhibitors, and statins. This has been proven to improve the prognosis of heart failure.

Conclusion

Vascular age is an important biomarker that is gaining increasing clinical significance in the pathophysiology of heart failure, yet it has not been fully integrated into routine assessment. In patients with heart failure, an increase in vascular age beyond chronological age is directly associated with disease progression, increased cardiac load, diastolic dysfunction, and cardiac remodeling. Parameters such as pulse wave velocity (PWV), which assess arterial stiffness, provide a reliable and straightforward method for determining vascular age. These measurements greatly aid in prognostic evaluation and the development of individualized treatment strategies for heart failure.

Notably, premature vascular aging in patients with metabolic syndrome worsens the clinical presentation of heart failure and increases the risk of progression to advanced stages. Vascular age is not merely a passive marker indicating disease severity; it is a modifiable biomarker amenable to preventive and therapeutic interventions. Therefore, incorporating vascular age measurement into the comprehensive assessment of patients with heart failure is essential for optimizing clinical management.

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