

CLINICAL AND PATHOPHYSIOLOGICAL ASPECTS OF CARDIOVASCULAR AGING:

CURRENT CONCEPTS, DIAGNOSTIC APPROACHES, AND PREVENTIVE PERSPECTIVES

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Abstract

Cardiovascular aging represents a complex, multifactorial process underlying the development of age-associated cardiovascular diseases and remains a leading contributor to morbidity and mortality in older populations. Accumulating evidence indicates that aging of the cardiovascular system is not merely a passive consequence of chronological age but is driven by interacting molecular, cellular, hemodynamic, and neurohumoral mechanisms. This article reviews contemporary concepts of cardiovascular aging, examines clinical markers and diagnostic approaches for its assessment, and discusses promising strategies for prevention and deceleration of age-related cardiovascular changes. Understanding the mechanisms of cardiovascular aging offers opportunities for early risk stratification and personalized preventive interventions.

Keywords: cardiovascular aging, arterial stiffness, endothelial dysfunction, biological age, cardiovascular prevention, cardiogerontology.

Introduction

Population aging is one of the defining demographic trends of the twenty-first century and represents a major challenge for modern healthcare systems. Although advances in medical science have significantly extended life expectancy, increased longevity is accompanied by a growing prevalence of chronic non-communicable diseases, particularly cardiovascular

disorders. Cardiovascular diseases remain the leading cause of death worldwide, with the highest incidence observed in individuals over the age of 60.

In recent years, the concept of cardiovascular aging has gained increasing attention as a framework for understanding age-related cardiovascular vulnerability. This concept emphasizes that aging-related changes in the heart and vasculature precede overt disease and may be modified through targeted preventive strategies. Elucidating the mechanisms of cardiovascular aging is therefore essential for improving early diagnosis, risk assessment, and clinical management in aging populations.

1. Concept of Cardiovascular Aging

Cardiovascular aging refers to a spectrum of structural and functional alterations affecting the heart and blood vessels that accumulate with advancing age and increase susceptibility to cardiovascular disease. Importantly, these changes may occur independently of overt pathology and remain subclinical for extended periods.

Recent research demonstrates that the rate of cardiovascular aging varies considerably among individuals. Genetic predisposition, lifestyle factors, comorbid conditions, and environmental exposures collectively influence the trajectory of cardiovascular aging. Consequently, the concept of *biological cardiovascular age* has emerged, reflecting functional cardiovascular status rather than chronological age alone.

2. Pathophysiological Mechanisms of Cardiovascular Aging

2.1 Vascular Aging

Increased arterial stiffness is a hallmark of cardiovascular aging. Age-related degradation of elastin fibers, accumulation of collagen, and vascular calcification reduce arterial compliance. These changes lead to elevated systolic blood pressure, increased pulse pressure, and greater left ventricular afterload.

Endothelial dysfunction plays a central role in vascular aging. Reduced nitric oxide bioavailability, enhanced oxidative stress, and chronic low-grade inflammation impair vasodilation and promote atherosclerotic progression.

2.2 Myocardial Aging

Aging of the myocardium is characterized by progressive loss of cardiomyocytes, interstitial fibrosis, and alterations in calcium handling. These changes contribute to impaired diastolic relaxation and diminished cardiac reserve, particularly during physical or emotional stress.

Age-associated alterations in autonomic regulation, including reduced β -adrenergic responsiveness, further limit cardiovascular adaptability in older individuals.

2.3 Molecular and Cellular Mechanisms

At the molecular level, cardiovascular aging is associated with telomere shortening, accumulation of DNA damage, mitochondrial dysfunction, and altered gene expression regulating inflammation and apoptosis. Cellular senescence of endothelial and vascular smooth muscle cells compromises regenerative capacity and exacerbates inflammatory signaling pathways.

3. Clinical Markers of Cardiovascular Aging

3.1 Arterial Stiffness

Pulse wave velocity is widely recognized as a reliable indicator of vascular aging. Elevated values correlate strongly with cardiovascular events and all-cause mortality, independent of traditional risk factors.

3.2 Echocardiographic Indicators

Echocardiography provides valuable insights into age-related cardiac remodeling. Increased left ventricular mass, diastolic dysfunction, and reduced myocardial strain are commonly observed markers of myocardial aging.

3.3 Biochemical and Inflammatory Markers

Biomarkers reflecting systemic inflammation, oxidative stress, and endothelial dysfunction are being investigated as potential indicators of cardiovascular aging. However, their routine clinical application requires further validation.

4. Diagnostic Approaches to Assessing Cardiovascular Biological Age

Contemporary diagnostic strategies aim to integrate clinical, imaging, and laboratory data to estimate cardiovascular biological age. Multimodal assessment models improve risk prediction and facilitate identification of individuals who may benefit from early preventive interventions.

5. Prevention and Deceleration of Cardiovascular Aging

5.1 Lifestyle Interventions

Lifestyle modification remains the cornerstone of cardiovascular aging prevention. Regular physical activity, balanced nutrition, smoking cessation, and weight control exert favorable effects on vascular function and myocardial performance.

5.2 Pharmacological Strategies

Effective management of blood pressure, lipid levels, and glycemic control not only reduces cardiovascular event risk but may also attenuate age-related vascular and cardiac changes. Emerging therapeutic approaches targeting inflammatory and molecular aging pathways are currently under investigation.

6. Perspectives in Cardiogerontology

Cardiogerontology, as an interdisciplinary field, integrates cardiology, gerontology, and molecular biology to address age-related cardiovascular decline. Personalized assessment and intervention strategies hold promise for extending healthspan and improving quality of life in older adults.

Conclusion

Cardiovascular aging is a dynamic and multifaceted process that substantially influences cardiovascular risk in older populations. Contemporary evidence suggests that cardiovascular aging is, at least in part, a modifiable process. Advances in diagnostic methodologies and preventive strategies provide opportunities to delay the progression of age-related cardiovascular changes. Continued integration of fundamental and clinical research in cardiogerontology will be essential for reducing the global burden of cardiovascular disease in aging societies.

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