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Plasma Biomarkers for Detecting Organ Damage Induced by Hypertension: A Comprehensive Review

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Abstract

Hypertension, a prevalent cardiovascular condition, significantly contributes to organ damage, affecting vital organs such as the heart, kidneys and brain. The early detection of hypertension-mediated organ damage is crucial for timely intervention and prevention of further complications. Plasma biomarkers have emerged as valuable tools in this context, offering a non-invasive method to monitor and assess the extent of organ damage. This comprehensive review examines the current state of research on plasma biomarkers associated with hypertension-induced organ damage. It highlights the roles of various biomarkers, including those related to inflammation, oxidative stress and endothelial dysfunction, in the detection and progression of organ damage. The review also discusses the potential for integrating these biomarkers into clinical practice for improved diagnosis and management of hypertension-related complications. By synthesizing recent findings and identifying gaps in the current knowledge, this review aims to provide a foundation for future research and development of diagnostic and therapeutic strategies in hypertension care.

Keywords: Plasma biomarkers • Organ damage • Cardiovascular risk • Endothelial dysfunction

Introduction

Hypertension is a major global health issue and a leading risk factor for a range of serious complications, including organ damage. Elevated blood pressure exerts chronic stress on various organs, leading to detrimental changes that can manifest as cardiovascular disease, chronic kidney disease and cognitive impairments. The challenge in managing hypertension lies not only in controlling blood pressure but also in identifying and monitoring the extent of organ damage that may result from prolonged hypertensive stress. Early and accurate detection of such damage is vital for preventing progression and implementing effective therapeutic strategies. Recent advances in biomarker research have provided new opportunities for non-invasive assessment of hypertension-mediated organ damage [1]. Plasma biomarkers, in particular, offer a promising approach for identifying early signs of organ injury and evaluating the severity of damage. These biomarkers can reflect underlying pathological processes such as inflammation, oxidative stress and endothelial dysfunction-key contributors to the development and progression of hypertension-related organ damage. For instance, biomarkers of endothelial dysfunction like soluble Vascular Cell Adhesion Molecule-1 (sVCAM-1) and Endothelial Nitric Oxide Synthase (eNOS) have been linked to adverse cardiovascular outcomes. Similarly, biomarkers associated with kidney injury, such as cystatin C and urinary albumin-to-creatinine ratio; provide insights into renal damage in hypertensive patients. This review aims to provide a comprehensive overview of the plasma biomarkers currently used to detect and monitor hypertension-mediated organ damage. It will cover the roles of these biomarkers in various contexts, from cardiovascular to renal and cerebral damage. By summarizing recent research findings, the review seeks to highlight the clinical relevance of these biomarkers, explore their potential applications in routine practice and identify areas where further research is needed. The goal is to offer a consolidated perspective on how plasma biomarkers can enhance the understanding and management of organ damage induced by hypertension, ultimately contributing to improved patient outcomes and more effective hypertension care [2].

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Literature Review

The relationship between hypertension and organ damage has been extensively studied, with considerable research focusing on the role of plasma biomarkers in detecting and monitoring this damage. Elevated blood pressure, sustained over time, leads to a cascade of pathological events affecting various organs, including the heart, kidneys and brain. Plasma biomarkers have emerged as crucial tools for identifying early signs of organ damage and assessing the severity of hypertension-related complications. Cardiovascular complications of hypertension include Left Ventricular Hypertrophy (LVH), heart failure and atherosclerosis. Biomarkers such as B-type Natriuretic Peptide (BNP) and High-Sensitivity Cardiac Troponin T (hs-cTnT) are commonly used to evaluate cardiac injury and function. Studies have shown that elevated levels of BNP and hs-cTnT correlate with adverse cardiovascular outcomes in hypertensive patients. Additionally, biomarkers like soluble Vascular Cell Adhesion Molecule-1 (sVCAM-1) and Endothelin-1 (ET-1) are indicative of endothelial dysfunction and have been linked to increased cardiovascular risk in hypertension [3].

Chronic hypertension can lead to kidney damage, characterized by glomerulosclerosis and tubular injury. Plasma biomarkers such as cystatin C, which reflects Glomerular Filtration Rate (GFR) and Urinary Albumin-to-Creatinine ratio (UACR) are used to assess renal function and injury. Elevated levels of cystatin C and UACR have been associated with worse renal outcomes and higher cardiovascular risk in hypertensive patients. Research has also highlighted the role of biomarkers like kidney injury molecule-1 (KIM-1) and Neutrophil Gelatinase-Associated Lipocalin (NGAL) in detecting early renal damage. Hypertension is a significant risk factor for cerebrovascular events, including stroke and cognitive decline. Plasma biomarkers such as S100B protein and Neurofilament Light chain (NfL) have been studied for their potential to detect brain injury and dysfunction associated with hypertension. Elevated levels of S100B and NfL are indicative of neuronal damage and have been linked to an increased risk of cognitive impairment and stroke in hypertensive individuals. Chronic inflammation and oxidative stress play critical roles in hypertension-induced organ damage. Biomarkers such as C-Reactive Protein (CRP) and Malondialdehyde (MDA) are commonly used to assess systemic inflammation and oxidative stress. Increased levels of CRP and MDA have been associated with more severe hypertension and increased risk of organ damage [4].

Discussion

The integration of plasma biomarkers into the management of hypertension offers several advantages. These biomarkers provide a non-invasive method for detecting early signs of organ damage, allowing for timely intervention and improved patient management. For cardiovascular damage, biomarkers like BNP and hs-cTnT help assess heart function and predict outcomes, facilitating better risk stratification and treatment planning. In renal damage, cystatin C and UACR offer valuable insights into kidney function and injury, guiding therapeutic decisions and monitoring disease progression. Similarly, biomarkers for cerebral damage and oxidative stress provide additional tools for evaluating the impact of hypertension on the brain and overall systemic health. Despite the promise of these biomarkers, several challenges remain. The variability in biomarker levels due to factors such as age, sex and comorbidities can complicate interpretation and clinical application. Additionally, while biomarkers can provide valuable information, they should be used in conjunction with other clinical assessments and diagnostic tools for a comprehensive evaluation. Future research should focus on validating these biomarkers across diverse patient populations and identifying new biomarkers that may offer additional diagnostic or prognostic value. Emerging technologies and approaches, such as high-throughput omics and advanced imaging techniques, hold potential for further enhancing biomarker discovery and application. Integrating biomarker data with genetic, proteomic and imaging information could provide a more holistic view of hypertension-mediated organ damage and improve personalized treatment strategies [5,6].

Conclusion

Plasma biomarkers play a crucial role in detecting and monitoring organ damage induced by hypertension. They offer a non-invasive and informative approach for assessing cardiovascular, renal and cerebral damage, as well as the systemic effects of inflammation and oxidative stress. While significant progress has been made in identifying and validating these biomarkers, on-going research and clinical validation are essential for optimizing their use in routine practice. The integration of biomarkers into clinical care can enhance the early detection of organ damage, guide therapeutic interventions and ultimately improve patient outcomes. Continued exploration of new biomarkers and advanced diagnostic technologies will further advance our understanding of hypertension-related complications and contribute to more effective and personalized management strategies.

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Conflict of Interest

No conflict of interest.

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