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Commentary

Cardiac Biomarkers in the Era of Precision Medicine: Beyond Troponin

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DESCRIPTION

The landscape of cardiac biomarkers has evolved dramatically over the past several decades, transforming our approach to the diagnosis, risk stratification, and management of cardiovascular diseases. From the early days of creatine kinase and lactate dehydrogenase to the current high-sensitivity troponin assays, cardiac biomarkers have become indispensable tools in clinical cardiology. As we enter the era of precision medicine, the role of biomarkers continues to expand beyond traditional applications in acute coronary syndromes to encompass a wide range of cardiovascular conditions and personalized therapeutic approaches.

Cardiac troponins have rightfully earned their position as the gold standard biomarkers for myocardial injury, with high-sensitivity assays capable of detecting minor elevations indicative of subtle myocardial damage. These assays have revolutionized the diagnosis and management of acute myocardial infarction, allowing for more rapid rule-in and rule-out protocols in emergency departments worldwide. However, the exquisite sensitivity of these tests has also presented challenges in clinical interpretation, as troponin elevations can occur in numerous conditions unrelated to acute coronary syndromes, including renal dysfunction, sepsis, pulmonary embolism, and even strenuous exercise. While troponins remain central to cardiovascular diagnostics, a multitude of novel biomarkers have emerged that provide insights into distinct pathophysiological processes beyond myocardial necrosis. Natriuretic peptides, particularly B-type Natriuretic Peptide (BNP) and N-Terminal proBNP (NT-proBNP), have established roles in the diagnosis and prognostication of heart failure. These biomarkers reflect ventricular wall stress and have proven valuable not only for diagnostic purposes but also for guiding therapy and monitoring disease progression.

Inflammatory biomarkers represent another important category in cardiovascular medicine. High-sensitivity C-Reactive Protein (hsCRP) has been extensively studied as a marker of inflammation and cardiovascular risk, with the jupiter trial demonstrating the benefit of statin therapy in patients with elevated hsCRP despite normal lipid levels. More recently, Interleukin-6 (IL-6) has emerged as a potential therapeutic target following the cantos trial, which showed that targeting the IL-1β pathway with canakinumab reduced cardiovascular events independent of lipid lowering. These findings have reinforced the inflammatory hypothesis of atherosclerosis and opened new avenues for anti-inflammatory therapies in cardiovascular disease prevention.

Beyond established biomarkers, advanced '-omics' technologies are unveiling novel biomarkers with potential applications in cardiovascular medicine. Proteomics approaches have identified proteins such as Growth Differentiation Factor-15 (GDF-15) and galectin-3 as markers of cardiac remodeling and fibrosis, while metabolomics has revealed metabolic signatures associated with cardiovascular risk that may precede traditional risk factors. The field of microRNAs represents another frontier, with these small non-coding RNA molecules showing promise as biomarkers for various cardiovascular conditions due to their stability in circulation and involvement in key pathophysiological processes. Genetic biomarkers are increasingly recognized for their value in risk prediction and therapeutic decision-making. Polygenic risk scores, which aggregate the effects of multiple genetic variants, can identify individuals at high risk for coronary artery disease even in the absence of traditional risk factors. Pharmacogenomic markers, such as those influencing clopidogrel metabolism or statin-associated muscle symptoms, offer the potential for more personalized approaches to cardiovascular pharmacotherapy, optimizing efficacy while minimizing adverse effects.

The concept of multimarker strategies has gained traction, with panels of complementary biomarkers providing more comprehensive insights than single markers alone. For instance, combining markers of myocardial injury, wall stress, inflammation, and renal function can enhance risk stratification in acute coronary syndromes beyond what is possible with troponin alone. Machine learning algorithms are increasingly being applied to integrate biomarker data with clinical variables, imaging findings, and genetic information, potentially leading to more accurate risk prediction and treatment selection.

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CONCLUSION

The integration of biomarkers into point-of-care testing represents a significant advance in clinical implementation. Rapid assays for troponin, natriuretic peptides, and other markers allow for immediate decision-making in emergency settings, potentially reducing time to treatment and improving outcomes. Wearable technologies and implantable sensors are on the horizon, offering the possibility of continuous biomarker monitoring and early detection. The evolution of cardiac biomarkers from simple indicators of myocardial necrosis to sophisticated tools for precision medicine exemplifies the rapid progress in cardiovascular diagnostics. As technology advances and our understanding of cardiovascular pathophysiology deepens, biomarkers will continue to play an increasingly central role in the delivery of personalized cardiovascular care, ultimately improving outcomes for patients with or at risk for cardiovascular disease.