

Biomarker Discovery for Inflammatory States Through Advanced Metabolomics

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Structured Abstract

Background:

Inflammation, a vital immune response to harmful stimuli, plays a central role in the pathogenesis of many chronic diseases including cardiovascular disease, cancer, diabetes, and autoimmune disorders. Traditional biomarkers such as C-reactive protein (CRP), interleukins, and TNF- α are routinely used to monitor inflammatory responses but often suffer from limited specificity and sensitivity. This review explores the potential of metabolomics as an advanced approach to identify novel biomarkers for differentiating acute and chronic inflammatory states, with a focus on their application in atherosclerosis.

Methods:

The objective of this review is to (i) identify metabolic biomarkers distinguishing acute and chronic inflammation, (ii) compare the diagnostic efficacy of metabolomics-based versus conventional biomarkers, and (iii) examine the clinical applicability of these biomarkers, particularly in the context of atherosclerosis. A systematic synthesis of peer-reviewed literature was conducted to evaluate current findings on metabolite profiles related to inflammation, including key compounds such as kynurenine, TMAO, succinate, and various amino acids. Studies selected for this review included both clinical and experimental metabolomics investigations, focusing on the temporal patterns and biological relevance of altered metabolite levels in disease contexts.

Results:

The findings reveal that acute and chronic inflammation exhibit distinct metabolic signatures—acute inflammation is associated with increased glycolysis and elevated lactate levels, while chronic inflammation is characterized by sustained shifts in fatty acid oxidation, amino acid depletion, and kynurenine pathway activation. In the case of atherosclerosis, metabolomics has uncovered several promising biomarkers, such as TMAO, β -pseudouridine, and bile acids, which correlate with disease progression and may enable early detection. Emerging evidence also supports the role of gut microbiota-derived metabolites as critical modulators in inflammatory pathways.

Conclusion:

This review concludes that metabolomics offers a powerful and more precise alternative to traditional inflammatory markers, with the ability to detect early biochemical perturbations, improve diagnostic accuracy, and inform personalized therapeutic strategies. However, challenges remain in translating metabolomics to clinical settings, including methodological standardization and validation of identified biomarkers.

Keywords: Metabolomics, Inflammation, Biomarkers, Atherosclerosis, Diagnostic Strategy

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