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GUT MICROBIOTA AND CARDIOVASCULAR DISEASE: MECHANISMS, NUTRITION, AND THERAPEUTIC PERSPECTIVES

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Abstract

The gut microbiota has emerged as a crucial regulator of cardiovascular health, influencing disease development through metabolic, inflammatory, and immunological pathways. This article reviews current evidence on the role of gut microbiota in cardiovascular disease (CVD), with a focus on microbial metabolites such as trimethylamine-N-oxide (TMAO), short-chain fatty acids (SCFAs), and bile acids. The interaction between diet and microbiota is explored as a key determinant of cardiovascular risk. Additionally, therapeutic strategies including dietary modification, probiotics, pharmacological interventions, and fecal microbiota transplantation (FMT) are discussed. Despite promising findings, limitations remain regarding causality and clinical application. Future research should focus on personalized microbiome-targeted therapies.

Introduction

Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide. Traditional risk factors such as hypertension, diabetes, obesity, and dyslipidemia do not fully explain disease variability, prompting interest in additional modulators such as the gut microbiota.

The gut microbiome consists of trillions of microorganisms that regulate host metabolism, immunity, and inflammation. Dysbiosis—an imbalance in

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microbial composition—has been linked to systemic inflammation, endothelial dysfunction, and metabolic disorders, all of which contribute to CVD progression.

Recent studies suggest that gut microbiota influences cardiovascular health through the production of bioactive metabolites, interaction with immune pathways, and modulation of host metabolic processes.

2. Gut Microbiota and Cardiovascular Risk Factors

The gut microbiota plays a critical role in modulating key cardiovascular risk factors.

2.1 Hypertension

Hypertension is associated with reduced microbial diversity and decreased production of SCFAs. Dysbiosis increases intestinal permeability, allowing endotoxins such as lipopolysaccharides (LPS) to enter circulation and trigger inflammation, leading to elevated blood pressure.

2.2 Hypercholesterolemia and Lipid Metabolism

Gut microbiota influences lipid metabolism through bile acid transformation and cholesterol regulation. Beneficial bacteria such as Bifidobacterium and Lactobacillus have been shown to reduce serum cholesterol levels.

2.3 Obesity and Diabetes

Obesity and type 2 diabetes are characterized by alterations in microbial composition, including reduced abundance of beneficial bacteria and increased pro-inflammatory species. These changes contribute to insulin resistance and chronic inflammation.

3. Molecular Mechanisms Linking Gut Microbiota and CVD

3.1 Trimethylamine-N-oxide (TMAO)

TMAO is produced from dietary choline and L-carnitine via microbial metabolism. Elevated TMAO levels are strongly associated with atherosclerosis, thrombosis, and cardiovascular events.

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3.2 Short-Chain Fatty Acids (SCFAs)

SCFAs, including acetate, propionate, and butyrate, are produced through fermentation of dietary fiber. They exert anti-inflammatory effects, regulate blood pressure, and maintain gut barrier integrity.

3.3 Bile Acids

Gut microbiota modifies bile acids, which act as signaling molecules regulating lipid metabolism and inflammation via receptors such as FXR and TGR5.

3.4 Inflammation and Endothelial Dysfunction

Microbial products such as LPS induce systemic inflammation and endothelial damage, promoting atherosclerosis and vascular dysfunction.

4. Nutrition and Gut Microbiota

Diet is a primary determinant of gut microbiota composition and function.

4.1 High-Fiber Diets

Dietary fiber promotes beneficial bacteria and SCFA production, reducing inflammation and improving cardiovascular outcomes.

4.2 Mediterranean Diet

The Mediterranean diet, rich in polyphenols and unsaturated fats, enhances microbial diversity and reduces oxidative stress.

4.3 Western Diet

High intake of saturated fats and sugars leads to dysbiosis, increased TMAO production, and elevated cardiovascular risk.

5. Therapeutic Strategies

5.1 Probiotics and Prebiotics

These interventions improve gut microbiota composition, reduce inflammation, and enhance metabolic health.

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5.2 Fecal Microbiota Transplantation (FMT)

FMT has shown potential in modulating blood pressure and metabolic parameters, although long-term effects remain unclear.

5.3 Pharmacological Interventions

Drugs such as metformin and statins influence gut microbiota and contribute to cardiovascular protection.

6. Limitations

Despite promising findings, several limitations remain:
lack of large-scale clinical trials
incomplete understanding of mechanisms
variability in individual microbiota
Safety concerns, particularly regarding FMT, must also be addressed.

7. Future Perspectives

Advances in technologies such as CRISPR and multi-omics approaches will enable precise modulation of gut microbiota. Personalized microbiome-based therapies hold great promise for preventing and treating cardiovascular diseases.

Conclusion

The gut microbiota plays a fundamental role in cardiovascular disease through its influence on metabolism, inflammation, and endothelial function. Targeting the gut microbiome represents a novel and promising approach for CVD prevention and treatment.

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