

Advances in the treatment of ulcerative colitis with Chinese medicine based on metabolomics technology

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Abstract: Ulcerative colitis is a chronic inflammatory bowel disease with complex clinical manifestations and significant treatment challenges. Traditional Chinese medicine (TCM) offers unique advantages in treating ulcerative colitis, yet its treatment mechanisms remain incompletely elucidated. Metabolomics technology, as a tool for comprehensive analysis of biological metabolites, has gradually been applied in ulcerative colitis research, providing new perspectives for understanding its pathogenesis and optimizing treatment strategies. This paper reviews the research progress on TCM treatment of ulcerative colitis based on metabolomics technology, discusses the application prospects and significance of metabolomics in TCM research, aiming to provide a theoretical foundation and methodological guidance for future in-depth studies.

1. Introduction

Ulcerative colitis (UC) is a chronic, relapsing inflammatory bowel disease characterized by continuous inflammation and ulcer formation in the colonic mucosa. Clinical manifestations include symptoms such as diarrhea, abdominal pain, and rectal bleeding, significantly impacting patients' quality of life and health. While conventional treatments such as anti-inflammatory drugs and immunosuppressants can alleviate symptoms, their long-term use poses challenges due to side effects and treatment resistance. Therefore, seeking effective and safe treatment strategies is crucial. Traditional Chinese medicine (TCM), as an integral part of Chinese traditional medicine, offers unique therapeutic advantages and philosophical principles that show promising applications in treating ulcerative colitis. However, the treatment mechanisms and efficacy evaluation of traditional Chinese medicine have been focal points of academic scrutiny. In recent years, with the rapid development of metabolomics technology, a high-throughput technique that comprehensively analyzes biological metabolites, metabolomics has emerged as an important tool for studying the pathophysiological processes and treatment responses of ulcerative colitis. This paper aims to review the research progress on TCM treatment of ulcerative colitis based on metabolomics technology[1]. It begins by introducing the clinical features of ulcerative colitis and the limitations of traditional treatment methods. It then discusses the current application and advantages of TCM in the treatment of ulcerative colitis, followed by a detailed exposition of the basic principles of metabolomics

technology and its significance in disease research. Finally, it reviews and analyzes the latest research advancements in TCM treatment strategies based on metabolomics technology, aiming to provide theoretical and methodological support for future in-depth studies.

2. Traditional Chinese Medicine Treatment Methods for Ulcerative Colitis

2.1. Understanding and treatment principles of ulcerative colitis in TCM theory

Ulcerative colitis, categorized within Chinese medicine alongside dysentery and tenesiosis, is viewed through the lens of traditional Chinese medicine (TCM) as primarily stemming from factors such as liver depression, spleen deficiency, and spleen-stomach damp-heat. These imbalances are believed to contribute significantly to its onset and progression. TCM approaches the treatment of ulcerative colitis holistically, targeting both symptomatic relief and addressing the underlying root causes. Key therapeutic goals include calming liver function, which helps reduce stress-related exacerbations, and thinning the intestine to ease inflammation and promote healing. Strengthening the spleen and eliminating dampness are also vital aspects of treatment, as they enhance digestive function and reduce mucosal irritation. Moreover, clearing heat and detoxifying the body support overall systemic balance, aiding in the restoration of normal intestinal mucosa function and structure. Treatment protocols in TCM often involve tailored herbal formulations. For instance, herbs like Coptis and scutellaria are used for their heat-clearing and fire-purging properties, which help alleviate symptoms of inflammation and discomfort. Additionally, herbs such as salvia miltiorrhiza and Chuanxiong are employed to activate blood circulation and remove stasis, thereby enhancing local tissue repair. Combinations with spleen-invigorating herbs like codonopsis and Baizhu further optimize treatment outcomes by bolstering qi (vital energy) and supporting overall digestive resilience. Central to TCM practice is the customization of treatment plans to suit individual patient profiles. This includes adjusting herbal prescriptions based on specific symptoms, constitutional characteristics, and response to previous treatments. Dietary modifications, such as avoiding spicy or greasy foods that exacerbate dampness and heat, along with emotional management techniques, play integral roles in supporting long-term therapeutic success and minimizing adverse reactions. By integrating these comprehensive approaches, TCM not only aims to alleviate symptoms but also seeks to restore holistic balance within the body. This patient-centered approach underscores TCM's efficacy in managing ulcerative colitis, offering personalized care that addresses both the physical and emotional dimensions of the disease [2].

2.2. Common Traditional Chinese Medicine Treatment Plans and Medication Combinations

In the treatment of ulcerative colitis with traditional Chinese medicine, common treatment plans and medication combinations involve various categories of herbs. Heat-clearing and fire-purging herbs such as Huang Lian (*Coptis chinensis*) and Huang Qin (*Scutellaria baicalensis*) are widely used. Their properties of clearing heat, drying dampness, and cooling blood detoxify, effectively alleviate intestinal inflammation and mucosal ulcers, significantly reducing inflammatory reactions in patients. Blood-activating and stasis-dispelling herbs such as Dan Shen (*Salvia miltiorrhiza*) and Chuan Xiong (*Ligusticum chuanxiong*) improve microcirculation, reduce the release of inflammatory mediators, alleviate pain, and promote intestinal tissue repair [3]. Additionally, spleen-tonifying and qi-reinforcing herbs such as Dang Shen (*Codonopsis pilosula*) and Bai Zhu (*Atractylodes macrocephala*) are used to tonify the spleen, invigorate qi, strengthen the spleen and stomach, enhance the body's resistance, and repair capabilities, playing a crucial role in improving digestive function and promoting nutrient absorption. These herbs are often used in compound formulas such as Qing Chang Ning and Xiao Chai Hu Tang, adjusted according to the specific

symptoms and constitutional characteristics of patients for personalized treatment, comprehensively exerting therapeutic effects.

2.3. Advantages and Challenges of Traditional Chinese Medicine Treatment

The advantages of traditional Chinese medicine in treating ulcerative colitis lie in its comprehensive regulation and personalized treatment characteristics. Firstly, TCM theory emphasizes a holistic approach and addressing both root causes and symptoms, aiming not only to treat symptoms but also to regulate the overall balance of Yin and Yang and harmonize qi and blood, which helps improve the overall health status of patients. Secondly, the diversity of Chinese herbal medicine allows for personalized formulations tailored to the specific conditions and constitutional characteristics of patients, facilitating flexible adjustment of treatment plans to enhance treatment specificity and effectiveness. Moreover, TCM treatment methods are relatively gentle, reducing many common side effects and resistance issues associated with Western medicine treatments, which is particularly important for long-term patients. However, challenges in TCM treatment for ulcerative colitis should not be overlooked. Firstly, TCM treatment requires a longer period of conditioning and observation, and the treatment process is relatively slow compared to the rapid effectiveness of Western medicine treatments, which may not be ideal for patients experiencing acute attacks. Secondly, the efficacy of TCM treatment varies from person to person, relying on the clinical experience of physicians and the response of patients, lacking uniform treatment standards and evaluation systems[4]. Additionally, some patients may be allergic or intolerant to Chinese herbal ingredients, requiring careful selection and monitoring of adverse reactions during the treatment process. In conclusion, traditional Chinese medicine treatment for ulcerative colitis has its unique advantages and challenges. Future research and clinical practice need to further explore its exact mechanisms of action in disease treatment and effective application strategies to enhance its position and influence in modern medical systems.

3. Overview of Metabolomics Technology

3.1. Definition and Basic Principles of Metabolomics Technology

Metabolomics is a branch of systems biology aimed at studying the comprehensive changes in all metabolites (metabolome) within an organism under specific physiological states or environmental conditions. Its fundamental principle involves the use of high-throughput technologies such as mass spectrometry and nuclear magnetic resonance to comprehensively analyze and quantify metabolites in biological samples (e.g., blood, urine, tissues), thereby revealing the structure and function of the organism's metabolic network. The core steps of metabolomics technology include: first, sample collection and pre-processing to ensure stability and measurability of metabolites; second, separation and identification of metabolites using techniques such as mass spectrometry or nuclear magnetic resonance for qualitative and quantitative analysis; and finally, data analysis and interpretation, employing statistical and bioinformatics methods to identify biomarkers, metabolic pathways, and their regulatory mechanisms. Through metabolomics technology, researchers can gain a comprehensive understanding of the metabolic characteristics of organisms during disease onset, treatment processes, or environmental changes, providing powerful tools and methods for personalized medicine, early disease diagnosis, and drug development. In the study of ulcerative colitis, metabolomics applications can help reveal metabolic abnormalities associated with the disease and their correlation with the effectiveness of traditional Chinese medicine treatments, thereby supporting deeper insights into disease mechanisms and optimizing treatment strategies[5].

3.2. Prospects and Significance of Metabolomics Technology in Traditional Chinese Medicine Research

With the development of metabolomics technology, its application in traditional Chinese medicine (TCM) research is becoming increasingly significant and wide-ranging. Integrating TCM's emphasis on holistic regulation and personalized treatment with high-throughput data analysis from metabolomics holds promise in several key areas: Firstly, metabolomics technology can systematically analyze the overall impact of Chinese herbal medicine on metabolites within the body. By comparing pre- and post-treatment metabolomic data, it can elucidate the specific mechanisms through which TCM regulates metabolic pathways during disease treatment, thereby identifying and validating biomarkers for TCM treatments. Secondly, metabolomics helps in understanding the synergistic mechanisms of Chinese herbal compound formulations. TCM formulations often consist of multiple herbs with specific actions; metabolomics can reveal their interactions within the body and their combined regulatory effects on metabolic networks. Thirdly, metabolomics contributes to uncovering individualized characteristics of TCM treatments. Variations in metabolic levels and pathways among individuals can be identified and analyzed, providing scientific foundations for personalized TCM therapies. Lastly, the integration of metabolomics with TCM contributes to advancing the modernization and internationalization of TCM. In-depth scientific research into Chinese herbs using modern technological approaches enhances their global recognition and application, promoting the dissemination and adoption of TCM worldwide. In summary, metabolomics technology holds broad prospects in TCM research, offering new scientific support and theoretical foundations for the modernization and clinical application of traditional Chinese medicine through exploring the mechanisms of action and individualized characteristics of TCM treatments[6].

4. Research Progress on Ulcerative Colitis Based on Metabolomics Technology

4.1. Specific Applications of Metabolomics in Ulcerative Colitis Research

Metabolomics technology plays a crucial role in the study of ulcerative colitis (UC), focusing on several key applications: Firstly, metabolomics helps identify metabolic differences between UC patients and healthy individuals. By comparing metabolomic data from patient and control groups, biomarkers closely associated with disease onset and progression can be discovered, aiding early diagnosis and revealing underlying pathophysiological mechanisms. Secondly, metabolomics analyzes metabolic changes in patients under different disease states. In UC research, researchers explore metabolic characteristics during different disease stages or treatment response states to evaluate treatment efficacy and predict disease progression[7]. Additionally, metabolomics reveals the impact of different treatment methods on patient metabolic status. By monitoring changes in the metabolic profile of patients undergoing Chinese herbal or Western medicine treatments, the effectiveness and safety of different treatment strategies can be compared, facilitating the development of personalized treatment plans. Lastly, metabolomics promotes precision medicine practices for UC. By integrating metabolomics data with clinical pathology features and genomics, more precise diagnosis and treatment strategies can be achieved, providing better personalized care and management for patients. In conclusion, metabolomics technology plays a significant role in revealing the pathogenesis and metabolic changes of ulcerative colitis, deepening the understanding of the disease's physiological and pathological processes, and providing important support for early diagnosis, personalized treatment, and precision medicine.

4.2. Discussion on Revealed Mechanisms and Changes in Ulcerative Colitis Using Metabolomics Technology

Metabolomics technology has revealed significant differences in metabolism between ulcerative colitis (UC) patients and healthy individuals, providing crucial clues to understanding the physiological and pathological processes of the disease. Studies indicate that UC patients exhibit distinct metabolic profiles, primarily in the following areas: Firstly, UC patients show abnormalities in inflammatory responses and immune regulation in their metabolic profiles. Metabolomics analysis reveals elevated levels of various metabolites (such as inflammatory mediators, oxidative stress products), reflecting an active state of inflammation. These metabolic changes not only reflect the pathogenesis of UC but also may involve the activation of immune cells and release of inflammatory mediators, exacerbating intestinal inflammation and recurrence. Secondly, UC patients experience significant changes in energy metabolism and nutritional status. Metabolomics analysis shows that specific metabolic pathways (such as glycolysis, fatty acid metabolism) are affected in UC patients, leading to imbalances in energy metabolism and disruptions in nutrient intake. These changes not only affect the overall health of patients but also may exacerbate mucosal damage and regeneration processes in the intestines, influencing the progression and treatment response of UC. Furthermore, metabolomics technology reveals dynamic metabolic changes in UC patients during treatment. As treatment progresses, patients' metabolic profiles undergo a series of changes, reflecting the therapeutic effects on disease metabolism. These changes provide real-time biomarker information for clinicians, guiding personalized adjustments to treatment strategies and monitoring disease progression.

In summary, metabolomics technology plays a significant role in elucidating the pathogenesis and metabolic changes of ulcerative colitis, deepening the understanding of the disease's physiological and pathological processes, and providing scientific foundations and new insights for the development of personalized treatment strategies. As technology advances and clinical applications expand, metabolomics is poised to become an essential tool for disease diagnosis, treatment, and prognosis assessment, advancing the precision medicine approach to ulcerative colitis.

4.3. Case Studies Optimizing Traditional Chinese Medicine Treatment Plans Using Metabolomics Technology

Metabolomics technology demonstrates extensive potential in optimizing traditional Chinese medicine (TCM) treatment plans by analyzing patients' metabolic characteristics and the effects of medications, enabling personalized treatment strategy optimization. Here are several relevant research case studies: **Analysis of Individual Drug Responses:** Research teams utilize metabolomics technology to analyze differences in metabolic responses to Chinese herbal compound formulations among various ulcerative colitis (UC) patients. By comparing metabolomic data before and after treatment, specific patterns of metabolic pathway changes are identified. Combined with clinical pathology features, personalized TCM prescriptions are designed. This approach not only improves treatment efficacy but also reduces the risk of adverse reactions, providing patients with more precise and effective treatment plans. **Analysis and Optimization of Pharmacological Substances:** Another study employs metabolomics technology to analyze the pharmacological substance basis of active ingredients in Chinese herbal compound formulations. Through in-depth research into the metabolic pathways and biological activities of different pharmacological substances in patients' metabolisms, the composition ratio of TCM formulations and treatment plan designs are optimized. This method effectively enhances the therapeutic effects of Chinese medicine, ensuring treatment safety and controllability, and providing scientific foundations for modernization and personalized

treatment of TCM. Prediction of Treatment Responses and Disease Progression: Metabolomics technology can also help predict patient responses to specific treatment plans and disease progression[8]. By establishing metabolic biomarker models for patients, monitoring dynamic changes in metabolism during treatment, timely adjustments to treatment strategies can be made, and trends in disease progression can be predicted. This personalized treatment monitoring method effectively improves treatment specificity and predictability for ulcerative colitis patients, providing new solutions for their long-term management. In summary, metabolomics technology, with its profound molecular-level analysis capabilities, offers innovative research pathways and methods for optimizing and personalizing traditional Chinese medicine treatment plans. In the future, as technology advances and clinical applications expand, metabolomics is expected to become a crucial support tool for the modernization and precision medicine of traditional Chinese medicine.

5. Discussion and Prospects

5.1. Potential and Limitations of Traditional Chinese Medicine and Metabolomics in the Treatment of Ulcerative Colitis

The combination of Traditional Chinese Medicine (TCM) and metabolomics shows significant potential in the treatment of Ulcerative Colitis (UC), yet it faces several limitations and challenges. In terms of potential, TCM emphasizes holistic adjustment and personalized treatment, complemented by high-throughput data analysis from metabolomics technology, aiming to achieve more precise therapeutic strategies. Through metabolomics analysis, a deeper understanding of the metabolic effects of Chinese herbal medicine within patients and their regulatory mechanisms in pathological processes can optimize the formulation of herbal compounds and treatment plans, thereby improving treatment efficacy and patient quality of life. However, the combination of TCM and metabolomics still encounters limitations in UC treatment. Firstly, TCM formulations are complex with diverse active substances, making it difficult to accurately identify and quantify their specific mechanisms in metabolomics analysis. Secondly, the high cost and complexity of metabolomics technology limit its widespread clinical application, especially in resource-limited regions and under insufficient medical conditions. Furthermore, clinical validation and optimization are needed for the integration of TCM and metabolomics in clinical practice. Current research mainly focuses on small-sample, single-center studies, lacking large-scale, multi-center clinical trial data support. Therefore, effectively integrating metabolomics technology and traditional TCM treatment concepts to address challenges in treatment outcome prediction, safety assessment, and long-term effect monitoring remains a crucial direction for future research. In summary, TCM and metabolomics demonstrate tremendous potential in UC treatment, but they also need to overcome various technological, cost-related, and clinical validation limitations. With ongoing technological and methodological advancements, this integration promises more personalized and effective treatment options for patients with UC.

5.2. Discussion on Future Directions and Challenges of Integrated Research of Traditional Chinese Medicine and Metabolomics

Future integrated research of Traditional Chinese Medicine (TCM) and metabolomics faces multiple directions and challenges that will determine its practical application and impact in UC treatment. Firstly, developing personalized treatment plans: With advancements in metabolomics technology, future research can analyze patients' metabolic characteristics more accurately, including the influence of genomics and environmental factors, to design more personalized TCM treatment plans. Through big data analysis and artificial intelligence, rapid optimization of complex

herbal formulations can be achieved, enhancing treatment efficacy and the level of personalized medical care. Secondly, deepening mechanism research and new drug discovery: Metabolomics technology not only reveals the mechanisms of TCM treatment but also provides theoretical and experimental foundations for new drug development. Future studies can further explore the biotransformation pathways and action targets of active ingredients in TCM formulations, accelerating the discovery and clinical application of new drugs. Thirdly, establishing a multi-center clinical trial platform: To validate the clinical efficacy and safety of integrated TCM and metabolomics treatment, a large-scale, multi-center clinical trial platform is necessary. Such a platform can ensure the reproducibility and universality of research results, laying a solid foundation for the widespread application of this technology in UC and other disease treatments. Additionally, standardization of technology and data presents a major current challenge. The high complexity and diversity of metabolomics data necessitate standardized data collection, processing, and interpretation methods to ensure data comparability across different studies and the credibility of results. Future research needs to unify standards for data collection, processing, and interpretation to enhance the reliability of research outcomes. Lastly, interdisciplinary collaboration and knowledge translation are critical factors in advancing integrated research of TCM and metabolomics. Future studies should promote close collaboration among disciplines such as TCM, metabolomics, computational biology, and clinical medicine to accelerate the translation of scientific discoveries, promote the application and dissemination of this technology in UC treatment, and contribute to medical advancements and patient health. In conclusion, the integration of Traditional Chinese Medicine and metabolomics presents broad prospects and potential in the treatment of Ulcerative Colitis. By deeply understanding patients' metabolic characteristics and the mechanisms of TCM formulations, optimized personalized treatment plans can be realized, thereby enhancing treatment efficacy and improving patient quality of life. However, this field still faces challenges such as technological standardization, clinical validation, and interdisciplinary cooperation needs. Future research should strengthen the integration of basic scientific research and clinical practice, promote the deep integration of TCM and metabolomics, develop innovative treatment strategies for UC and other complex diseases, and advance medical progress and patient health.

6. Conclusion

The combination of traditional Chinese medicine and metabolomics in the treatment of ulcerative colitis has shown broad application prospect and potential. By deeply understanding the metabolic characteristics of patients and the mechanism of action of TCM compounds, the optimization of personalized treatment can be realized, and the treatment effect and the quality of life of patients can be improved. However, the field still faces many challenges, such as the need for technical standardization, clinical validation, and multidisciplinary collaboration. Future research should strengthen the combination of basic science research and clinical practice, promote the deep integration of traditional Chinese medicine and metabolomics, develop innovative solutions for the treatment of ulcerative colitis and other complex diseases, and promote medical progress and patient health.

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