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Gut Microbiome and Allergic Rhinitis: A New Paradigm in Understanding and Treatment

(Microbiota Usus dan Alergi Rhinitis: Paradigma Baru dalam Pemahaman dan Rawatan)

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Abstract:

This paper explores the correlation between allergic rhinitis (AR) and gut microbiome, emphasizing the role of intestinal microflora in disease progression. The epidemiological characteristics and pathophysiological basis of AR are initially discussed, highlighting its association with the inflammatory response mediated by immunoglobulin E (IgE). In addition, the classification, diagnosis, and standard treatment options for AR are reviewed, including skin prick testing, serum-specific IgE detection, and allergen-specific immunotherapy. The ensuing sections of the paper explore the mechanism and clinical use of probiotics for modulating the intestinal microbiota, bolstering immune function, and alleviating symptoms of allergic rhinitis, as well as providing an overview of relevant clinical research advancements. The discussion explores the interchange between gut flora and the respiratory system, highlighting the attributes and potential therapeutic applications of probiotics in reducing the risk of allergic rhinitis.

Keywords: Allergic rhinitis; Probiotic bacteria; Gut microbiome; Immunoglobulin E; Gut flora

Abstrak

Kajian ini meneroka hubungan antara alergi rhinitis (AR) dan mikrobiota usus, menekankan kesan microbiota usus terhadap perkembangan dan kemajuan penyakit tersebut. Ciri-ciri epidemiologi dan asas patofisiologi AR dibincangkan pada awalnya, menonjolkan kaitannya dengan tindak balas keradangan yang dimediasi oleh imunoglobulin E (IgE). Selain itu, klasifikasi, diagnosis, dan pilihan rawatan standard untuk AR dibincangkan, termasuk ujian tusukan kulit, pengesanan IgE serum spesifik, dan imunoterapi khusus alergen. Bahagian seterusnya dalam kertas ini meneroka mekanisma dan penggunaan klinikal probiotik untuk memodulasi mikrobiota usus, memperkuat fungsi imun, dan mengurangkan simptom alergi rhinitis, serta memberikan gambaran keseluruhan tentang kemajuan penyelidikan klinikal yang relevan. Perbincangan ini juga meneroka hubungan timbal balik antara mikrobiota usus dan sistem pernafasan, menonjolkan kesan dan potensi aplikasi terapeutik probiotik dalam mengurangkan risiko alergi rhinitis.

Kata Kunci: Alergi rhinitis; Kuman Probiotik; Mikrobiota usus; Imunoglobulin E; Flora usus.

INTRODUCTION

Allergic rhinitis (AR) is a non-infectious, chronic inflammatory disease affecting the nasal mucosa, primarily mediated by Immunoglobulin E (IgE) in individuals with atopy upon exposure to allergens (Subspeciality Group of Rhinology, 2022). Recent epidemiological studies indicate a sharp increase in AR prevalence, posing significant challenges for affected patients (Subspecialty Group of Rhinology, 2022). Currently, around 10% of the global population is affected by AR, underscoring the disease's public health impact. Some countries, such as China, exhibit a higher prevalence than the global average. The prevalence of AR in China was found to be 19% among adults and 22% among children, according to a meta-analysis (Pang et al. 2022).

The role of gut microbiota in overall health and its link to AR is gaining increased attention (Watts et al. 2021). The gut microbiota's complex metabolic network comprises a vast diversity of species and metabolic pathways. Shifts in the composition of intestinal microbial metabolites can impact physiological processes like material metabolism, signal transduction, gene expression, and energy balance. These alterations can lead to local or systemic physiological changes, potentially influencing disease development and progression. Recognizing and analyzing these metabolic changes are crucial in understanding disease mechanisms and improving diagnostic strategies.

This paper examines the current evidence linking AR with intestinal microbiota composition, focusing on the microbiota's role in AR pathogenesis and treatment. Notably, disturbances in intestinal microbial metabolism are implicated in major diseases such as cardiovascular disease, liver disease, and cancer. Understanding intestinal microorganisms and their metabolites can support disease staging, provide insight into pathogenesis, and guide targeted therapeutic approaches.

Allergic Rhinitis

Allergic rhinitis refers to an individual with atopic characteristics exposed to an allergen, resulting in the predominant mediation of specific IgE and involvement of neuroimmune disorders (Lourenço et al. 2020). In atopic individuals, the regional draining of lymph nodes and nasal cavities leads to the production of specific IgE upon allergen stimulation. This specific IgE binds to the high-affinity IgE receptor on the surface of mast cells and basophils in the nasal mucosa, establishing a sensitized state (Yao et al. 2019). Re-exposure to the same allergen triggers both immediate and delayed phase reactions, as documented by Yao (Yao et al. 2019). The development of AR is intricately linked to the interplay between genetic predisposition and environmental factors (Figure 1). Notably, AR is characterized by a genetic susceptibility, as evidenced by genome-wide association studies that have identified specific single nucleotide polymorphisms, including rs34004019, which may be implicated in the pathogenesis of allergic diseases such as AR and asthma (Waage et al. 2018). While the primary pathogenesis of AR is attributed to IgE-mediated type I allergy, a subset of AR patients exhibits a non-IgE-mediated inflammatory response. It is widely acknowledged that AR and asthma share a common airway and disease mechanism. However, the extent of nasal tissue remodeling in AR patients varies from that observed in bronchial tissue.

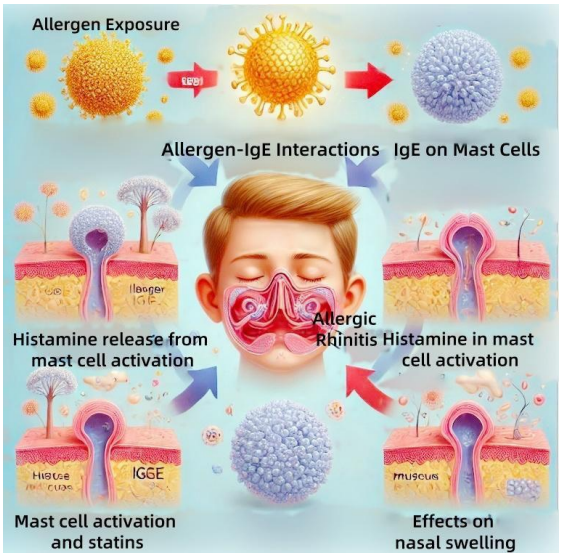

Figure 1. Diagram illustrating the immune response in allergic rhinitis (this image was generated with the aid of ChatGPT)

Currently, there are three existing primary methods for categorizing AR based on the nature of the allergen, timing of symptom manifestation, and disease severity. In terms of the allergen type, AR can be classified as either seasonal or perennial. Regarding the timing of symptom onset, patients can be categorized as having either intermittent or persistent AR. The third classification encompasses mild AR and moderate-severe AR (Subspecialty Group of Rhinology, 2022). The characteristic symptoms of AR include nasal pruritus, nasal congestion, paroxysmal sneezing, and rhinorrhea, often accompanied by ocular symptoms such as lacrimation, ocular pruritus, ocular burning, and conjunctival redness.

Diagnosis of AR

The skin prick test (SPT) is the primary approach utilized to ascertain IgE-mediated type I allergy. Nevertheless, the outcomes of SPT can be influenced by the oral consumption of H1 antihistamines, antidepressants, and topical glucocorticoids. In clinical settings, the detection of serum-specific IgE is a prevalent method for quantitatively detecting AR. However, it is important to note that an elevation in serum total IgE levels can merely suggest the possibility of type I allergy and cannot be utilized as an independent criterion for diagnosing AR. Additional tests conducted in the study encompassed the nasal provocation test, determination of allergen-specific IgE and eosinophil cationic protein in nasal lavage fluid, serum allergen component-specific IgE test, peripheral blood basophil activation test, nasal secretion smear cytological examination, exhaled nitric oxide test, and pulmonary function test.

In China, AR diagnosis relies primarily on clinical assessments and allergen detection. The symptoms include the presence of two or more indicators such as watery nasal discharge, paroxysmal sneezing, nasal congestion, and itching, with the persistence or accumulation of these symptoms for over an hour daily. Additionally, the presence of accompanying eye symptoms like itching, tearing, and redness is also considered. Furthermore, common indicators of AR encompass nasal mucosa pallor, edema, and the presence of watery nasal secretions. At least one allergen-specific SPT and/or serum-specific IgE positive, or a positive nasal provocation test, were identified as diagnostic criteria for AR (Subspecialty Group of Rhinology, 2022). The diagnosis of AR was based on the clinical manifestations, allergic history, and allergen test results of patients with AR. AR is frequently accompanied by a range of diseases, including bronchial asthma, allergic conjunctivitis, chronic sinusitis, upper airway cough syndrome, secretory otitis media, sleep disorders, atopic dermatitis, and eosinophil esophagitis.

Treatment of AR

The treatment approach for AR involves the avoidance of allergen exposure and the appropriate utilization of antihistamines and glucocorticoids. The primary pharmacological interventions for AR encompass glucocorticoids, antihistamines, anti-leukotrienes, mast cell membrane stabilizers, decongestants, anticholinergic drugs, traditional Chinese medicine, nasal saline irrigation, anti-IgE therapy, and combination therapy. Immunotherapy serves as a primary treatment option for AR and is particularly effective for allergen-specific IgE-mediated diseases. However, there are instances where immunotherapy may not be a suitable course of treatment for AR. These instances include cases involving severe asthma and irreversible respiratory obstructive diseases, active immune diseases, malignant tumors, ongoing use of beta blockers, severe cardiovascular diseases, remission of autoimmune diseases, patients with severe mental illnesses or poor compliance, primary or secondary immunodeficiency, severe adverse reactions during immunotherapy, and pregnancy. Additionally, surgical interventions can also be employed to address AR. Non-IgE-mediated allergic rhinitis has a unique pathomechanism and, unlike classical IgE-mediated allergic reactions, may exhibit differential responses to gut microbiota interventions. Non-IgE-mediated AR is usually dominated by cell-mediated immune responses (e.g., Th1, Th17 cells, and macrophages). The associated inflammatory response mainly involves chronic low-grade inflammation rather than tachyphylactic hypersensitivity. Nonspecific responses of the nasal mucosa (e.g., abnormal responses to environmental stimuli) may dominate the course of the disease. Probiotics may alleviate inflammation by modulating T-cell differentiation (promoting Treg and inhibiting Th1/Th17 overactivation). Still, non-IgE-mediated patients may be less sensitive to probiotic modulation because of their cell-mediated specific immune mechanisms.

Procedures such as inferior turbinoplasty and nasal septum correction can improve nasal ventilation. Another approach is neurotomy, which aims to reduce the hyperresponsiveness of the nasal mucosa (Wu et al. 2022). It is important to highlight that modulation of gut microbiome, such as the use of probiotics, has been found to have a positive impact on AR (Liu et al. 2022). Following probiotics treatment, significant improvements in clinical symptoms and serum inflammatory factors were observed in AR patients (Wu et al. 2021).

There are two methods for assessing the effectiveness of AR: subjective evaluation and objective evaluation. The subjective evaluation encompasses the assessment of symptom score, drug score, quality of life score, and asthma control score. On the other hand, the objective evaluation involves conducting a nasal provocation test and blood test. Additionally, it has been suggested that effective environmental control measures can contribute to the prevention and management of AR (Subspecialty Group of Rhinology, 2022). For instance, in the case of individuals diagnosed with AR and exhibiting allergic reactions to dust mites, the eradication of dust mites has been found to effectively ameliorate or potentially eradicate AR symptoms. Using comprehensive health education about AR, patients' understanding of disease management and prevention was enhanced, leading

to heightened compliance and self-assurance among AR patients, ultimately bolstering the therapeutic outcome. Dysbiosis has been connected to a higher risk of allergy diseases. A research investigation showed significant variations in gut microbiota composition between the ones with AR and healthy controls, showing a possible connection between dysbiosis and AR (Kaczynska et al. 2022). The study showed beneficial microbes like Lactobacillus were less prevalent in AR patients. A viable strategy for treating AR is to utilize interventions that change the gut microbiota, such as probiotics, prebiotics, or changes in diet (Li et al. 2022). Currently, the following problems exist in common clinical treatments for allergic rhinitis: Long-term medication has side effects, efficacy varies from person to person, the efficacy of desensitization therapy is uncertain, and it is difficult to solve the problem of immune imbalance in a single therapy and other defects. Probiotics can regulate intestinal flora, thus improving the body's immune balance and strengthening its immune ability, thus alleviating allergies.

Relationship between AR and Probiotic bacteria

The gut-lung axis is the interplay between the gut microbiota and respiratory health. A homeostatic imbalance in the gut microbiota causes an immune response in the respiratory system, which may lead to exacerbation of symptoms in patients with AR. For example, a study confirmed the importance of the gut-lung axis in respiratory disease, including the potential role of gut microbiota regulation in influencing metabolic responses (Bulanda and Wypych 2022).

Many IgE-mediated allergic reactions can be attributed to food sources(Breiteneder et al. 2020). Respiratory symptoms are present in approximately 60% of individuals with food allergies. Extensive research has established a significant association between dietary patterns and the prevalence of allergies. In the case of patients with AR and physical deficiencies accompanied by cold symptoms, it is advisable to limit the consumption of cold foods such as watermelons, oranges, soda, beer, radish, and cabbage. Conversely, individuals with a warm constitution should moderate their intake of greasy, spicy, and stomach-irritating foods (Lam et al. 2020). Patients with AR should consider reducing their consumption of fried and grilled foods, seafood, coffee, and peppers (Lam et al. 2020).

The gut microbiota significantly impacts host physiology, aiding nutrient absorption and maintaining intestinal balance. Disruptions in this balance are linked to conditions like *Click or tap here to enter text* AR (Liu et al. 2022).These insights highlight the potential for biotherapeutics to restore microbiota balance in AR. An imbalance in the intestinal flora of patients with allergic rhinitis leads to changes in host pattern recognition receptors (e.g., Toll-like receptors, TLRs), which results in an imbalance in T-cell differentiation, ultimately leading to sensitization of the body and the development of symptoms of allergic rhinitis(Hu et al. 2024). Probiotic bacteria (PB) were first used in the study of intestinal pathology. However, with in-depth research at home and abroad, it is found that PB has an important immunomodulatory effect on allergic diseases. At present, PB is most used in the treatment of digestive diseases, such as inflammatory bowel disease, antibiotic-associated diarrhea, neonatal jaundice, and so on. However, the proposal of the "hygiene hypothesis" and later more and more studies have proved that intestinal microorganisms can affect human immune function.

Probiotic bacteria are live microorganisms that alter the host microenvironment through colonisation. At present, the number of PB in China has reached dozens, and the disease spectrum of clinical treatment is also expanding. Studies have shown that PB can relieve allergic symptoms by immunomodulating the disorder of gut microbiome in patients. The prevalence of allergic diseases is on the rise around the world, which seriously affects the health and quality of life of atopic individuals. Allergic diseases are associated with intestinal microecology imbalance, which has been demonstrated to have a significant effect on the onset, development, and prognosis of these diseases. PB can play a certain role in the prevention and treatment of allergic diseases by correcting microecological imbalances, maintaining mucosal barriers, and regulating immune function.

Probiotic bacteria have shown potential in treating immune-related and allergic diseases, including AR, by improving symptoms and quality of life and influencing immune markers (Liu et al. 2022). However, research is limited and inconsistent, necessitating more high-quality studies with standardized designs. Click or tap here to enter text.

The therapeutic role of PB in AR has also attracted much attention. Oral PB can effectively control the allergic symptoms of AR patients, although oral PB has no significant preventive effect on the occurrence of AR in the short term. Long-term use can, however, reduce serum IgE levels and eosinophil counts (Ahn et al. 2020). This proves that long-term oral PB may be an ideal adjuvant therapy for the treatment of AR. The symptoms of AR patients in the PB group were significantly improved compared with the placebo group. Moreover, there was no significant difference in the efficacy of PB in the treatment of AR among different bacteria. Much data show that *Lactobacillus acidophilus,*

Lactobacillus rhamnosus and other strains have a certain efficacy in the treatment of allergic rhinitis. In the treatment of respiratory tract infection, PB can achieve treatment by improving the severity of the disease and shortening the time of onset. In terms of reducing blood lipids, *Lactobacillus plantarum*, and *Lactobacillus acidophilus* have good results in clinical research. PB can correct the disorder of gut microbiome by regulating the balance of Th1/Th2, thus relieving allergic symptoms (Xu et al. 2024).

Probiotic bacteria is effective in the treatment of allergic rhinitis. Symptoms and signs can be relieved, and immune function can be improved(P. Liu et al. 2022). PB combined with montelukast sodium granule is effective in the treatment of children with allergic asthma with AR, which can promote the recovery of pulmonary ventilation function and improve immune function. The current study indicated that probiotics were both effective and safe in enhancing symptoms of pediatric allergic rhinitis and improving quality of life. Nonetheless, probiotics did not demonstrate efficacy in preventing pediatric allergic rhinitis (Luo et al. 2024), Nasal symptoms and asthma symptoms can be effectively improved by it. PB adjuvant therapy may be beneficial to the control of pollen-allergic asthma in children. In addition, standard treatment during pollen season combined with PB is beneficial to reduce the risk of thunderstorm asthma. Children with allergic rhinitis have a different gut microbiome than healthy children (Xueying et al. 2019). This imbalance may play a role in promoting the development of allergic rhinitis. PB has a good effect on the prevention of infantile allergic diseases. *Bifidobacterium* triple live bacteria powder plays an auxiliary role in the treatment of allergic rhinitis (Li et al. 2023). It can significantly improve the clinical symptoms and regulate the immune ability of the body.

Probiotic bacteria combined with montelukast sodium in the treatment of allergic cough in children can quickly improve the symptoms of cough and itching of pharynx (Cetkin 2023; Busse et al. 2022), and it is safe. The combination of PB and montelukast sodium chewable tablets is effective in treating bronchial asthma with AR. It can improve lung function and immune function and will not aggravate the adverse reactions. Active PB is effective in the treatment of allergic rhinitis. At the same time, it is helpful to improve the immune regulation function of patients and promote the recovery of patients.

Through the treatment of PB in children with bronchial asthma with AR, the pulmonary function of children was effectively improved. Moreover, the symptoms of rhinitis were relieved. The immune balance of Th17/Treg was effectively improved (Liu et al. 2022). The use of PB combined with Mometasone furoate spray and cetirizine hydrochloride tablets in the treatment of AR can significantly improve the symptoms of patients, improve the total clinical effectiveness rate, and have high safety. Oral PB and specific immunotherapy play a combined role in the treatment of AR, and the combined effect is better than that of a single effect (Liu et al. 2022). Oral-specific PB combination can reduce the incidence of PAR and reduce the allergic inflammation of nasal mucosa. PB may inhibit the pathogenesis of PAR by regulating intestinal or systemic immune status.

Lactobacillus rhamnosus GG can exert its anti-allergic effect by inhibiting Th2 cell response and enhancing CD4+CD25+T cell activity. Probiotics combined with PB early life intervention can activate and promote the Th1 immune process and dynamically balance the immune system (Liu et al. 2024). It also suppresses the Th2-type immune response and the occurrence of allergic reactions. Lysed *Enterococcus faecalis* FK-23 (LFK) has a certain regulatory effect on cytokine IL-12, which is inferred to be related to an anti-allergic effect (Lee et al. 2023; Zhu et al. 2012). PBDNA nasal dripping relieves type I allergy by reducing the level of IgE in animal models.

Recent studies have shown the potential of microbiome testing in enhancing the diagnosis of AR. Significant differences in the composition of the nasal microbiota between AR patients and healthy controls were found, with specific bacterial genera, such as *Klebsiella* and *Staphylococcus*, found to be more abundant in AR patients (Chiang et al. 2022; Yuan et al. 2022). Microbiome analysis of nasal extracellular vesicles has also revealed a unique microbial pattern in AR patients (Chiang et al. 2022). It provides a potential biomarker for AR diagnosis (Yuan et al. 2022) as an increasing number of studies confirm the role of microbiota dysbiosis in the development of AR. It highlights its important role in treatment and prevention strategies. Emerging diagnostic approaches, represented by component-resolved diagnostics and molecular allergology, improve precise and personalized therapeutic approaches (Tidke et al. 2024).

The Relationship between Allergic Rhinitis and Gut microbiome

Probiotics a beneficial microorganism that can settle and proliferate in the intestinal tract. They maintain intestinal health by regulating the balance of gut microbiome and inhibiting the growth of harmful bacteria. In addition, probiotics can also promote the development and function of the immune system and enhance the immunity of the body.

Probiotics can regulate the balance of gut microbiota, enhance immunity, and alleviate

symptoms of allergic rhinitis. Some clinical trials have shown that probiotics can significantly reduce symptoms such as nasal congestion, runny nose, sneezing, and itching in patients with allergic rhinitis, as well as relieve allergic reactions. Most patients with allergic rhinitis have gut microbiome imbalance, which is related to the abnormality of the immune system. Therefore, by regulating the balance of gut microbiome, the immune system's function can be improved, thus relieving the symptoms of allergic rhinitis.

In addition to regulating the balance of gut microbiome, probiotics play a certain role in the treatment of allergic rhinitis. Liu pooled results first revealed that GMS yielded acceptable benefits for patients with AR compared with controls with sound certainties, after balancing the benefits and harms. Besides, A study (Liu et al. 2022) found that taking probiotics can significantly reduce the amount of medication used by patients with allergic rhinitis and improve their quality of life. Li et. al. (2023) found that probiotics combined with folic acid treatment could significantly improve the symptoms of patients with allergic rhinitis and reduce serum IL-6 and TNF-αlevels. This indicates that probiotics can relieve the symptoms of allergic rhinitis by regulating the immune system.

Probiotics are a kind of beneficial microorganism, which can regulate the balance of gut microbiome, enhance immunity and relieve the symptoms of allergic rhinitis. Although many studies have shown that probiotics play a certain role in the treatment of allergic rhinitis, more high-quality clinical trials are needed to confirm its effect, and its specific mechanism still needs to be further explored. Therefore, when choosing to use probiotics to treat allergic rhinitis, it is necessary to choose carefully and under the guidance of a doctor.

The alterations in the composition and functionality of the microflora within the gastrointestinal tract exert an impact on the respiratory system via the shared mucosal immune system. Conversely, the perturbation of microflora within the respiratory tract can also influence the gastrointestinal tract through immune regulation (Waage et al. 2018). The phenomenon of the reciprocal influence between the gastrointestinal tract and the respiratory system is commonly referred to as the lung-intestinal axis (Invernizzi et al. 2020). The concept of the "lung-intestine axis" introduces a novel perspective for the subsequent clinical management of respiratory conditions, including asthma and pulmonary tuberculosis. Lymphocytes can migrate from the intestines to the lungs, thereby contributing to the immune response in the respiratory system. Specifically, inflammatory type 2 innate lymphocytes traverse the lymphatic system to enter the bloodstream and exert their effects within the pulmonary tissue. Lymphocytes migrate from the intestines to the lungs and carry out their respective functions within the pulmonary system. The modulation of the immune system by the gut microbiome can enhance the body's ability to combat acute and chronic respiratory infections caused by diverse pathogens. Numerous studies have explored the association between gut microbiome and lung diseases. Several studies have demonstrated that the elimination of gut microbiome in mice using antibiotics renders them more vulnerable to the influenza virus, thereby impeding the eradication of said virus from the body (Zhang & He 2015). Furthermore, the infection in the lungs also exerts an influence on the composition of the gut microbiome, as the occurrence of infectious diseases in the lungs leads to corresponding alterations in the gut microbiome. Multiple studies have demonstrated a correlation between respiratory diseases and inflammatory bowel disease among patients. It has been observed that approximately 50% of individuals diagnosed with inflammatory bowel disease also exhibit impaired lung function. Consequently, the notion of a "lung-intestinal axis" has been proposed (Vutcovici et al. 2016). According to Zheng et al. (2017), research has demonstrated that the human lung and trachea originate from the foregut, indicating a shared developmental origin between the respiratory and intestinal tracts. Consequently, an imbalance in gut microbiome disrupts the integrity of the intestinal barrier and triggers a cascade of immune responses involving antigens and bacteria, ultimately resulting in the development of allergic diseases (Kim et al. 2019).

The effectiveness of probiotics in treating AR remains uncertain due to the variability in study designs, differences in probiotic strains, and dosage levels. The therapeutic effects of probiotics are strain-specific, making it challenging to establish a standardized treatment protocol. Some studies report limited or no improvement in symptoms, highlighting the variability in individual probiotic responses. Probiotics may offer temporary symptom relief, and their long-term efficacy requires integration with sustained interventions

Changes in the composition and functionality of the gut microbiota affect the respiratory system through the shared mucosal immune system. Conversely, disturbances in the respiratory microbiota can also influence the gut via immune modulation (Waage et al. 2018; Dhar et al. 2020). This bidirectional interaction between the gut and respiratory systems called as the "gut-lung axis" (Invernizzi et al. 2020). Pulmonary infections can alter the composition of the gut microbiota, as the occurrence of infectious diseases in the lungs induces corresponding changes in gut microbiota.

Studies have found a correlation between respiratory diseases and inflammatory bowel disease, with approximately 50% of patients with inflammatory bowel disease also exhibiting impaired lung function (Gorobchenko & Dyachenko 2017). The human lungs and trachea originate from the foregut, indicating a shared developmental origin between the respiratory and digestive tracts. An imbalance in the gut microbiota can compromise the integrity of the intestinal barrier and trigger a series of immune responses involving antigens and bacteria, ultimately contributing to the development of allergic diseases (Kim et al. 2019). Notably, modulation of the gut microbiota, such as through probiotics, has been shown to have positive effects on AR. Studies have demonstrated that probiotic treatment significantly improves clinical symptoms and serum inflammatory factors in AR patients (Wu et al. 2021). The human microbiome holds promise as a biomarker of disease severity and treatment response (Hajjo et al. 2022). However, individual differences have limited microbiome research (Shah et al. 2020). Future studies should focus on microorganisms in specific populations to improve the clinical utility of microbiome-based biomarkers (Buytaers et al. 2024). In conclusion, with the in-depth research on the mechanism between gut microbiota and allergic rhinitis, the therapeutic potential by regulating the structure of gut microbiota can be explored as alternative treatment with lesser side effects in allergic rhinitis individuals.

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