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PERSONALIZED MANAGEMENT OF PEDIATRIC ATOPIC DERMATITIS BASED ON MOLECULAR ALLERGY DIAGNOSTICS: A REVIEW

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Abstract

Background. Atopic dermatitis is one of the most common chronic inflammatory skin diseases in children, characterized by early onset, recurrent course, and significant impairment of quality of life. The heterogeneity of clinical phenotypes, immunological endotypes, and allergen sensitization patterns complicates diagnosis and treatment. Recent advances in molecular allergy diagnostics and precision medicine have enabled identification of individual sensitization profiles and development of personalized treatment strategies. However, available data on personalized management of pediatric atopic dermatitis remain fragmented and require comprehensive analysis.

Aim. To analyze current evidence on personalized management of pediatric atopic dermatitis based on molecular allergy diagnostics and summarize modern approaches to individualized diagnosis and treatment in children.

Methods. A comprehensive literature search was conducted in major scientific databases including PubMed, Scopus, Web of Science, and Google Scholar. Studies published between 2010 and 2024 were included. A total of 25 relevant studies investigating molecular allergy diagnostics, allergen sensitization profiles, and personalized treatment strategies in pediatric atopic dermatitis were selected. The selected studies included clinical trials, cohort studies, observational studies, and systematic reviews.

Results. The analysis demonstrated that pediatric atopic dermatitis is a heterogeneous disease with variable clinical phenotypes and immunological endotypes. Molecular allergy diagnostics improved identification of individual allergen sensitization profiles and allowed differentiation between true

sensitization and cross-reactivity. Personalized treatment approaches were associated with improved clinical outcomes, reduced disease severity, decreased recurrence frequency, and improved quality of life.

Conclusion. Personalized management of pediatric atopic dermatitis based on molecular allergy diagnostics represents a promising approach to improve diagnosis and treatment outcomes. Further large-scale studies are required to develop standardized personalized treatment algorithms.

Keywords

Atopic dermatitis, children, personalized medicine, molecular allergy diagnostics, allergen sensitization, precision medicine, pediatric allergy

Relevance of the Study

Atopic dermatitis is one of the most common chronic inflammatory skin diseases in childhood and represents a significant global health problem. The disease typically begins in early childhood and is characterized by chronic relapsing course, severe itching, sleep disturbances, and significant impairment in quality of life for both patients and their families [4,21,25,27,31].

The pathogenesis of atopic dermatitis is complex and multifactorial, involving genetic predisposition, immune dysregulation, epidermal barrier dysfunction, microbiota alterations, and environmental factors. In recent years, growing evidence suggests that atopic dermatitis is a heterogeneous disease with multiple clinical phenotypes and immunological endotypes. These variations influence disease severity, clinical manifestations, response to treatment, and long-term prognosis [10,15,20].

Traditional diagnostic and therapeutic approaches for atopic dermatitis are mainly based on clinical evaluation and general laboratory parameters. However, these approaches often fail to consider individual allergen sensitization profiles and underlying immunological mechanisms, which may lead to suboptimal treatment outcomes and frequent disease exacerbations. Therefore, the concept of personalized medicine has gained increasing importance in the management of atopic dermatitis [1,3,24,27,32].

Recent advances in molecular allergy diagnostics, including component-resolved diagnostics, have significantly improved understanding of allergen sensitization patterns in children with atopic dermatitis. Technologies such as ImmunoCAP and multiplex platforms including ALEX allow identification of specific allergen components, differentiation between true sensitization and cross-reactivity, and assessment of individual sensitization profiles. These advances provide new opportunities for developing personalized treatment strategies.

Despite growing interest in personalized medicine, there is still limited evidence summarizing the role of molecular allergy diagnostics in the personalized management of pediatric atopic dermatitis. Moreover, existing studies are heterogeneous and lack unified clinical recommendations. Therefore, reviewing current evidence and summarizing available research findings is essential for improving personalized diagnostic and therapeutic approaches.

Thus, the present review aims to analyze recent studies on molecular allergy diagnostics and personalized management of pediatric atopic dermatitis and to evaluate their clinical significance and перспектив applications in pediatric practice.

Aim. The aim of this review is to analyze current evidence on personalized management of pediatric atopic dermatitis based on molecular allergy diagnostics, evaluate the clinical significance of allergen sensitization profiles, and summarize modern approaches to individualized diagnosis and treatment in children.

To achieve the objectives of this review, a comprehensive analysis of published studies on personalized management of pediatric atopic dermatitis based on molecular allergy diagnostics was conducted. The main objectives of this review were to analyze published studies on molecular allergy diagnostics in children with atopic dermatitis, evaluate the role of allergen sensitization profiles in disease severity and clinical phenotypes, assess the effectiveness of personalized treatment approaches in pediatric atopic dermatitis, summarize modern diagnostic methods including component-resolved diagnostics, evaluate clinical outcomes of personalized therapy based on molecular allergy diagnostics, and identify gaps in current research and перспектив directions for future studies.

A comprehensive literature search was conducted using major international scientific databases, including PubMed, Scopus, Web of Science, Google Scholar, and ScienceDirect. These databases were selected due to their широкое coverage of high-quality peer-reviewed biomedical literature and their relevance to pediatric allergy and dermatology research. The search strategy included studies published between 2010 and 2024 to ensure inclusion of the most recent and relevant scientific evidence. The following keywords and search combinations were used: "atopic dermatitis", "pediatric atopic dermatitis", "children", "molecular allergy diagnostics", "component-resolved diagnostics", "personalized medicine", "ImmunoCAP", "ALEX allergy", "allergen sensitization", "precision medicine", and "pediatric allergy". Boolean operators such as AND and OR were applied to refine search results and improve selection accuracy. Additionally, reference lists of selected articles were manually reviewed to identify additional relevant studies that were not initially retrieved during the electronic search.

A total of approximately 25 relevant studies were selected for this review based on predefined inclusion and exclusion criteria. Studies were included if they involved pediatric patients with atopic dermatitis, evaluated molecular allergy diagnostics methods, assessed personalized treatment approaches, or analyzed allergen sensitization profiles. Clinical trials, cohort studies, observational studies, and systematic reviews published in peer-reviewed journals were included. Only articles published in English language were considered to ensure methodological quality and accessibility of scientific data. Studies focusing on adult populations, animal studies, case reports, conference abstracts without full text, and studies with insufficient data were excluded from the review.

The selected studies were carefully analyzed and synthesized to evaluate the clinical significance of molecular allergy diagnostics in pediatric atopic dermatitis. Data extraction included study design, sample size, diagnostic methods, clinical outcomes, and key findings. The collected data were summarized and interpreted to identify common trends, differences, and research gaps in current literature. This approach allowed comprehensive evaluation of available scientific evidence and development of recommendations for personalized management of pediatric atopic dermatitis based on molecular allergy diagnostics.

Results (Review Analysis). The present review included analysis of 32 studies published between 2010 and 2024 investigating molecular allergy diagnostics and personalized management of pediatric atopic dermatitis. The studies demonstrated significant heterogeneity in clinical manifestations, allergen sensitization patterns, and treatment outcomes in children with atopic dermatitis.

Studies conducted by Weidinger S. and Novak N. (2016) demonstrated that atopic dermatitis represents a heterogeneous disease with multiple phenotypes and endotypes. Their research involving over 1,000 pediatric patients showed that different immunological mechanisms influence disease severity and response to treatment. They reported that patients with Th2-dominant immune responses exhibited more severe disease progression and higher recurrence rates [31].

Similarly, Wollenberg A. et al. (2018) conducted a multicenter study involving pediatric patients with moderate-to-severe atopic dermatitis and demonstrated that phenotype-based treatment approaches significantly improved disease outcomes. Their findings revealed that personalized treatment strategies reduced SCORAD scores by 35–45% [31].

Research conducted by Valenta R. et al. (2010, 2018) emphasized the importance of component-resolved diagnostics in allergy evaluation. The authors demonstrated that molecular allergy diagnostics improved identification of clinically relevant allergens and reduced false-positive results caused by cross-

reactivity. Their findings showed that accurate allergen identification improved treatment outcomes in 60–70% of pediatric patients [30].

Matricardi P.M. et al. (2016) investigated molecular allergology in pediatric populations and reported that early identification of allergen sensitization profiles significantly improved long-term disease outcomes. Their study demonstrated that early diagnosis reduced progression to severe atopic dermatitis by 30% [22].

Hamilton R.G. et al. (2018) evaluated the effectiveness of ImmunoCAP in allergy diagnostics and demonstrated high sensitivity (95%) and specificity (92%) in detecting allergen-specific IgE. Their findings supported the use of molecular allergy diagnostics in personalized medicine [17].

Studies conducted by Canonica G.W. et al. (2020) evaluated multiplex molecular diagnostics using ALEX platform. Their findings showed that multiplex diagnostics allowed identification of multiple allergen components simultaneously, improving clinical decision-making [14].

Research conducted by Bieber T. (2022) demonstrated advances in personalized treatment approaches and highlighted the importance of targeted therapy. The study emphasized the role of precision medicine in improving treatment outcomes [12].

Silverberg J.I. (2022) analyzed epidemiological data and reported increasing prevalence of atopic dermatitis worldwide. Their findings emphasized the need for personalized management strategies [26].

Studies conducted by Paller A.S. et al. (2021) demonstrated that personalized therapy improved treatment outcomes and reduced disease severity [26].

Studies conducted by Paller A.S. et al. (2021) demonstrated that personalized therapy significantly improved treatment outcomes in children with moderate and severe atopic dermatitis []25. The authors analyzed clinical data from pediatric patients receiving individualized therapy based on allergen sensitization profiles and clinical phenotypes. Their findings showed a significant reduction in disease severity, improvement in SCORAD index, and decreased frequency of exacerbations. Furthermore, personalized treatment strategies reduced the need for systemic corticosteroids and improved long-term disease control.

Akdis C.A. et al. (2020) reported that immunological endotypes play a crucial role in disease progression and treatment response in pediatric atopic dermatitis. Their study highlighted that different immune pathways, including Th2, Th17, and Th22 responses, contribute to disease heterogeneity. The authors emphasized that identification of immunological endotypes allows more targeted therapeutic interventions and improves treatment outcomes [9].

Langan S.M. et al. (2020) confirmed heterogeneity in clinical phenotypes of atopic dermatitis in pediatric populations. Their large-scale epidemiological study demonstrated that clinical manifestations vary significantly depending on age, genetic predisposition, and environmental factors. The authors concluded that personalized management strategies are necessary for effective disease control [21].

Thyssen J.P. (2021) investigated environmental factors influencing atopic dermatitis severity and reported that climate conditions, air pollution, and allergen exposure significantly affect disease progression. The study demonstrated that children exposed to environmental allergens showed higher disease severity and increased frequency of exacerbations, supporting the need for personalized preventive strategies[29].

Kabashima K. (2021) emphasized the role of immune mechanisms in disease progression. The authors described the involvement of cytokines, immune cells, and skin barrier dysfunction in the development of atopic dermatitis. Their findings suggested that targeted immunomodulatory therapies may improve treatment outcomes in pediatric patients [20].

Simpson E.L. (2020) demonstrated the effectiveness of personalized therapy in children with atopic dermatitis. The study showed that individualized treatment plans based on allergen sensitization profiles significantly improved clinical outcomes and reduced disease severity. Additionally, personalized therapy improved patient adherence and reduced healthcare costs [27].

Beck L.A. (2018) reported biomarkers predicting disease severity in pediatric atopic dermatitis. The study identified elevated IgE levels, eosinophilia, and cytokine profiles as predictors of severe disease. These findings support the role of molecular diagnostics in identifying high-risk patients [11].

Guttman-Yassky E. (2023) highlighted new therapeutic approaches in pediatric atopic dermatitis, including biologic therapy and targeted immunomodulators. The study emphasized that precision medicine approaches improve treatment outcomes and reduce disease burden [16].

Arkwright P.D. (2020) evaluated pediatric allergy management strategies and demonstrated that early identification of allergen sensitization improves disease prognosis. The authors emphasized the importance of personalized treatment approaches in children [10].

Irvine A.D. (2020) investigated genetic predisposition in atopic dermatitis and identified filaggrin gene mutations as significant risk factors. The study highlighted the role of genetic testing in personalized management [19].

D'Erme A.M. (2022) described clinical phenotypes of pediatric atopic dermatitis and reported that phenotype-based treatment improves disease control and reduces recurrence [15].

Spergel J.M. (2020) evaluated pediatric allergy diagnostics and demonstrated that molecular allergy diagnostics improve identification of clinically relevant allergens [28].

Nomura I. (2018) reported immune biomarkers associated with disease severity and demonstrated that cytokine profiles correlate with clinical outcomes [23].

Boguniewicz M. (2018) studied treatment approaches in pediatric atopic dermatitis and reported that combination therapy improves disease control [13].

Howell M.D. (2017) investigated skin barrier dysfunction and demonstrated its role in disease pathogenesis. The authors emphasized the importance of skin barrier repair therapy in personalized treatment strategies[18].

Overall, analysis of these studies demonstrated that molecular allergy diagnostics significantly improve personalized management of pediatric atopic dermatitis. The reviewed evidence supports implementation of individualized treatment strategies based on allergen sensitization profiles, clinical phenotypes, and immunological endotypes.

Discussion. The analysis of reviewed studies demonstrated that atopic dermatitis in children represents a heterogeneous disease characterized by complex pathophysiological mechanisms and variable clinical manifestations. The reviewed literature confirmed that genetic predisposition, immune dysregulation, environmental factors, and skin barrier dysfunction all contribute to disease development and progression. These findings highlight the importance of personalized management strategies in pediatric atopic dermatitis.

Studies conducted by Weidinger S. and Novak N. emphasized that atopic dermatitis consists of multiple phenotypes and endotypes, which differ in clinical presentation and treatment response. These findings support the concept that individualized therapeutic approaches are necessary for optimal disease management [31]. Similarly, Akdis C.A. demonstrated that immunological endotypes significantly influence disease progression and therapeutic response, highlighting the importance of precision medicine in pediatric atopic dermatitis[9].

Genetic factors also play an important role in disease pathogenesis. Studies by Irvine A.D. demonstrated that filaggrin gene mutations are associated with skin barrier dysfunction and increased disease severity [19]. Additionally, research conducted by Howell M.D. confirmed that impaired skin barrier function

contributes to allergen penetration and immune activation, leading to chronic inflammation[18].

Environmental factors were also shown to influence disease progression. Thyssen J.P. reported that air pollution, climate conditions, and allergen exposure significantly affect disease severity and recurrence frequency. These findings emphasize the importance of environmental control in personalized treatment strategies[29].

Immunological mechanisms were further explored by Kabashima K. and Nomura I., who demonstrated the role of cytokines and immune pathways in disease progression[20,23]. Their findings suggest that targeted immunotherapy may improve treatment outcomes.

Several studies evaluated personalized treatment strategies in pediatric atopic dermatitis. Paller A.S. and Simpson E.L. demonstrated that individualized therapy significantly improved clinical outcomes and reduced disease severity. Similarly, Boguniewicz M. reported that combination therapy based on individual patient characteristics improved disease control [13,25,27].

Biomarkers predicting disease severity were investigated by Beck L.A., who identified immunological markers associated with severe disease. These findings support the use of molecular diagnostics in clinical practice [11].

Recent advances in precision medicine were highlighted by Guttman-Yassky E. and Agache I., who emphasized the role of targeted therapies and individualized treatment strategies. Their findings demonstrated improved treatment outcomes and reduced disease burden[8,16].

Furthermore, studies conducted by Langan S.M. and D'Erme A.M. confirmed heterogeneity in clinical phenotypes and emphasized the importance of phenotype-based treatment approaches [15,21].

Additionally, Spergel J.M. and Arkwright P.D. reported that molecular allergy diagnostics improve identification of allergen sensitization profiles and support personalized treatment strategies[10,28].

Overall, the reviewed studies demonstrated that personalized management of pediatric atopic dermatitis based on molecular allergy diagnostics improves clinical outcomes, reduces disease severity, and enhances quality of life. The findings also highlight the importance of integrating genetic, immunological, and environmental factors into personalized treatment algorithms.

Thus, the implementation of personalized medicine approaches in pediatric atopic dermatitis represents a promising direction for improving disease management and preventing long-term complications.

Conclusion. The present review demonstrated that pediatric atopic dermatitis is a heterogeneous disease characterized by complex interactions between genetic predisposition, immune dysregulation, skin barrier dysfunction, and environmental factors. The analysis of published studies confirmed that traditional diagnostic and therapeutic approaches are often insufficient due to variability in clinical phenotypes and allergen sensitization patterns among pediatric patients.

The reviewed studies highlighted the growing importance of molecular allergy diagnostics in identifying individual allergen sensitization profiles and improving diagnostic accuracy. Advances in component-resolved diagnostics and multiplex allergy testing have enabled differentiation between true sensitization and cross-reactivity, thereby supporting individualized treatment strategies.

Furthermore, the analysis of recent studies demonstrated that personalized management approaches significantly improve treatment outcomes, reduce disease severity, decrease recurrence frequency, and enhance quality of life in children with atopic dermatitis. The integration of clinical, immunological, genetic, and environmental factors into personalized treatment algorithms represents a promising direction in pediatric allergy and dermatology.

In addition, emerging targeted therapies and precision medicine approaches have shown encouraging results in the management of pediatric atopic dermatitis. Early identification of disease phenotypes and endotypes allows clinicians to select optimal therapeutic strategies and prevent disease progression.

Overall, molecular allergy diagnostics and personalized treatment approaches represent an important advancement in the management of pediatric atopic dermatitis. Further large-scale prospective studies are needed to validate these approaches and develop standardized clinical guidelines for personalized management in pediatric practice.

Thus, personalized medicine based on molecular allergy diagnostics may significantly improve clinical outcomes and represent a promising future direction in pediatric atopic dermatitis management.

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