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Research article

Inhalation allergen sensitization patterns in children with allergic rhinitis and asthma

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Abstract: Objective: To investigate the differences in sensitization status and patterns of inhaled allergens in children with allergic rhinitis, cough allergic asthma, and bronchial asthma, to avoid allergens, and to explore the relationship between the sensitization status and patterns of inhaled allergens in allergic rhinitis and asthma.
Method: A retrospective evaluation was conducted on 1028 children with allergic rhinitis and asthma who underwent allergen specific IgE antibody testing at Xiamen University Affiliated Women's and Children's Hospital from 2022 to 2024. Based on basic medical information and clinical results, they were divided into allergic rhinitis group, cough allergic asthma group, and bronchial asthma group.
Results: The most common inhaled allergen detected in this study was house dust mite, followed by house dust and mold. The positive frequency of most inhaled allergens in the bronchial asthma group was much higher than that in the cough allergic asthma group. The allergic rhinitis group had a higher frequency of sensitization to a single inhaled allergen, while the bronchial asthma group had a higher frequency of sensitization to quadruple sensitization. For single inhaled allergens, the bronchial asthma group had a higher frequency of strong positive sensitization. Patients with allergic rhinitis who were sensitive to house dust had a 2.763-fold increased risk of developing bronchial asthma. Patients with cough allergic asthma who were sensitive to house dust mites, cat hair, or house dust had a 3-fold increased risk of developing bronchial asthma. Multiple sensitization increases the likelihood of cough allergic asthma transforming into bronchial asthma.
Conclusion: The most common allergens detected in this study were house dust mites, house dust, and

mold. Children with bronchial asthma were associated with sensitization to most inhaled allergens, especially strong positive sensitization and multiple sensitization.

Keywords: inhalation allergen; sensitization patterns; allergic rhinitis;asthma

1. Introduction

With the development of industrial technology and the aggravation of environmental pollution, the incidence of allergic diseases is showing an upward trend. The phenomenon of the same patient suffering from multiple allergic diseases such as allergic rhinitis and asthma has become common. The comorbidity and multiplicity of allergic diseases make the condition more complex and the treatment more difficult to achieve [1]. Meanwhile, due to the interrelated effects of different allergic diseases, childhood asthma and adolescent rhinitis are common and difficult to control [2].

Rhinitis is an inflammatory disease that causes dysfunction of the nasal mucosa, Allergic rhinitis is the most common type, with symptoms mainly including nasal congestion, runny nose, nasal itching, and sneezing; children may also experience sleep disorders [3]. Allergic rhinitis affects 10%–40% of the global population [4]. It has been reported that the global incidence of allergic rhinitis in children is as high as 40% [5,6]. According to data from 2001 to 2021, the overall prevalence of allergic rhinitis in Chinese children is 18.46%, with differences in age, region, gender, and ethnicity [7]. Asthma is a heterogeneous disease, and allergic asthma is one of the most common phenotypes in asthma patients, especially in children with severe asthma. Cough allergic asthma is an atypical asthma without wheezing symptoms or wheezing sounds [8]. Epidemiological surveys have shown that from 1989 to 2015, the prevalence of asthma among children aged 0–14 years in China was 2.6%, with boys having a higher prevalence than girls [9]. Allergic rhinitis is associated with asthma, and asthma often occurs in patients with allergic rhinitis [10]. Asthma and rhinitis often coexist and are often seen as a single respiratory disease. A cross-sectional study from the northern plateau region of China found that 20.6% of allergic patients also suffer from asthma; among asthma patients, 29.4% also suffer from allergic rhinitis [11]. There is a close relationship between allergic rhinitis and asthma [12], but the causal relationship is still unclear. Research has reported that most patients with asthma rhinitis comorbidity have multiple sensitization; whether the patient is single or multiple sensitized, the main allergen remains house dust mites [13]. Allergic rhinitis has been recognized as an independent risk factor for the development of allergic asthma [14].

Allergens play a crucial role in the occurrence and development of allergic diseases. Inhalation allergens refer to various airborne substances, including house dust, cockroaches, or tree grass pollen, which can cause type I IgE-mediated hypersensitivity reactions. The types of inhaled allergens are influenced by the environment, vegetation, and lifestyle, with significant differences in geographical location [15]. Understanding the sensitization patterns in the local area is beneficial for disease prevention and clinical intervention. This study explores the differences in sensitization patterns of inhaled allergen serum specific IgE (sIgE) in children with allergic rhinitis and asthma and analyzes the role of various sensitization patterns in the causal relationship between allergic rhinitis and asthma.

2. Data and methods

2.1. Clinical data

This study retrospectively analyzed children aged 1–18 years who were diagnosed with allergic rhinitis, bronchial asthma, and cough allergic asthma at the pediatric clinic or allergy clinic of Xiamen University Affiliated Women and Children's Hospital between 2022 and 2024. This study included a total of 1028 children, who were divided into three groups based on their clinical symptoms: Allergic rhinitis group (420 cases), bronchial asthma group (332 cases), and cough allergic asthma group (276 cases).

2.2. Method

Diagnosis of bronchial asthma and cough allergic asthma was based on the guidelines for the prevention and treatment of bronchial asthma (2020 edition) [8]. Diagnosis of allergic rhinitis was based on the Chinese Guidelines for Diagnosis and Treatment of Allergic Rhinitis (2022) [16]. Basic information of children (gender, age), clinical diagnosis, and serum-specific IgE test results were extracted from the medical record system. This study was approved by the Ethics Committee of Xiamen Maternal and Child Health Hospital. This study used immunoblotting (China, Zhejiang Aikang detection kit) for serum-specific IgE detection. The types of inhaled allergens detected include house dust mites, cat hair, dog hair, house dust, cockroaches, fungi, mulberry trees, tree combinations, humus, ragweed, amaranth, and mugwort.

2.3. Statistical analysis

Categorical variables are represented as n (%). Chi-square test or Fisher's exact probability method were used to compare categorical variables between groups and the correlation between each variable and IgE results. Clinical variables of interest were analyzed through logistic regression. Statistical analysis was conducted using the statistical software SPSS Statistics version 19.0, and all statistics were two-sided tests. A p-value < 0.05 was considered statistically significant.

3. Results

3.1. Study population characteristics

A total of 1028 children participated in the study. Table 1 shows the general characteristics of the children, with a higher proportion of children aged 4–6 and 7–12 years in each group. The proportion of girls in all groups was relatively low, and there was no statistical differences in the proportion of each group.

Table 1. Characteristics of the study population.

Characteristic	Allergic rhinitis (n = 420)	Coughallergic asthma (n = 276)	Bronchial asthma (n = 332)	P-value
Age (years), n (%)				
1–3	23 (5.476)	16 (5.797)	18 (5.422)	0.977
4–6	156 (37.143)	163 (59.058)	185 (55.723)	<0.001
7–12	220 (52.381)	95 (34.42)	121 (36.446)	<0.001
13–18	21 (5)	2 (0.725)	8 (2.41)	0.004
Sex, n (%)				
Female	159 (37.857)	107 (38.768)	111 (33.434)	0.321

3.2. Allergen sensitization characteristics

Table 2. Sensitization characteristics of inhaled allergens detected by serum sIgE.

	Allergic rhinitis (n = 420)	Cough allergic asthma (n = 276)	Bronchial asthma (n = 332)	P-value
Household dust mite (ds1)	250 (59.52)	93 (33.70)	211 (63.55)	<0.001**
+	39 (9.29)	31 (11.23)	25 (7.53)	0.292
++	122 (29.05)	46 (16.67)	105 (31.63)	<0.001**
+++	89 (21.13)	16 (5.8)	81 (24.4)	<0.001**
Cat hair (e1)	37 (8.81)	8 (2.90)	32 (9.64)	0.003*
+	5 (1.33)	1 (0.35)	6 (1.81)	0.255
++	19 (4.52)	5 (1.81)	12 (3.61)	0.162
+++	13 (3.1)	2 (0.72)	14 (4.22)	0.032*
Dog hairs (e2)	12 (2.86)	5 (1.81)	6 (1.81)	0.536
+	4 (0.95)	3 (1.09)	1 (0.3)	0.476
++	4 (0.95)	1 (0.35)	4 (1.2)	0.527
+++	4 (0.95)	1 (0.35)	1 (0.3)	0.433
House dust (h1)	131 (31.19)	48 (17.39)	129 (36.14)	<0.001**
+	70 (16.67)	25 (9.06)	52 (15.66)	0.013
++	54 (12.86)	17 (6.15)	67 (20.18)	<0.001**
+++	7 (1.67)	6 (2.17)	10 (3.01)	0.463
Cockroach (i6)	17 (4.05)	14 (5.07)	19 (5.72)	0.560
+	3 (0.71)	7 (2.54)	10 (3.01)	0.054
++	10 (2.33)	5 (1.81)	5 (1.51)	0.677
+++	4 (0.95)	2 (0.72)	4 (1.2)	0.834
Mold (ms1)	50 (11.90)	33 (11.96)	39 (11.75)	0.996
+	10 (2.33)	9 (3.26)	3 (0.9)	0.123
++	23 (5.48)	8 (2.89)	14 (4.22)	0.263
+++	17 (4.05)	16 (5.8)	22 (6.63)	0.275

*P < 0.05, **P < 0.01.

The serum-specific IgE positive frequencies of different inhaled allergens in patients with allergic

rhinitis and asthma are shown in Table 2. The most common allergen was house dust mite, followed by house dust and mold. The positive frequency of most inhaled allergens in the bronchial asthma group was much higher than that in the cough allergic asthma group, such as house dust mites, cat hair, and house dust. In addition, the strong positive frequency of house dust mites and cat hair in the bronchial asthma group was much higher than that in the cough allergic asthma group. Dog hair, cockroaches, and fungi did not show significant differences among the groups. It is worth noting that there were almost no children in this area who were allergic to several allergens such as mulberry trees, tree combinations, foxtail grass, dwarf ragweed, amaranth, and mugwort.

3.3. Multiple sensitization

To better understand the multiple sensitization of inhalation allergens in each group according to the number of sensitization types, we divided the types of sensitization to inhalation allergens (house dust mites, cat hair, dog hair, house dust, cockroaches, and mold) into six categories. *Single sensitization* refers to sensitization to only one type of allergen, while *double sensitization* refers to sensitization to any two types of allergens, and so on. The allergic rhinitis group had a higher positive frequency of sensitization to *single sensitization*, while the bronchial asthma group had a higher positive frequency of sensitization to *quadruple sensitization*, as shown in Table 3. For multiple sensitization cases with strong positive inhalation allergens, the strong positive frequency of *single sensitization* in the bronchial asthma group was much higher than that in the cough allergic asthma group, as shown in Table 4.

Table 3. Multiple sensitization.

	Allergic rhinitis (n = 420)	Cough allergic asthma (n = 276)	Bronchial asthma (n = 332)	P-value
Single sensitization	127 (30.23)	58 (21.01)	88 (26.5)	0.026*
Double sensitization	81 (19.29)	42 (15.22)	63 (18.98)	0.347
Triple sensitization	43 (10.23)	13 (4.71)	35 (10.54)	0.018*
Quadruple sensitization	9 (2.14)	3 (1.09)	16 (4.81)	0.012*
Five-fold sensitization	8 (1.9)	1 (0.35)	3 (0.9)	0.155
Six-fold sensitization	1 (0.23)	1 (0.35)	1 (0.3)	0.956

*P < 0.05.

Table 4. Multiple sensitization (strong positive+++).

	Allergic rhinitis (n = 420)	Cough allergic asthma (n = 276)	Bronchial asthma (n = 332)	P-value
Single sensitization (+++)	90 (21.43)	22 (7.97)	87 (26.2)	<0.001**
Double sensitization (+++)	9 (2.14)	7 (2.54)	17 (5.12)	0.054
Triple sensitization (+++)	2 (0.48)	1 (0.36)	2 (0.60)	0.913
Quadruple sensitization (+++)	3 (0.71)	1 (0.36)	1 (0.30)	0.679
Five-fold sensitization (+++)	1 (0.24)	0 (0)	0 (0)	0.485

**P < 0.01.

3.4. Allergenic characteristics and asthma

To determine whether sensitization to inhaled allergens increases the likelihood of allergic rhinitis developing into asthma, we conducted a correlation analysis. As shown in Table 5, children with rhinitis who were sensitive to house dust had a 2.763-fold increased risk of developing bronchial asthma. As shown in Table 6, children with cough allergic asthma who were sensitive to house dust mites, cat hair, or house dust had a 3-fold increased risk of developing bronchial asthma from cough allergic asthma.

Table 5. Association between sensitization characteristics and the occurrence of asthma.

	Allergic rhinitis (n = 420)	Bronchial asthma (n = 332)	OR (95%CI)
Household dust mite (ds1)	250 (59.52)	211 (63.55)	1.186 (0.882–1.595)
Cat hair (e1)	37 (8.8)	32 (9.63)	1.104 (0.672–1.814)
Dog hairs (e2)	12 (2.86)	6 (1.81)	0.626 (0.232–1.685)
House dust (h1)	131 (31.19)	129 (38.86)	2.763 (1.984–3.848)*
Cockroach (i6)	17 (4.05)	19 (5.72)	1.439 (0.736–2.814)
Mold (ms1)	50 (11.9)	39 (11.75)	0.985 (0.631–1.538)

*Statistically significant.

Table 6. Association between sensitization characteristics and asthma categories.

	Cough allergic asthma (n = 276)	Bronchial asthma (n = 332)	OR (95%CI)
Household dust mite (ds1)	93 (33.7)	211 (63.55)	3.431 (2.454–4.797)*
Cat hair (e1)	8 (2.89)	32 (9.63)	3.573 (1.618–7.890)*
Dog hairs (e2)	5 (1.81)	6 (1.81)	0.998 (0.301–3.304)
House dust (h1)	48 (17.39)	129 (38.86)	3.018 (2.061–4.421)*
Cockroach (i6)	14 (5.07)	19 (5.72)	1.136 (0.559–2.310)
Mold (ms1)	33 (11.96)	39 (11.75)	0.980 (0.598–1.606)

*Statistically significant.

3.5. Multiple sensitization and asthma

There was a certain causal relationship between multiple sensitization and the transition from cough allergic asthma to bronchial asthma. As shown in Table 7, multiple sensitization of three or more categories increases the likelihood of cough allergic asthma transitioning to bronchial asthma. In patients with cough allergic asthma, multiple sensitization was positively correlated with the development of bronchial asthma.

Table 7. Association between multiple sensitization and the occurrence of asthma.

	Cough allergic asthma (n = 276)	Bronchial asthma (n = 332)	OR (95%CI)
Single sensitization	58 (21.01)	88 (26.5)	1.356 (0.928–1.979)
Double sensitization	42 (15.22)	63 (18.98)	1.305 (0.851–2.002)
Triple sensitization	13 (4.71)	35 (10.54)	2.384 (1.235–4.603)*
Quadruple sensitization	3 (1.09)	16 (4.81)	4.608 (1.328–15.981)*

*Statistically significant.

4. Discussion

Asthma and rhinitis are the most common chronic diseases, and they cannot be simply treated as a single disease. Their relationship has been increasingly uncovered through research. There is evidence to suggest that in the absence of asthma symptoms, patients with allergic rhinitis exhibit significant physiological and histological changes in airway function abnormalities [17]. Poor control of allergic rhinitis may be associated with worsening asthma symptoms in the later stages [18]. A cross-sectional epidemiological study found that during adolescence, asthma phenotypes with allergic rhinitis are mostly associated with nonspecific bronchial hyperresponsiveness and airway inflammation [19].

In a study of respiratory allergic diseases in northwest China, it was reported that the positive rate of serum sIgE in males was higher than in females [20]. Similar reports indicate that, regardless of age, sensitization rate of males is higher than that of females [21]. This viewpoint is consistent with the conclusion of this study, in which the sensitization rate of inhaled allergens in boys was significantly higher than in girls. In our study, we also observed that allergic rhinitis and asthma mainly occur in children aged 4–12 years. An epidemiological survey on animal dander–related allergic diseases found that patients with allergic diseases were mainly concentrated in school-aged children (6–12 years old) and adolescents (12–18 years old) [22]. This may be related to the wider exposure of children to allergens at this stage.

In this study, we evaluated the sensitization of children with allergic rhinitis and asthma to inhaled allergens through serum-specific IgE testing, as well as the correlation between sensitization characteristics in children with allergic rhinitis, asthma, and different types of asthma. This study evaluated the sensitization of several common inhaled allergens, among which the most common was house dust mite, followed by house dust and mold. Cough allergic asthma patients presented a lower frequency of sensitization to inhaled allergens. This could be explained by the southern part of Fujian Province being a coastal area with a humid climate, prone to breeding mites and fungi. According to a report in Türkiye, house dust mite allergy is more common in humid coastal areas [23], consistent with our viewpoint. It is worth noting that research has found that sensitivity to cat hair is not strictly related to cat ownership. In a study on the characteristics of cat-sensitive children, it was found that even if there is no cat at home, children may present a high risk of cat allergies. The study suggested that owning a cat can affect the development of cat sensitivity, but most cat-sensitive patients do not have cats at home [24]. Individuals are not only exposed to their home environment, and their exposure to public places may also affect the development of cat sensitivity. In addition, plants such as mulberry trees, humus grass, dwarf ragweed, amaranth, and mugwort are relatively rare in this area, so children who are sensitive to these plants were relatively rare.

Regarding the relationship between asthma and multiple sensitization, some reports suggest that individuals with multiple sensitization are associated with the presence of asthma [25]. The allergen sensitization rate, especially the multiple sensitization rate, varies greatly among individuals with asthma and rhinitis in different states [26]. Siroux et al. also found that multiple asthma rhinitis diseases in adolescents and adults are associated with multiple IgE sensitization [27]. In addition to discovering that asthma is associated with multiple sensitization, we also found that asthma is associated with strong positive sensitization.

In this study, we also evaluated the risk factors for asthma and found that children with allergic rhinitis had an increased risk of developing bronchial asthma due to house dust allergies, while children with cough allergic asthma have an increased risk of developing bronchial asthma due to house dust mites, cat hair, or house dust allergies. A previous study found that sensitization to mites is a risk factor for developing asthma [28], and another study on prevalence found that dust mite and cat hair allergies are common and independently associated with asthma, respiratory symptoms, and rhinitis [29], consistent with our research findings. Additionally, we demonstrated that multiple sensitization increases the likelihood of transforming cough allergic asthma into bronchial asthma. In patients with cough allergic asthma, multiple sensitization was positively correlated with the development of bronchial asthma. This viewpoint is consistent with previous reports that chronic rhinitis patients with multiple allergies and certain specific types of air allergens are more likely to develop asthma [25].

Finally, due to the observational and retrospective nature of our study and the lack of skin prick or nasal provocation tests, we cannot rule out false-positive allergen sensitization in terms of methodology. The lack of total IgE results in most children makes it impossible to analyze the relationship between total IgE and specific IgE. The comorbidity of allergic rhinitis and asthma and the presence of multiple related conditions complicate the ability to distinguish between both diseases. This study is mainly a single-center study, and larger prospective studies should be conducted.

5. Conclusion

Xiamen Maternal and Child Health Hospital is the largest specialized hospital for women and children in the southern Fujian region of China. This study assessed the inhaled allergens in a pediatric population in the southern Fujian region. The most common allergens detected in this study were house dust mites, house dust, and mold, indicating the need to pay attention to children's living environment and hygiene conditions. Also, our study demonstrated that children with asthma have a higher frequency of multiple sensitization or strong positive sensitization to inhaled allergens, indicating a correlation between multiple sensitization or strong positive sensitization and the presence of asthma. Finally, we evaluated the risk factors for asthma and provided rational recommendations for the prevention and treatment of childhood bronchial asthma regarding inhaled allergens.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Ethics approval of research

This study was approved by the Ethics Committee of Women and Children's Hospital, Xiamen University, and conducted in accordance with the declaration of Helsinki. The permit number(s) for ethical approval is "KY-2024-126-K01". This study is a retrospective study, where researchers only conduct retrospective analysis on the laboratory information, without inquiring about patient names. Strict confidentiality is maintained for other personal information of the patients. Therefore, the Ethics Committee of Women and Children's Hospital, Xiamen University does not require patient consent for reviewing their medical records in such retrospective studies.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

XJ Li provided the study concept and design. XJ Li and JM Lin wrote and revised the manuscript.XJ Li, JM Lin, CX Li and Y Li participated in discussion and made a significant contribution to the interpretation of the results. M Zhu and MC lin collected the data, and performed the experiments. XJ Li and CX Li performed the statistical analyses. All authors read and approved the final version of the manuscript.

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