ORIGINAL RESEARCH

Examining the Correlation between Allergic Conjunctivitis and Allergic Rhinitis

Fang Xu, BSc; Kunna Yang, MSc

ABSTRACT

Objective • This study aims to assess the correlation between allergic conjunctivitis (AC) and allergic rhinitis (AR).

Methods • A total of 462 patients diagnosed with either allergic conjunctivitis or allergic rhinitis and treated at our hospital from January 2018 to December 2020 were included. Patients were categorized into two groups, the AC group and the AR group, based on their initial department of consultation. The AC group comprised 232 patients diagnosed with allergic conjunctivitis in the ophthalmology department, while the AR group consisted of 230 patients diagnosed with allergic rhinitis in the ENT department. Allergen analysis was conducted on patients presenting with both AC and AR and conjunctival and nasal mucosal scrapings were performed to examine eosinophil presence. The study analyzed the association between allergic AC and AR.

Results • In the AC group, 174 patients (75.00%) had concurrent AR, while in the AR group, 169 patients (73.48%) had concurrent AC. Inhalant allergen testing among patients with concurrent AC and AR revealed that the primary inhalant allergens were dust mites, house dust, and fungi, with specific immunoglobulin E (IgE) positivity of 91.23%. Testing for food allergens identified fish, shrimp, and crab as ingestive allergens, with a specific IgE positivity of 58.58%. Eosinophil presence was assessed through conjunctival and nasal mucosal scrapings in patients with concurrent AC and AR. Eosinophils were detected in 188 cases (54.81%) through conjunctival scraping and 197 cases (57.43%) through nasal mucosal scraping, with no significant differences observed ($P > .05$).

Conclusions• AC and AR share a common pathophysiological process and allergen profile, with the conjunctiva and nasal mucosa serving as sites of allergic reactions. This study suggests the integration of AC prevention and treatment into AR prevention strategies. (*Altern Ther Health Med.* [E-pub ahead of print.])

Fang Xu, BSc, Department of Ophthalmology, Cangzhou Medical College, Yunhe District, Cangzhou, Hebei Province, China. **Kunna Yang, MSc,** Department of Otolaryngology, Cangzhou Medical College, Yunhe District, Cangzhou, Hebei Province, China.

Corresponding author: Kunna Yang, MSc
E-mail: kuan9593@163.com

INTRODUCTION

Allergic Conjunctivitis (AC)[1] is characterized by a hypersensitivity reaction of the conjunctiva to external allergens. Epidemiological data reveal a prevalence of 40% for AC in the United States and 15-20% in Japan,[2] indicating a high prevalence of AC.[3] Common symptoms associated with AC include pruritus, ocular redness, tearing, and an increased production of ocular mucus. These symptoms typically alleviate when the allergen is avoided.[4,5]

Severe AC, such as springtime keratoconjunctivitis and atopic keratoconjunctivitis, can potentially result in vision loss.[6] Furthermore, AC often presents as a condition with recurrent episodes.[7] The allergic reaction comprises two primary phases. The sensitization phase occurs when allergens enter the body for the first time, followed by the allergic phase, during which various target cells in the body bind to immunoglobulin E (IgE) and release sensitizing factors. These factors impact the body's response upon subsequent exposure to the same allergen.

Allergic rhinitis (AR)[8] is a non-infectious inflammatory condition affecting the nasal mucosa. It involves the release of IgE-mediated mediators, primarily histamine, upon exposure to allergens in atopic individuals. This activation leads to a heightened expression of immunoreactive cells and cytokines. Clinical and pathological data indicate the presence of risk factors for AR in individuals of all age groups, with a higher incidence observed in children and young adults. Worldwide, approximately 500 million people are affected by AR, and its prevalence shows a growing trend.[9,10]

The pathophysiological mechanisms underlying AR are multifaceted,[22] with risk factors encompassing genetics,[23]

environmental influences,[24] psychological factors,[25] and regional disparities, among others.[26,27] AR can contribute to or exacerbate symptoms such as fatigue, headaches, cognitive impairment, and sleep disturbances, making it a notable risk factor for asthma.[28]

Furthermore, AR necessitates three critical conditions for disease development: specific antigens, atopic individuals, and their interaction. Considering that both the conjunctiva and nasal mucosa consist of mucosal epithelium, allergens may simultaneously initiate the pathological processes of AC and AR. Currently, there are limited studies on the correlation between AC and AR. Therefore, this study evaluated this correlation, aiming to provide a foundation for clinical prevention and treatment strategies.

METHODS

Study Design

This study employs a retrospective cohort design involving 462 patients with AC and AR treated at our hospital from January 2018 to December 2020. These patients were categorized into either an AC group or an AR group based on the department of their initial visit. The AC group comprised 232 patients diagnosed with AC in the ophthalmology department, while the AR group included 230 patients diagnosed with AR in the ENT department. The eligible patients in this study ranged from 0.5 to 23 years of age, with a distribution of 263 males and 199 females.

Inclusion And Exclusion Criteria

Inclusion criteria were as follows: (1) all patients in the AC group met the clinical diagnostic criteria for AC; (2) all patients in the AR group met the clinical diagnostic criteria for AR; (3) patients and their families were informed about this study and voluntarily provided consent. Exclusion criteria were as follows: (1) patients with incomplete clinical case information; (2) patients with a history of psychiatric morbidity or a family history of psychiatric disorders; (3) patients with other immune-dependent ocular and nasal conditions.

Clinical Symptoms

Patients with allergic conjunctivitis commonly present with a range of clinical symptoms. These include itching of the eyes, often the most prevalent symptom, along with redness in the white part of the eye, a burning sensation, a feeling of a foreign body within the eye, and eyelid swelling. Additionally, individuals may experience photophobia, frequent eye rubbing, increased blinking, excessive tearing, and heightened production of eye mucus. Severe forms of allergic conjunctivitis, such as springtime keratoconjunctivitis and atopic keratoconjunctivitis, can potentially lead to vision impairment.

Symptoms like nasal itching, paroxysmal sneezing, runny nose, and nasal congestion characterize AR.[13] Seasonal allergen sensitization typically leads to symptoms lasting several weeks, naturally resolving after the season, and recurring in subsequent years. Common symptoms include a clear, watery discharge from the nose, frequent sneezing, itching of the nose, ears, and throat, and nasal congestion. Individuals with perennial allergies may encounter recurring or constant symptoms, such as pronounced nasal congestion, postnasal drip, and a pallid appearance of the nasal mucosa. Diagnosing AR can be challenging due to symptom similarity with chronic sinusitis and vasoconstrictive rhinitis.[14]

Observation Indicators

In this study, we carefully monitored and documented the clinical symptoms and diagnostic criteria for both AR and AC within our patient groups. Our complete set of observation indicators included the following for AR: (1) Nasal itching: Documented both frequency and severity; (2) Paroxysmal sneezing: Recorded both the frequency and duration of these episodes; (3) Runny nose: Describing its characteristics, duration, and frequency; (4) Nasal congestion: Assessed the severity, frequency, and duration; (5) Seasonal or perennial pattern: Observations on whether symptoms exhibited a seasonal or persistent nature; (6) Other nasal symptoms: This included additional symptoms such as clear watery nasal discharge, repeated sneezing, and itching in the nose, ears, and throat.

For AC: (1) Itchy eyes: Documenting both frequency and severity; (2) Redness of the eyes: Assessed both severity and duration; (3) Burning sensation: Evaluated both frequency and intensity; (4) Foreign body sensation: Noted observations and frequency; (5) Eyelid swelling: Recorded severity and duration; (6) Photophobia: Documented the occurrence and intensity; (7) Eye rubbing and blinking: Noted the frequency; (8) Tearing and eye mucus: Assessed intensity and frequency.

Allergen Analysis. Additionally, we conducted an allergen analysis in patients presenting with both AR and AC. We examined conjunctival and nasal mucosa scrapings for eosinophils to confirm the allergic nature of these conditions.

Statistical Analysis

We conducted statistical analysis using SPSS 22.0 software (IBM, Armonk, NY, USA). Measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$) and were tested using an independent sample t test. Count data were presented as the number of cases (%) and were tested using the chi-square test (χ^2). A significance level of $P < .05$ was employed to determine statistical significance.

RESULTS

Comparison of Patient Characteristics

In the AC group, there were 232 patients, comprising 133 males and 99 females, with ages ranging from 0.5 to 23 years (mean age 9.94 ± 4.23 years). The duration of the disease in this group ranged from 0.4 to 2.5 years (mean duration 1.11 ± 0.23 years). The AR group consisted of 230 patients, with 130 males and 100 females. The ages in this group ranged from 0.5 to 23 years (mean age 9.85 ± 4.36

Table 1. Comparison of Patient Characteristics ($\bar{x} \pm s$)

Group	n	Gender (male/ female)		Age (years)		Duration of Disease (years)	
AC	232	133	99	0.5-23	9.94±4.23	0.4-2.5	1.11±0.23
AR	230	130	100	0.5-23	9.85±4.36	0.5-2.5	1.12±0.21
t value	-	-	-	-	0.799	-	0.568
P value	-	-	-	-	.428	-	.532

Note: Values are presented as means ± standard deviations ($\bar{x} \pm s$). *t* value and *P* value indicate the results of the independent sample *t* test for age and duration of disease, comparing the AC and AR groups.

years), and the disease duration varied from 0.5 to 2.5 years (mean duration 1.12 ± 0.21 years). Importantly, patient characteristics were comparable between the two groups ($P > .05$), as demonstrated in Table 1.

Concurrent Onset of AC and AR

Within the AC group, 174 patients (75.00%) presented with concurrent AR, while in the AR group, 169 patients (73.48%) exhibited concurrent AC. Notably, there was no statistically significant difference in the occurrence of concurrent AC and AR between the two groups ($P > .05$), as depicted in Figure 1.

Comparison of Allergens

Inhalant allergen testing in patients with concurrent AC and AR indicated a predominant presence of dust mites, house dust, and fungi as major inhalant allergens, with a specific IgE positivity rate of 91.23%. Among food allergens, fish, shrimp, and crab were notable, showing a specific IgE positivity rate of 58.58%, as illustrated in Figure. 2.

Assessment of Eosinophils

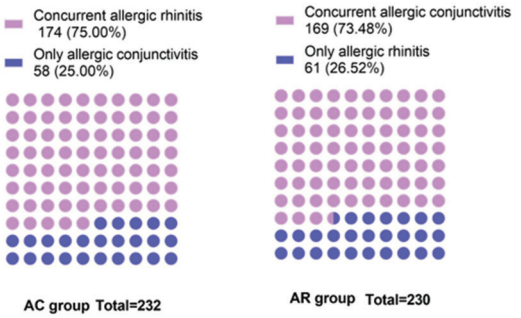
Eosinophil counts were assessed by scraping the conjunctiva and nasal mucosa in patients presenting with concurrent AC and AR. Eosinophils were detected in 188 cases (54.81%) from conjunctival scrapings and 197 cases (57.43%) from nasal mucosa scrapings, and no statistically significant differences were observed ($P > .05$), as illustrated in Figure 3.

DISCUSSION

The growing prevalence of allergic diseases represents a significant and challenging global public health concern.[14-15] AC frequently occurs due to exposure to airborne allergens or microbial infections, leading to its prevalence in individuals with allergic predispositions and having familial clustering.[15] Microbial infections can also contribute to the occurrence of AC when they trigger an immune response, exacerbating symptoms in individuals with a predisposition to allergies.[16,17] However, further analysis is required to understand the correlation between AC and AR.

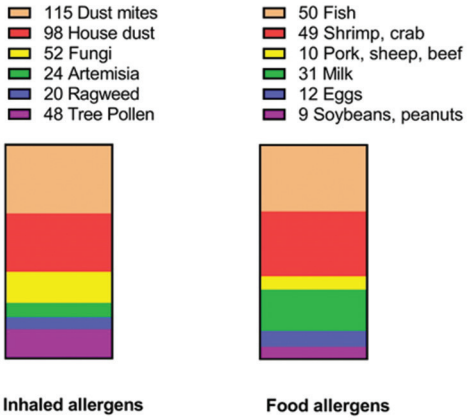
The nasal cavity, as part of the upper respiratory tract, shares close anatomical and physiological links with the bronchi and lungs. It serves a specialized function in filtering and cleansing, protecting the lower respiratory tract.[18-20] However, the nasal cavity faces a higher density and intensity

Figure 1. Comorbid Allergic Conjunctivitis/Allergic Rhinitis (%)



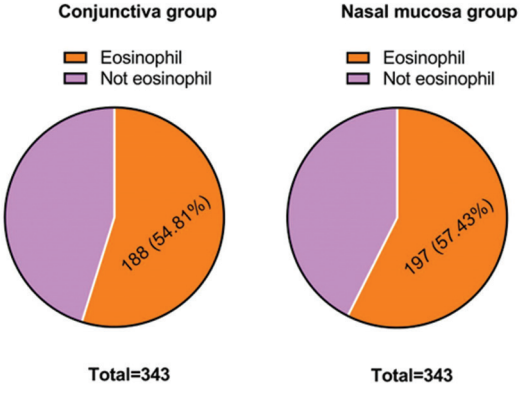
Note: This Figure illustrates the percentage of patients with comorbid allergic conjunctivitis in the allergic rhinitis (AR) group and the percentage of patients with comorbid allergic rhinitis in the allergic conjunctivitis (AC) group. The data show a high rate of comorbidity between these conditions, indicating a close relationship.

Figure 2. Inhalation/Ingestion Allergen Analysis



Note: This Figure provides an overview of the results from inhalation and ingestion allergen analysis. It highlights the major allergens found in patients with concurrent allergic conjunctivitis and allergic rhinitis, showing specific immunoglobulin E (IgE) positivity rates. The data reveal the prevalent allergens associated with these conditions, offering insights into potential triggers and guiding further research directions.

Figure 3. Eosinophils (%)



Note: This Figure displays the percentage of eosinophils in patients with concurrent allergic conjunctivitis and allergic rhinitis. Eosinophils play a significant role in allergic reactions, and this data helps in confirming the allergic nature of these conditions. The results demonstrate the presence of eosinophils in both conjunctival and nasal mucosa scrapings, suggesting a correlation between the two conditions.

of antigenic exposure per unit area compared to the lower airways.[21] The principal pathological characteristics of AR encompass allergic inflammation and heightened reactivity of the nasal mucosa. AC predominantly arises from type I and type IV allergic responses, with sensitizing mediators such as histamine and prokinetic enzymes. The reaction phase involves mediators like prostaglandin D2, platelet-activating factor, and leukotrienes.[22-26]

Previous studies have established a strong association between AC and asthma.[27-28] Clinical data consistently demonstrate that episodes of allergic rhinitis, or AC, frequently coincide with asthma or other allergic conditions. Earlier research reported a 17.6% incidence and a 92% prevalence of concurrent AC and rhinitis.[18] Additionally, the severity and duration of AC showed significant correlations with the severity and duration of both rhinitis and asthma.[21] AC and AR are widespread allergic conditions in China, affecting a significant portion of the population. The high prevalence of AC and AR highlights their impact on public health in the region, necessitating comprehensive research and management strategies.[29 -31]

The findings of this study revealed that 174 patients (75.00%) in the AC group exhibited concurrent AR, while 169 patients (73.48%) in the AR group presented concurrent AC. These results align with prior research, underscoring the epidemiological similarity between AC and AR.[28-30] In terms of physiological anatomy, the nose and the eye are interconnected through the nasolacrimal duct, and the histopathological structure of the conjunctiva closely resembles that of the nasal mucosa.

The pathogenesis of AC primarily involves 'type I and type IV allergies' mediated by IgE. In this process, eosinophils and mast cells are the primary target cells, while sensitizing mediators such as histamine and prokinetic enzymes play a crucial role.[27] In the reaction phase, mediators like platelet-activating factor, prostaglandin D2, and leukotrienes come into play. Notably, allergic rhinitis exhibits a tachyphylactic hypersensitivity reaction with pathogenesis closely related to AC.[28]

In our study, inhalant allergen testing in patients with concurrent AC and AR revealed that the primary inhalant allergens included dust mites, house dust, and fungi, with a specific IgE positivity rate of 91.23%. Additionally, food allergen testing identified fish, shrimp, and crab as the predominant allergens, showing a specific IgE positivity rate of 58.58%. Moreover, patients underwent eosinophil assessment via scraping of the conjunctiva and nasal mucosa. Eosinophils were detected in 188 cases (54.81%) in conjunctival scrapings and 197 cases (57.43%) in nasal mucosa scrapings ($P > .05$). These findings suggest a significant correlation between allergic conjunctivitis and allergic rhinitis.

Similar pathophysiological processes underlie both diseases. Both the conjunctiva and nasal mucosa serve as sites for allergic reactions involving type I IgE-mediated hypersensitivity responses to external allergens. Patients with concurrent AC and AR demonstrated a heightened expression of IgE.[19] Furthermore, there is an overlap in allergens between these two conditions.

Our findings suggest that the primary allergens associated with allergic conjunctivitis encompass cosmetics, pollen, and dust. On the other hand, allergic rhinitis is predominantly triggered by inhalant allergens such as dust mites, molds, animal epithelium, and pollen. Food allergens, mainly fish, shrimp, and crab, have received limited attention in previous studies on allergic conjunctivitis and rhinitis. Therefore, further research on food allergens is warranted for a comprehensive understanding of these conditions.

The presence of shared allergens and non-human intervening factors, such as pollen, enables the concurrent and recurring episodes of both conditions. However, despite multiple similarities, the severity of these two diseases does not exhibit a linear correlation. This finding suggests the importance of conducting timely examinations for one disease when the other manifests. The present study highlights the commonalities in the epidemiology, inflammatory response, and pathophysiological processes between AC and AR.

The findings of this study significantly contribute to our understanding of the relationship between AC and AR. The research demonstrates an epidemiological solid and pathophysiological correlation between these conditions, highlighting their shared allergens and overlapping inflammatory responses. The co-occurrence of AC and AR is notably common, emphasizing the importance of integrated approaches in both prevention and management. This study offers valuable insights for healthcare practitioners and researchers by recognizing the substantial correlation between these conditions, emphasizing the need for a more holistic approach to address the impact of AC and AR on patients.

Study Limitations

The current study is subject to certain limitations. Firstly, this study acknowledges the continuous nature of the two phases of allergic conjunctivitis and the significant time lapse often present between early and late reaction phases in the pathogenesis of allergic rhinitis.[20] Future research should focus on exploring the temporal dynamics of these phases to gain a more nuanced understanding. Secondly, the present study primarily concentrated on epidemiological and pathophysiological aspects without investigating the temporal relationships between the phases of AC. Future investigations should research these temporal connections to provide a comprehensive review of disease progression.

While this study successfully identified major inhalants and food allergens associated with both conditions, the discussion of food allergens, particularly in the context of allergic conjunctivitis, was limited. Future research should explore deeper into the role of food allergens in allergic conjunctivitis to offer a more comprehensive view of allergen profiles. Furthermore, despite the striking similarities in epidemiology, inflammatory responses, and pathophysiological processes, our study observed that the severity of AC and AR is not necessarily parallel. Investigating the underlying reasons for this discrepancy and identifying factors that influence disease severity could provide insights for more targeted and effective treatment strategies.

CONCLUSION

In conclusion, this study significantly advances our comprehension of the interconnected nature of AC and AR. We have established that these conditions share common pathophysiological processes and allergens, with both the conjunctiva and nasal mucosa serving as sites for allergic reactions. This close relationship underscores the importance of integrating allergic conjunctivitis prevention and treatment into the broader strategies for managing allergic rhinitis. Despite the numerous similarities between these two conditions, our study has revealed that the severity of allergic conjunctivitis and allergic rhinitis does not necessarily correlate. Therefore, healthcare providers and patients should remain vigilant for potential concurrent episodes of the other condition when one is diagnosed or presents itself. This vigilance will enable timely diagnosis and effective management, ultimately improving patient outcomes.

However, it is crucial to acknowledge the research's limitations. Further investigations are needed to explore the temporal dynamics of AC, explore the role of food allergens, and identify the factors contributing to disease severity. By addressing these limitations, we can achieve a more comprehensive understanding of these conditions, leading to the development of more effective prevention and management strategies. Our study emphasizes the need for future research. Subsequent studies should explore the continuous process of allergic conjunctivitis and the time lapse between the early and late reaction phases in the pathogenesis of allergic rhinitis. Such investigations will contribute to a deeper understanding of these conditions and enhance our ability to provide more targeted and effective prevention and treatment strategies.

ACKNOWLEDGEMENTS

Special thanks to all subjects and researchers for their incredible support of this clinical study

CONFLICT OF INTEREST

The data supporting the findings of this study are available from the corresponding author upon request, subject to reasonable conditions.

ETHICAL COMPLIANCE

The Ethics Committee of Cangzhou Medical College has approved this clinical study protocol. All the methods were conducted in accordance with the Declaration of Helsinki.

FUNDING

No funding was received.

REFERENCES

1. La Rosa M, Lionetti E, Reibaldi M, et al. Allergic conjunctivitis: a comprehensive review of the literature. *Ital J Pediatr*. 2013;39(1):18. doi:10.1186/1824-7288-39-18
2. Villegas BV, Benitez-Del-Castillo JM. Current Knowledge in Allergic Conjunctivitis. *Turk J Ophthalmol*. 2021;51(1):45-54. doi:10.4274/tjo.galenos.2020.11456
3. Miyazaki D, Fukagawa K, Okamoto S, et al. Epidemiological aspects of allergic conjunctivitis. *Allergol Int*. 2020;69(4):487-495. doi:10.1016/j.alit.2020.06.004
4. Bielory L, Delgado L, Katelaris CH, Leonardi A, Rosario N, Vichyanoud P. ICON: diagnosis and management of allergic conjunctivitis. *Ann Allergy Asthma Immunol*. 2020;124(2):118-134. doi:10.1016/j.anai.2019.11.014
5. Fauquert JL. Diagnosing and managing allergic conjunctivitis in childhood: the allergist's perspective. *Pediatr Allergy Immunol*, 2019. 30(4): P. 405-414.
6. Vazirani J, et al., Allergic conjunctivitis in children: current understanding and future perspectives. *Curr Opin Allergy Clin Immunol*, 2020. 20 (20(5): p. 507-515. doi:10.1097/ACI.0000000000000675
7. Sacchetti, M., et al., *Allergic conjunctivitis: current concepts on pathogenesis and management*. j Biol Regul Homeost Agents, 2018. 32(1 Suppl. 1): p . 49-60.
8. Schuler Iv CF, Montejo JM. Allergic Rhinitis in Children and Adolescents. *Pediatr Clin North Am*. 2019;66(5):981-993. doi:10.1016/j.pcl.2019.06.004
9. Bernstein DI, Schwartz G, Bernstein JA. Allergic Rhinitis: mechanisms and Treatment. *Immunol Allergy Clin North Am*. 2016;36(2):261-278. doi:10.1016/j.iac.2015.12.004
10. Agnihotri NT, McGrath KG. Allergic and nonallergic rhinitis. *Allergy Asthma Proc*. 2019;40(6):376-379. doi:10.2500/aap.2019.40.4251
11. Campo, P., et al., Local allergic rhinitis: Implications for management. *clin Exp Allergy*, 2019. 49(1): p. 6-16. doi:10.1111/cea.13192
12. Incorvaia C, Cavaliere C, Frati F, Masieri S. Allergic rhinitis. *J Biol Regul Homeost Agents*. 2018;32(1)(suppl 1):61-66.
13. Brown T. Diagnosis and Management of Allergic Rhinitis in Children. *Pediatr Ann*. 2019;48(12):e485-e488. doi:10.3928/19382359-20191111-01
14. Seidman MD, Gurgel RK, Lin SY, et al; Guideline Otolaryngology Development Group. AAO-HNSF. Clinical practice guideline: allergic rhinitis. *Otolaryngol Head Neck Surg*. 2015;152(1)(suppl):S1-S43.
15. Hoyte, F.C.L. and H.S. Nelson, *Recent advances in allergic rhinitis*. f1000Res, 2018. 7. doi:10.12688/f1000research.15367.1
16. Mueller A. Allergic Conjunctivitis: an Update. *Handb Exp Pharmacol*. 2022;268:95-99. doi:10.1007/164_2021_491
17. O'Brien TP. Allergic conjunctivitis: an update on diagnosis and management. *Curr Opin Allergy Clin Immunol*. 2013;13(5):543-549. doi:10.1097/ACI.0b013e328364ec3a
18. Iordache A, Boruga M, Mușat O, Jipa DA, Tătaru CP, Mușat GC. Relationship between allergic rhinitis and allergic conjunctivitis (allergic rhinoconjunctivitis) - review. *Rom J Ophthalmol*. 2022;66(1):8-12.
19. Scadding GK, Scadding GW. Diagnosing Allergic Rhinitis. *Immunol Allergy Clin North Am*. 2016;36(2):249-260. doi:10.1016/j.iac.2015.12.003
20. Siddiqui ZA, Walker A, Pirwani MM, Tahiri M, Syed I. Allergic rhinitis: diagnosis and management. *Br J Hosp Med (Lond)*. 2022;83(2):1-9. doi:10.12968/hmed.2021.0570
21. Sánchez-Hernández MC, Dordal MT, Navarro AM, et al. Severity and duration of allergic conjunctivitis: are they associated with severity and duration of allergic rhinitis and asthma? *Eur Ann Allergy Clin Immunol*. 2022;54(6):277-283. doi:10.23822/EurAnnACI.1764-1489.231
22. Hoyte FCL, Nelson HS. Recent advances in allergic rhinitis. F1000Res. 2018;7:F1000 *Faculty Rev*-1333.
23. Choi BY, Han M, Kwak JW, Kim TH. Genetics and epigenetics in allergic rhinitis. *Genes (Basel)*. 2021;12(12):2004. doi:10.3390/genes12122004
24. Wu AC, Dahlin A, Wang AL. The role of environmental risk factors on the development of childhood allergic rhinitis. *Children (Basel)*. 2021;8(8):708. doi:10.3390/children8080708
25. Shirkhani M, Aali S, Khoshkhui M. Quality of life, psychological state, and cognitive emotion regulation strategies in allergic rhinitis patients vs healthy population: a comparative study. *Pract Clin Psychol*. 2022;10(2):121-130. doi:10.32598/jpcp.10.2.817.1
26. Ota M, Nishida Y, Yagi H, et al. Regional differences in the prevalence of oral allergy syndrome among Japanese children: A questionnaire-based survey. *Asian Pac J Allergy Immunol*. 2023;41(2):142-149.
27. Testa D, DI Bari M, Nunziata M, et al. Allergic rhinitis and asthma assessment of risk factors in pediatric patients: A systematic review. *Int J Pediatr Otorhinolaryngol*. 2020;129:109759. doi:10.1016/j.ijporl.2019.109759
28. Eguiluz-Gracia I, Mathioudakis AG, Bartel S, et al. The need for clean air: the way air pollution and climate change affect allergic rhinitis and asthma. *Allergy*. 2020;75(9):2170-2184. doi:10.1111/all.14177
29. Bousquet J, Khaltaev N, Cruz AA, et al; AllerGen. Allergic Rhinitis and its Impact on Asthma (ARIA) 2008 update (in collaboration with the World Health Organization, GA(2)LEN and AllerGen). *Allergy*. 2008;63(suppl 86):8-160. doi:10.1111/j.1398-9995.2007.01620.x
30. Lou H, Ma S, Zhao Y, et al. Sensitization patterns and minimum screening panels for aeroallergens in self-reported allergic rhinitis in China. *Sci Rep*. 2017;7(1):9286. doi:10.1038/s41598-017-10111-9
31. Ouyang Y, Yin Z, Li Y, Fan E, Zhang L. Associations among air pollutants, grass pollens, and daily number of grass pollen allergen-positive patients: a longitudinal study from 2012 to 2016. *Int Forum Allergy Rhinol*. 2019;9(11):1297-1303. doi:10.1002/alr.22389