

Ongoing Allergic Rhinitis Impairs Asthma Control by Enhancing the Lower Airway Inflammation

Asako Oka, MD^a, Kazuto Matsunaga, MD, PhD^a, Tadashi Kamei, MD, PhD^b, Yukihiro Sakamoto, MD, PhD^c, Tsunahiko Hirano, MD, PhD^a, Atsushi Hayata, MD^d, Keiichiro Akamatsu, MD, PhD^a, Takashi Kikuchi, MD, PhD^a, Masataka Hiramatsu, MD^a, Tomohiro Ichikawa, MD, PhD^a, Masanori Nakanishi, MD, PhD^a, Yoshiaki Minakata, MD, PhD^a, and Nobuyuki Yamamoto, MD, PhD^a *Wakayama, Takamatsu, Komatsushima, and Kinokawa, Japan*

What is already known about this topic? Allergic rhinitis is common in asthma and has an impact on asthma condition. The pathophysiologic events critical to the clinical manifestations of allergic rhinitis and asthma are similar.

What does this article add to our knowledge? This study provides data regarding the mechanism of interactions between the upper and lower airways. Ongoing allergic rhinitis is associated with incomplete asthma control by enhancing lower airway inflammation.

How does this study impact current management guidelines? Evaluation of the activity of allergic rhinitis is useful for assessing the impact of rhinitis on asthma, and adequate control of allergic rhinitis may improve asthma condition.

BACKGROUND: The relationship between allergic rhinitis and asthma is well accepted; however, little is known about the mechanism that underlies the interactions between the upper and lower airways.

OBJECTIVE: To investigate the symptomatic and inflammatory linkages between allergic rhinitis and asthma in patients with atopy.

METHODS: We enrolled 520 patients with asthma who were taking inhaled corticosteroids, and examined them by using the Asthma Control Questionnaire, spirometry, exhaled nitric oxide fraction (FENO), visual analog scale for nasal symptoms, allergic rhinitis questionnaire, and serum specific IgE (study 1). The symptomatic and inflammatory marker responses to nasal corticosteroids in patients with incompletely controlled asthma (Asthma Control Questionnaire > 0.75) and moderate-to-severe persistent allergic rhinitis were also observed (study 2).

RESULTS: A total of 348 patients (66.9%) had atopy and allergic rhinitis. There was a striking difference in the proportion of patients with incomplete asthma control, depending on the

presence as well as the activity of rhinitis (no rhinitis, 11.0%; mild intermittent, 20.4%; moderate-to-severe intermittent, 44.6%; mild persistent, 53.1%; moderate-to-severe persistent, 65.7%). The FENO levels were increased with the activity of rhinitis, and the nasal visual analog scale was positively correlated with the FENO levels ($r = 0.31$; $P < .0001$). The additive treatment with nasal corticosteroids improved the nasal visual analog scale, Asthma Control Questionnaire, and FENO levels, and the changes in these variables were correlated with each other in all parameters (all $P < .001$).

CONCLUSION: This observational study of patients with atopy indicates that the ongoing allergic rhinitis is related to worsening of asthma by enhancing the lower airway inflammation. © 2013 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2014;2:172-8)

Key words: Airflow limitation; Airway inflammation; Atopy; Exhaled nitric oxide; Inhaled corticosteroids; Nasal corticosteroids

Allergic rhinitis is common in asthma.¹ Previous studies provided evidence that the presence of rhinitis increases the social burden of asthma.^{2,3} Patients with asthma and with concomitant rhinitis experience more asthma-related hospitalizations and physician visits, and higher medical costs than patients with asthma alone. Moreover, results of several studies indicated a link between the severity and/or control of rhinitis and asthma.⁴⁻⁷ However, these studies defined allergic rhinitis by clinical symptoms and/or patient questionnaire, and many studies were *post hoc* analyses. To date, the relationships between the upper and lower airway conditions have not been fully examined in patients with confirmed atopic allergic rhinitis and asthma.

The mechanism that underlies the interaction between the upper and lower airways is still unclear, although pathophysiologic events critical to the development and clinical manifestations of

^aThird Department of Internal Medicine, Wakayama Medical University, Wakayama, Japan

^bKamei Respiratory Clinic, Takamatsu, Japan

^cMinami Tokushima Clinic, Komatsushima, Japan

^dDivision of Respiratory Medicine, Naga Hospital, Kinokawa, Japan

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Corresponding author: Kazuto Matsunaga, MD, PhD, Third Department of Internal Medicine, Wakayama Medical University, 811-1 Kimiidera, Wakayama 641-8509, Japan. E-mail: kazmatsu@wakayama-med.ac.jp.

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Abbreviations used

ACQ- Asthma Control Questionnaire

AR- Allergic rhinitis

ARIA- Allergic Rhinitis and its Impact on Asthma

FVC- Forced vital capacity

FENO- Exhaled nitric oxide fraction

FEV₁- Forced expiratory volume in 1 second

ICS- inhaled corticosteroid

VAS- Visual analog scale

allergic rhinitis and asthma are similar.⁸⁻¹¹ Previous studies showed that nasal allergen challenge induces eosinophilic inflammation in the upper and lower airways, and causes airflow limitation in patients with allergic rhinitis.¹⁰ Bronchial allergen provocation can induce nasal and bronchial symptoms as well as reductions in pulmonary and nasal function.¹¹ Moreover, several studies have reported that treatment of concomitant rhinitis was related to reductions in the risk of emergency department visits and hospitalizations for asthma^{12,13} and that nasal corticosteroid therapy is related to improved respiratory symptoms and patient quality of life in mild intermittent asthma.^{14,15} Analysis of these data suggests symptomatic and inflammatory linkages between the upper and lower airways in allergic rhinitis and asthma.

This study is based on the concept that allergic rhinitis may be a contributor to impaired asthma control with the possibility that the upper and lower airway inflammation is linked. In study 1, a cross-sectional survey was performed for assessing the linkages between the upper and lower airway conditions in patients with atopy and with allergic rhinitis and asthma. In the current guidelines for allergic rhinitis, intranasal corticosteroids are recommended as the first-line treatment for persistent moderate-severe disease.¹ Therefore, the symptomatic and inflammatory marker responses to the addition of nasal corticosteroids to asthma treatment in patients with incompletely controlled asthma and moderate-severe persistent allergic rhinitis were also observed (study 2).

METHODS

Study subjects

All the subjects were recruited from July 2012 to December 2012 to avoid the influence of the cedar pollen season in Japan. Subjects older than 20 years old were considered eligible if they satisfied the standard criteria for asthma.¹⁶ The patients had a history of episodic dyspnea, wheezing, and documented reversible airway obstruction. According to the Global Initiative for Asthma,¹⁶ asthma treatment included inhaled corticosteroids (ICS) with or without inhaled long-acting β_2 -agonist, leukotriene receptor antagonist, or theophylline. It is known that asthma conditions, including lung function and airway inflammation, are modified by tobacco smoking, exacerbations of asthma, and corticosteroid therapy.¹⁶⁻¹⁸ Subjects were excluded if they were current smokers or had experienced an asthma exacerbation or had been treated with systemic and/or nasal corticosteroids during the 8 weeks before the study. Also, patients with poor adherence to the treatment (defined as <80% adherence calculated by dividing the number of days supplied for a medication by the number of days between the office visits) or with other pulmonary diseases, such as chronic obstructive

pulmonary disease or bronchiectasis, which could influence asthma control, were excluded. Serum-specific immunoglobulin (Ig) E for common inhaled allergens (house dust mite, cedar, ragweed, cocksfoot, dog, and cat) was examined by using the ImmunoCAP system (Pharmacia Diagnostics, Uppsala, Sweden). Positive specific IgE (>0.7 UA/mL) to at least one allergen was assumed to confirm atopy. Allergic rhinitis was defined as the presence of atopy and a positive answer to the rhinitis questionnaire based on allergic rhinitis and its impact on asthma (ARIA).¹ This study was approved by the local ethics committee (institutional review board 526) and registered with the University Hospital Medical Information Network (000008609). Informed written consent was obtained from each participant.

Study design

This was a multicenter, prospective, observational study. We studied the medical records, including medication use and smoking history. After the inclusion period, a cross-sectional survey, by using the asthma control questionnaire (ACQ), spirometry, exhaled nitric oxide fraction (FENO), visual analog scale (VAS) for nasal symptoms, the allergic rhinitis questionnaire, and serum-specific IgE, was performed (study 1). After this survey, the patients with incompletely controlled asthma (ACQ score >0.75) and moderate-severe persistent rhinitis were selected, and additive therapy with 200 μ g nasal mometasone furoate per day was administered for 4 weeks if the patient agreed to participate. We used the nasal symptom VAS, ACQ, spirometry, blood eosinophil counts, and FENO at the start and end of the nasal corticosteroid therapy (study 2). The baseline treatment for asthma was continued without any changes during the study period. The flow diagram of the study is shown in Figure E1 (in this article's Online Repository at www.jaci-inpractice.org).

Questionnaire and VAS

The patient questionnaire for rhinitis approved by the Japanese ARIA and the Global Initiative for Asthma committee was used to assess the presence of symptoms of allergic rhinitis.^{1,4} The activity of allergic rhinitis and the impact on the quality of life were also evaluated.¹ The ACQ-5 is a composite control measure that assesses the asthma condition according to 5 items, each of which can be rated on a 7-point scale.¹⁹ The overall score was the mean of the 5 responses, and ACQ $\leq$ 0.75 was considered to indicate well-controlled asthma.¹⁹ Both questionnaires have been used in earlier studies in Japan.^{4,20} Furthermore, the VAS, which ranges from 0 cm (absence of symptoms) to 10 cm (very severe symptoms) for all combined nasal symptoms, was self-assessed by the patient.^{21,22}

Pulmonary function and exhaled nitric oxide measurement

The forced vital capacity (FVC) and FEV₁ were measured by using a dry rolling seal spirometer (CHESTAC-8800; Chest, Tokyo, Japan). The FENO was measured by an online electrochemical nitric oxide analyzer (NIOX MINO; Aerocrine, Solna, Sweden) as previously described.²³

Statistical analysis

All data were expressed as mean (SD) values for continuous variables. For categorical variables, the numbers of observations and percentages were given in each category. Comparisons among different subgroups were performed by the Fisher exact

TABLE I. Demographics of patients with asthma according to the presence or absence of allergic rhinitis

Characteristic	Patients with asthma and with allergic rhinitis (n = 348)	Patients with asthma and without allergic rhinitis (n = 172)	P value*
No. of women/men	213/135	105/67	.97
Age (y), mean $\pm$ SD	53.3 $\pm$ 16.5	55.0 $\pm$ 15.5	.26
Smoking status (Never: Ex), no. (%)	262 (75.3): 86 (24.7)	135 (78.5): 37 (21.5)	.42
Atopy, no. (%)	348 (100.0)	61 (35.5)	<.001
Dose of ICS (μ g/d), mean $\pm$ SD†	388 $\pm$ 168	340 $\pm$ 138	<.001
Inhaled long-acting β_2 -agonist, no. (%)	228 (72.6)	110 (64.0)	.73
Leukotriene receptor antagonist, no. (%)	137 (39.4)	45 (26.2)	<.005
ARIA classification of allergic rhinitis, no. (%)			
Mild intermittent	152 (43.7)	—	—
Moderate-severe intermittent	65 (18.7)	—	—
Mild persistent	32 (9.2)	—	—
Moderate/severe persistent	99 (28.4)	—	—
VAS for nasal symptoms (cm), mean $\pm$ SD	2.8 $\pm$ 2.6	0.1 $\pm$ 0.4	<.001
Asthma Control Questionnaire, mean $\pm$ SD	0.63 $\pm$ 0.61	0.22 $\pm$ 0.37	<.001
Asthma control levels, no. (%)			<.001
Well controlled‡	206 (59.2)	153 (89.0)	—
Incompletely controlled§	142 (40.8)	19 (11.0)	—
FVC % of predicted, mean $\pm$ SD	100.8 $\pm$ 12.7	100.8 $\pm$ 13.9	.99
FEV ₁ /FVC ratio (%), mean $\pm$ SD	75.9 $\pm$ 11.5	78.9 $\pm$ 7.4	<.01
FEV ₁ % of predicted, mean $\pm$ SD	91.9 $\pm$ 16.3	94.9 $\pm$ 15.4	<.01
FENO (ppb), mean $\pm$ SD	30.0 $\pm$ 21.5	19.4 $\pm$ 13.0	<.001

Never: Ex, Never smoked: Ex-smokers.

*Compared between the groups.

†ICS, expressed as fluticasone propionate equivalent.

‡ACQ $\leq$ 0.75.

§ACQ > 0.75.

test, χ^2 test, and Kruskal-Wallis test. The Spearman correlation analysis was performed to assess the correlations. A *P* value of <.05 was considered significant.

RESULTS

A total of 520 patients who fulfilled all inclusion criteria were approached for participation in the cross-sectional study. None of the patients refused to participate. The demographics of these patients are shown in Table I. A total of 348 patients (66.9%) had atopy and allergic rhinitis. Compared with the subjects with asthma alone, the patients with asthma and rhinitis had higher rates of incompletely controlled asthma, more airway inflammation (all *P* < .001), and more airflow limitation (*P* < .01) despite receiving more intensive asthma treatment (daily dose of ICS and leukotriene receptor antagonist use). The data on allergen sensitization are shown in Table I and Table E1 (in this article's Online Repository at www.jaci-inpractice.org). The proportion of patients with allergen sensitization was higher in those with (100%) than in those without rhinitis (35.5%). However, the profiles of allergen sensitization did not differ between the 2 groups (Table E1).

The patient characteristics according to the activity of allergic rhinitis are shown in Table II. The nasal symptoms, ACQ, airflow limitation, and airway inflammation tended to be worse with a higher activity of allergic rhinitis. Compared with patients with asthma and with mild rhinitis, the patients with moderate-severe rhinitis were more likely to have incompletely controlled asthma (28% vs 57%; *P* < .0001), although there was no

significant difference in lung function between the groups. Also, patients with asthma and with persistent rhinitis had a higher proportion of incompletely controlled asthma compared with the patients with intermittent rhinitis (63% vs 28%; *P* < .0001). There was a striking difference in the proportion of patients with incomplete asthma control, depending on the presence as well as the activity of allergic rhinitis (no rhinitis, 11.0%; mild intermittent, 20.4%; moderate-severe intermittent, 44.6%; mild persistent, 53.1%; moderate-severe persistent, 65.7%) (Figure 1, A). Also, a significant increase in the FENO levels was found in accordance with the activity of allergic rhinitis (Figure 1, B). The nasal symptom VAS showed a weak but significant correlation with the ACQ score (*r* = 0.44; *P* < .0001) and the FENO levels (*r* = 0.31; *P* < .0001) in patients with allergic rhinitis and asthma.

After the cross-sectional study, 65 patients with incompletely controlled asthma and moderate-severe persistent rhinitis were approached for receiving additive therapy with nasal corticosteroids, and a total of 40 patients agreed to participate. As shown in Table III, intranasal corticosteroid improved the nasal VAS level from 4.8 cm at baseline to 2.7 cm at week 4 (*P* < .0001). Significant improvements in ACQ (*P* < .0001) and the FENO levels (*P* < .01) also were found (Figure 2, A), and well-controlled asthma was achieved in 55% of these patients. The blood eosinophil level tended to be decreased by nasal corticosteroid therapy but not significantly (*P* = 0.10). As shown in Figure 2, B and C, the reductions in the FENO levels were significantly correlated with the improvements in the nasal symptoms and the ACQ (*r* = 0.52, *P* < .001; and *r* = 0.73,

TABLE II. Patient characteristics according to the ARIA classification of allergic rhinitis¹

Characteristic	Patients with asthma and with mild intermittent AR	Patients with asthma with moderate-severe intermittent AR	Patients with asthma and with mild persistent AR	Patients with asthma with moderate-severe persistent AR	Patients with asthma and with mild vs moderate-severe AR, <i>P</i> value*	Patients with asthma and with intermittent vs persistent AR, <i>P</i> value*
No. of patients	152	65	32	99		
VAS for nasal symptoms (cm), mean $\pm$ SD	1.0 $\pm$ 1.2	2.3 $\pm$ 1.6	3.8 $\pm$ 2.2	5.6 $\pm$ 2.4	<.0001	<.0001
ACQ score, mean $\pm$ SD	0.38 $\pm$ 0.46	0.67 $\pm$ 0.57	0.77 $\pm$ 0.69	0.94 $\pm$ 0.66	<.0001	<.0001
Asthma control levels, no. (%)						
Well controlled [†]	121 (79.6)	36 (55.4)	15 (46.9)	34 (34.3)		
Incompletely controlled [‡]	31 (20.4)	29 (44.6)	17 (53.1)	65 (65.7)		
FVC % of predicted, mean $\pm$ SD	101.9 $\pm$ 11.9	100.7 $\pm$ 12.8	100.1 $\pm$ 12.9	98.1 $\pm$ 15.1	.56	.14
FEV ₁ /FVC ratio (%), mean $\pm$ SD	76.4 $\pm$ 11.0	76.4 $\pm$ 12.1	76.0 $\pm$ 9.8	74.0 $\pm$ 12.2	.18	.31
FEV ₁ % of predicted, mean $\pm$ SD	94.0 $\pm$ 14.4	92.2 $\pm$ 16.8	91.4 $\pm$ 18.3	88.8 $\pm$ 17.7	.29	<.05
FENO (ppb), mean $\pm$ SD	22.0 $\pm$ 12.2	30.5 $\pm$ 19.4	32.2 $\pm$ 26.3	41.1 $\pm$ 26.7	<.0001	<.0001

*Compared between the groups.

[†]ACQ $\leq$ 0.75.

[‡]ACQ $>$ 0.75.

$P < .001$, respectively). The reductions in the nasal VAS levels were related to the improvements in the ACQ score ($r = 0.52$; $P < .001$). A correlation matrix of the variables (nasal VAS, blood eosinophils, FENO, FEV₁, and ACQ) is shown in Table E2 (in this article's Online Repository at www.jaci-inpractice.org). The changes in these variables were correlated with each other in most parameters for allergic rhinitis and asthma.

DISCUSSION

We demonstrated that there were close relationships between the upper and lower airway conditions in patients with atopy and with allergic rhinitis and asthma. There was a striking difference in the proportion of patients with incomplete asthma control, depending on the presence as well as the activity of rhinitis. A significant elevation in the FENO levels also was found in accordance with the activity of rhinitis. The additive treatment with nasal corticosteroids improved the nasal VAS, ACQ, and FENO levels, and the improvements in these variables were significantly correlated with each other.

Asthma control was impaired with the presence as well as the activity of confirmed atopic allergic rhinitis. This is a novel finding because no previous large studies included the full definition of allergic rhinitis on ARIA. All ARIA classifications and nasal VAS levels were consistent. In addition, there was a significant correlation between nasal VAS and ACQ scores. Although a recent study demonstrated that moderate-severe allergic rhinitis impairs asthma control in patients with severe asthma,⁷ the influence of rhinitis activity on asthma control is still unclear. Our study is the first to show an ARIA classification dependent increase in the proportion of incomplete asthma control in patients with atopy and with asthma and rhinitis, which indicated an interrelationship between the activity of allergic disease in both the upper and lower airways. In this study, the allergen sensitization tended to be more common in patients with asthma and with rhinitis than in those without, but the difference was not significant. These data supported the previous study, which described that the profile of allergen sensitization is not associated with the relationship between allergic rhinitis and asthma control.⁶

Another main finding of our study was that the FENO levels were increased with the activity of allergic rhinitis. The nasal symptom VAS was correlated with the FENO levels. Analysis of these results suggests that symptomatic rhinitis is associated with increased lower airway inflammation irrespective of conventional ICS treatment. Indeed, atopy and allergic rhinitis are identified as contributors to sustained high levels of FENO in patients with asthma and on ICS treatment.^{24,25} Some studies have reported that the addition of nasal corticosteroids to asthma maintenance treatment has beneficial effects on the symptoms and control of asthma and rhinitis.^{14,15,26-29} A meta-analysis showed that nasal corticosteroids tended to improve asthma symptoms and FEV₁, although the results did not reach significance.²⁹ To date, it is still unclear whether nasal corticosteroid therapy helps to improve the bronchial inflammation.^{14,26-28} To our knowledge, there had been no study that took into account both the levels of asthma control and the activity of rhinitis to assess the efficacy of nasal corticosteroids on the lower airway outcomes. In the present study, we observed that 4 weeks of additive treatment with nasal corticosteroids reduced the mean FENO level from 49.7 to 36.7 ppb in patients with incompletely controlled asthma and

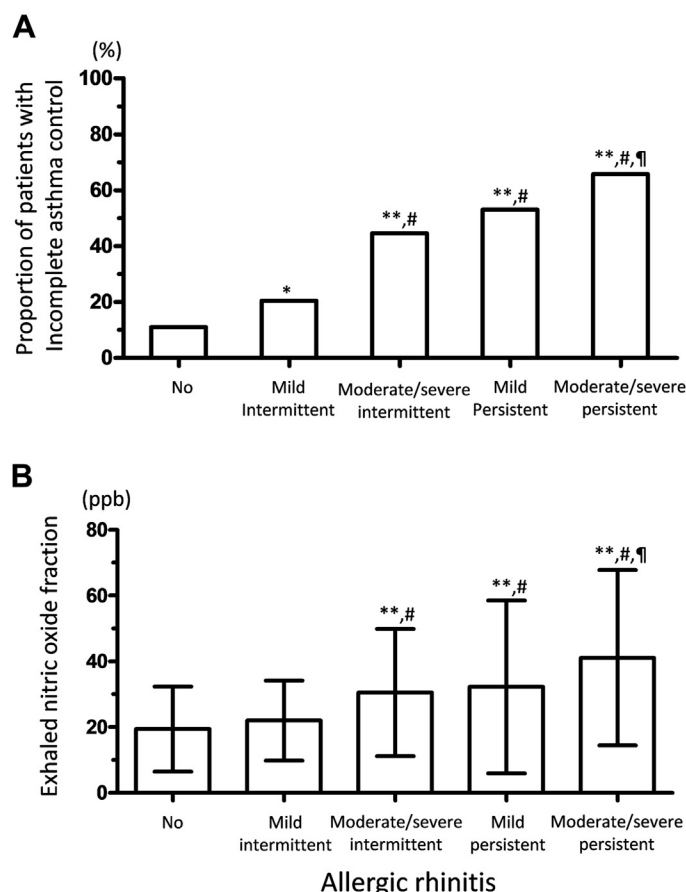


FIGURE 1. Influences of the activity of allergic rhinitis on (A) the proportion of patients with incomplete asthma control, and on (B) the levels of FENO (mean [SD]). * $P < .05$ versus no rhinitis. ** $P < .01$. # $P < .01$ versus mild intermittent rhinitis. ¶ $P < .05$ versus moderate-severe intermittent rhinitis.

TABLE III. Demographics and clinical characteristics of patients who received the additional treatment with nasal mometasone furoate

Characteristic	Patients with incompletely controlled asthma and moderate-severe allergic rhinitis		
No. of women/men	20/20		
Age (y), mean $\pm$ SD	57.0 $\pm$ 15.2		
Smoking status (Never: Ex), no. (%)	26 (65.0): 14 (35.0)		
Dose of ICS (μ g/d), mean $\pm$ SD*	432 $\pm$ 168		
Inhaled long-acting β 2-agonist, no. (%)	31 (77.5)		
Leukotriene receptor antagonist, no. (%)	17 (42.5)		
	Pretreatment	Posttreatment	P value
VAS for nasal symptoms (cm), mean $\pm$ SD	4.8 $\pm$ 2.0	2.7 $\pm$ 1.8	<.0001
ACQ score, mean $\pm$ SD	1.12 $\pm$ 0.36	0.65 $\pm$ 0.39	<.0001
Asthma control levels, no. (%)			<.0001
Well controlled†	0 (0)	22 (55.0)	
Incompletely controlled‡	40 (100.0)	18 (45.0)	
FVC % of predicted, mean $\pm$ SD	98.5 $\pm$ 11.3	101.7 $\pm$ 11.5	.26
FEV ₁ /FVC ratio (%), mean $\pm$ SD	73.1 $\pm$ 9.3	73.4 $\pm$ 9.5	.93
FEV ₁ % of predicted, mean $\pm$ SD	87.4 $\pm$ 14.1	90.6 $\pm$ 16.3	.37
FENO (ppb), mean $\pm$ SD	49.7 $\pm$ 25.6	36.7 $\pm$ 17.0	<.01
Blood eosinophils (cells/ μ L), mean $\pm$ SD	355 $\pm$ 218	283 $\pm$ 224	.10

Never: Ex, Never smoked: Ex-smokers.

*ICS, expressed as fluticasone propionate equivalent.

†ACQ $\leq$ 0.75.

‡ACQ > 0.75.

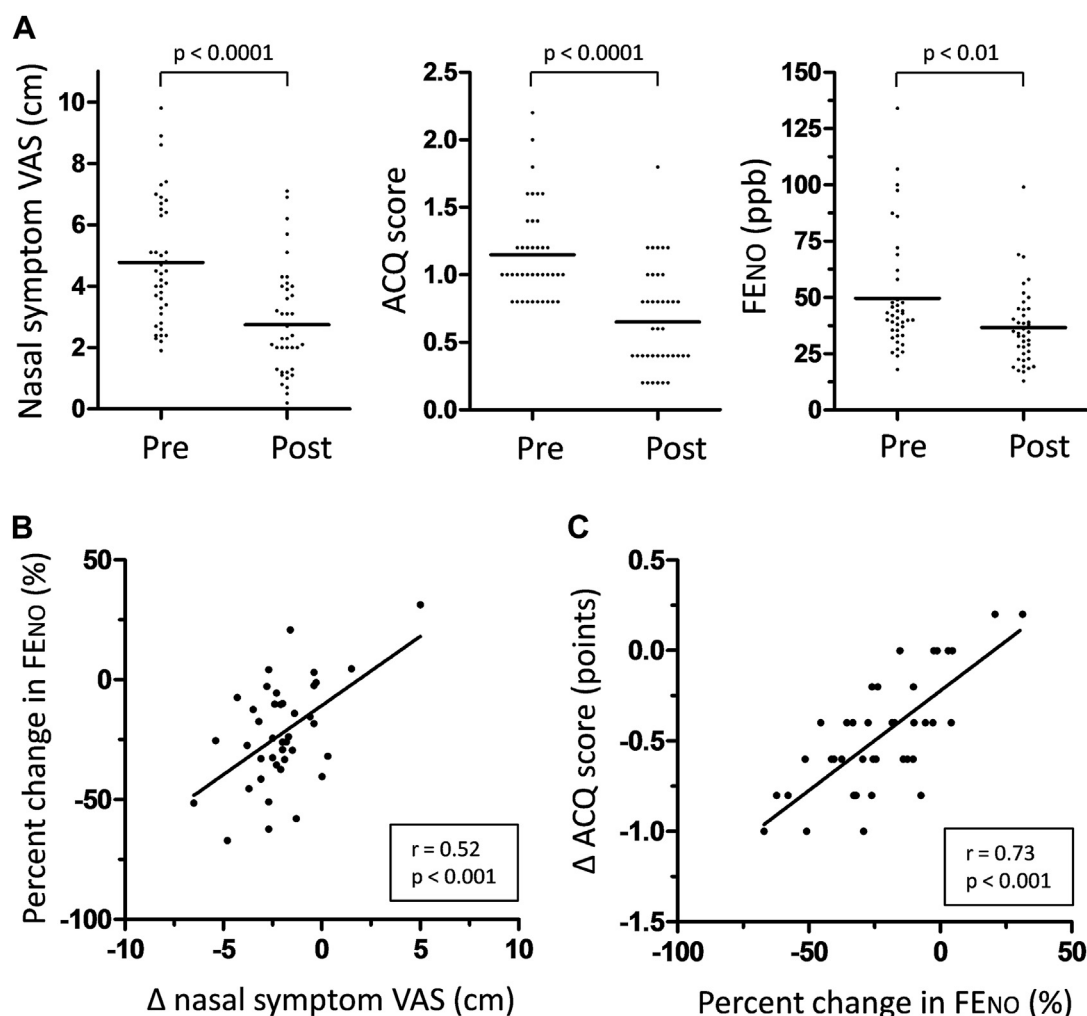


FIGURE 2. (A) Changes in the VAS for nasal symptoms, ACQ, and FENO at the start and end of nasal corticosteroid therapy. Horizontal bars represent means of VAS, ACQ, and FENO levels in each period. Relationships among the percentage change in the FENO level and the changes in (B) nasal symptom VAS level, and in (C) ACQ score.

moderate-severe rhinitis. In addition, nasal corticosteroids significantly improved the nasal VAS and ACQ scores. The major limitation in the second step of the study is the absence of a control group and randomization of the subjects. Although further studies are needed to clarify the effects of nasal corticosteroids on asthma, we believe that our data support the existence of inflammatory linkages between the upper and lower airways. Taken together, analysis of these results suggests that there are interactions between the upper and lower airways in patients with atopy and with rhinitis and asthma, and ongoing rhinitis may enhance the bronchial inflammation and increase the FENO levels. This hypothesis was supported by the association between the changes in the parameters for asthma and rhinitis by nasal corticosteroid therapy.

Several mechanisms have been proposed for the interaction between the upper and lower airways in asthma and rhinitis.^{9-11,27-31} To date, most studies point toward a systemic pathway that links the upper and lower airways, which involves both circulating blood and bone marrow. In the present study, the blood eosinophil level tended to be decreased by nasal corticosteroid therapy but was not statistically significant. This

result may be due to the distribution of the blood eosinophil levels among the subjects. Randomized, prospective trials that use more specific markers such as interleukin-5 and eosinophilic cationic protein²⁷ may be useful to assess the systemic signaling pathway linking the upper and lower airways.

Our study had several limitations. First, a selection bias is possible because this study was performed in a hospital-based asthma clinic. Also, patients whose adherence was <80% based on the prescription refill data were excluded. Second, because the ACQ score reflects symptoms and their effect on quality of life, we could not verify that the symptoms being reported were due to asthma alone. The quality of life may be influenced by shared, misattributed symptoms. Finally, the upper airway outcome was not monitored by inflammatory markers, such as cellular examination and nasal NO measurement.^{14,27} However, several recent studies have reported that the VAS for nasal symptoms can be used as a quantitative evaluation of the severity of rhinitis and serve as a tool to assess the efficacy of rhinitis treatment.^{21,22}

In conclusion, in this observational study of patients with atopy and with allergic rhinitis and asthma, we demonstrated symptomatic and inflammatory linkages between the upper and lower

airways. It has been indicated that the ongoing allergic rhinitis is related to worsening of asthma by enhancing the lower airway inflammation. Evaluation of the activity of allergic rhinitis is useful for assessing the impact of rhinitis on asthma, and adequate control of allergic rhinitis may improve asthma condition.

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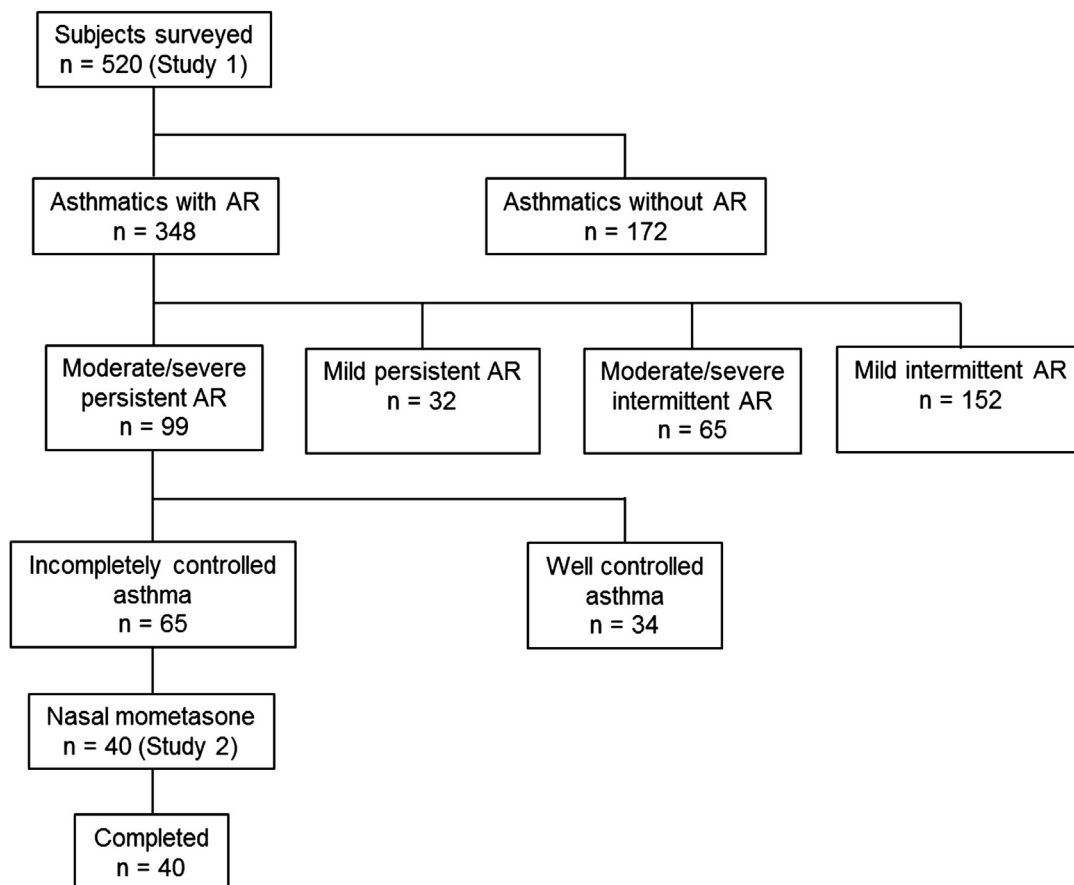


FIGURE E1. Disposition of the study patient population. AR, Allergic rhinitis.

TABLE E1. Patients sensitized to specific aeroallergens in 409 patients with atopy and with asthma, with and without allergic rhinitis

Allergen	Patients with asthma and with allergic rhinitis, no. (%) (n = 348)	Patients with asthma and without allergic rhinitis, no. (%) (n = 61)	P value
House dust mite	238 (68.4)	37 (60.7)	.24
Cedar	182 (52.3)	28 (42.6)	.36
Ragweed	154 (44.3)	22 (36.1)	.23
Cocksfoot	142 (40.8)	20 (32.9)	.24
Dog dander	56 (16.1)	7 (11.5)	.36
Cat dander	86 (24.7)	11 (18.0)	.26

TABLE E2. Interrelationships among the changes in nasal symptoms, blood eosinophil count, FENO, lung function, and asthma control after nasal corticosteroid therapy

Characteristic	% Change in blood eosinophil	% Change in FENO	% Change in FEV ₁	Δ ACQ
Δ Nasal VAS	$r = 0.34; P < .05$	$r = 0.52; P < .001$	$r = -0.16; P = .33$	$r = 0.52; P < .001$
% Change in blood eos	—	$r = 0.36; P < .05$	$r = -0.37; P < .05$	$r = 0.18; P = .25$
% Change in FENO	—	—	$r = -0.38; P < .05$	$r = 0.73; P < .001$
% Change in FEV ₁	—	—	—	$r = 0.38; P < .05$

