

Clinical effects of air cleaners in homes of asthmatic children sensitized to pet allergens

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Background: Exposure to cat and dog allergens is very common in the Western World and is a serious cause of asthma in sensitized subjects.

Objective: We sought to study the clinical effects of air cleaners in living rooms and bedrooms of asthmatic children sensitized to cat or dog allergens.

Methods: Twenty asthmatic children sensitized to pet allergens (cat/dog) and with an animal at home participated in a double-blind, placebo-controlled, cross-over study in which the effects of air cleaners placed in the living room and bedroom for 3 months were compared with the effects of sham air cleaners. Before and after each study period, lung function, airway hyperresponsiveness (adenosine monophosphate), and peak flow variation were recorded. Cat and dog allergen levels were assessed in the filters of the air cleaners.

Results: After a 3-month intervention with active air cleaners, airway hyperresponsiveness decreased significantly, showing a 1.2 doubling dose increase of PC₂₀ adenosine ($P = .003$). Peak flow amplitude also decreased ($P = .045$). Substantial amounts of airborne cat and dog allergen were captured by the air cleaners in living rooms and bedrooms as well. Allergen levels in floor dust were not changed.

Conclusion: In young asthmatic patients sensitized and exposed to pets in the home, application of air cleaners in living rooms and bedrooms was accompanied by a significant improvement in airway hyperresponsiveness and a decrease in peak flow amplitude. (*J Allergy Clin Immunol* 1999;104:447-51.)

Key words: Air cleaners, allergen avoidance, allergens, asthma, airway hyperresponsiveness, peak flow amplitude, pets, children

Exposure to indoor allergens plays an important role in allergic sensitization of predisposed subjects and in elicitation of symptoms in sensitized asthmatic patients.^{1,2} In Western Europe, aside from house dust mites, sensitiza-

Abbreviation used

EDN: Eosinophil-derived neurotoxin

tion to pet allergens (cat/dog) occurs frequently in the allergic population.^{3,4} In addition, the prevalence of pets in homes is high (up to 60% of the homes) and is the same for sensitized and nonsensitized patients.⁵ Furthermore, aside from exposure in the domestic environment, high levels of cat and dog allergens are often found in dust from public buildings.⁶⁻⁸

Allergen avoidance measures have an important role in the treatment of allergic asthmatic patients. In a previous study it was shown that the effects of air cleaners in significantly reducing exposure to house dust mite allergens are limited.⁹ A beneficial role on airway hyperresponsiveness in asthmatic adults sensitized to house dust mites was found only when air cleaners were combined with allergen-impermeable mattress encasings.⁹ House dust mite allergens are bound to relatively large particles, which only become airborne with air turbulence and which settle rapidly.^{10,11} This probably accounts for the restricted effects of air cleaners in the prevention of exposure to house dust mite allergens.⁹

Allergens from pets, however, are partly bound to smaller particles, which can stay airborne for prolonged periods.¹⁰⁻¹³ As a consequence, considerable amounts of cat allergen were shown to be captured by air cleaners in living rooms and bedrooms.⁹ Additionally, the concentrations of airborne cat allergens in rooms in which a cat was present were significantly reduced after application of these or other air cleaners.^{12,14}

To obtain more information on the potential benefits of air cleaners, especially with regard to effects on clinical variables such as lung function, peak flow amplitude, and airway hyperresponsiveness, we studied the effects of application of air cleaners in the living rooms and bedrooms of asthmatic children sensitized to cat or dog and exposed to such animals in the home.

METHODS

Subjects

Twenty children from the outpatient clinic for pediatric pulmonology who had moderate asthma but minimal symptoms when using inhaled steroids and who were sensitized to cat or dog aller-

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TABLE I. Clinical and demographic characteristics of the 20 patients allergic to pets

Sex (F/M)	8/12
Age (y)	11.7 ± 2.2
FEV ₁ (% predicted)	90.2 ± 11.2
PC ₂₀ adenosine (mg/mL)*	5.39 (95% CI: 2.64-11.00)
Mite IgE-positive response	20/20
Pollen IgE-positive response	16/20
Cat IgE-positive response	18/20
Dog IgE-positive response	17/20
Inhaled steroids	14/20
Use of mattress encasings	11/20
Smoking by coresidents	7/20

CI, Confidence interval.

*Geometric mean.

gens (RAST class ≥2) were included in the study. The animal to which each patient was sensitized had to be present in the house of that patient. None of the patients were smokers. All patients had increased airway responsiveness to adenosine monophosphate (PC₂₀adenosine ≤320 mg/mL). Clinical characteristics, sensitization pattern to different inhalant allergens, and housing features of the participants are summarized in Table I. Aside from sensitization to pets, all patients were sensitized to house dust mites (*Dermatophagoides pteronyssinus*). No patients had clinically evident viral upper respiratory tract infections during the study period. All parents of the children gave their written informed consent for the study, which was approved by the Medical Ethical Committee of University Hospital Groningen.

Study design

The study was performed in a double-blind, placebo-controlled manner with a cross-over design. The study period was from September 1997 until April 1998, which is mainly outside the grass and tree pollen seasons in our region. At 0 months, active or sham (placebo) air cleaners were placed in the living rooms and bedrooms of the patients. After 3 months, the air cleaners were replaced by the alternate-type air cleaner for another 3 months. The allocation of the patients (starting with active or with sham air cleaners) was performed with a computer by using a minimization program, with stratification for airway hyperresponsiveness (PC₂₀adenosine) and age.

At 0, 3, and 6 months, the different clinical and laboratory parameters were recorded.

Intervention with air cleaners

Air cleaners (Philips, Division of Domestic Appliances and Personal Care) were used in living rooms and bedrooms (Model HR 4330 and HR 4320, respectively). The characteristics of these air cleaners have been described previously.⁹ Briefly, the air cleaners contain 3 types of filters in sequence: a prefilter for capturing crude particles such as hair, a rotfilter, and a high-efficiency particulate air-type filter. Sham air cleaners could not be distinguished from active air cleaners by appearance or sound but contained no filter devices.

Measurement of lung function and airway hyperresponsiveness

Nonspecific airway hyperresponsiveness was measured by stepwise inhalation of increasing concentrations of adenosine 5-monophosphate solution over a period of 2 minutes until a decrease in FEV₁ of 20% or more was observed.¹⁵ Peak expiratory flow was measured with a mini-Wright meter and recorded every morning

and evening during a 1-week period before intervention and during the same period after intervention with both active and sham air cleaners. The best of 3 attempts was recorded. Peak flow variation was expressed as amplitude percent of the mean and as lowest peak expiratory flow value observed during a 7-day period as percentage of the highest value.¹⁶ All medication (except inhaled steroids) was stopped before the adenosine-monophosphate challenges: short-acting β-agonists 12 hours before provocation and long-acting β-agonists 48 hours before provocation. No patients received oral steroids, antihistamines, cromones, or theophylline.

Medication and symptoms

Patients were asked to keep their amount of medication constant. Changes during the interventions were recorded.

Asthma symptoms (wheezing, shortness of breath, and cough) were recorded during a 1-week period before and after each intervention. Symptoms were rated every day on a scale from 1 (no symptoms) to 5 (severe symptoms), giving a total score between 7 and 35 for a week.

Determination of eosinophil-derived neurotoxin in urine

Eosinophil-derived neurotoxin (EDN) was measured in morning urine by means of an RIA (Pharmacia & Upjohn, Uppsala, Sweden). The EDN/creatinine ratio was calculated after determination of the creatinine concentration.

Allergen-specific IgE measurements

Before inclusion in the study, allergen-specific IgE directed against house dust mites (*D pteronyssinus*), a mixture of grass pollen, a mixture of tree pollen, and cat and dog allergens were measured in the serum of the patients by using the Pharmacia CAP-RAST FEIA (Pharmacia & Upjohn, Sweden).

Collection and extraction of dust samples

At 0, 3, and 6 months, dust samples from floors of bedrooms and living rooms were collected by vacuum cleaning 1 m² from each floor area, as described previously.⁹ The collected dust was weighed, and a 10% (wt/vol) extract in 0.1 mol/L borate-buffered saline with 0.1% Tween-20 was obtained by overhead rotation for 2 hours at room temperature. All extracts were centrifuged, and the supernatants were stored at -18°C until measurement of allergen content was carried out. At the end of the study, the air cleaners were disassembled, and the filters were analyzed with regard to the quantity of collected dust and the amount of cat allergen (Fel d 1) and dog allergen (Can f 1). The high-efficiency particulate air-type filters were extracted with 500 mL of 0.01 mol/L NH₄HCO₃ buffer. The extracts were freeze-dried and stored at -20°C.

Measurement of animal allergen levels in dust extracts

Cat allergen (Fel d 1) and dog allergen (Can f 1) were measured with 2-site mAb ELISAs, according to the instructions of the manufacturer (Indoor Biotechnologies Inc, Charlottesville, Va).¹⁷ The cat allergen standard 94/01 (containing 1.6 U/mL Fel d 1) and the dog allergen standard 98/01 (containing 5000 IU/mL Can f 1) were used for calculation of the results. Allergen concentrations were expressed in micrograms, assuming that 1 IU of Can f 1 corresponds to 1 ng of Can f 1, whereas 1 U of Fel d 1 corresponds to 4 μg of Fel d 1.

Data analysis

Statistical analysis was performed with the SPSS package for PC computers (SPSS Inc, Chicago, Ill). Data of airway hyperrespon-

TABLE II. Amounts of captured cat allergen (Fel d 1) and dog allergen (Can f 1) in active and sham air cleaners in living rooms and bedrooms of houses with or without animals

	Active air cleaners	Sham air cleaners
Fel d 1		
LR with cat	32.7 (2.2-117.9)	0.97 (0.47-2.03)
LR without cat	1.01 (0.41-2.90)	0.31 (0.04-1.23)
BR with cat	5.9 (0.52-16.8)	0.51 (0.22-1.16)
BR without cat	0.80 (0.39-1.63)	0.16 (0.02-0.80)
Can f 1		
LR with dog	98.4 (35.8-264.9)	0.98 (0.25-3.7)
LR without dog	0.45 (0.11-1.72)	0.05 (0.02-0.15)
BR with dog	12.2 (4.1-36.7)	0.29 (0.06-1.3)
BR without dog	0.06 (0.04-1.11)	0.01 (0.01-0.05)

LR, Living room; BR, bedroom.

Values are micrograms per air cleaner (geometric means); 95% confidence intervals are shown in brackets.

siveness (PC₂₀adenosine) and allergen levels in dust samples were not distributed normally (Kolmogorov-Smirnov test) and were therefore log transformed to normalize the distributions. The PC₂₀adenosine data were transformed to ²log units because a change of 1 unit reflects a doubling dose. Because of a possible carry-over effect, data obtained after 3 months of intervention with an air cleaner (active or sham) were always compared with baseline values. Differences between groups were analyzed by the Student *t* test. When not distributed normally, differences were analyzed by the Wilcoxon nonparametric test. Correlations between variables were expressed by the Spearman correlation coefficient. Differences with *P* values of less than .05 (2-tailed) were considered statistically significant.

RESULTS

Dust- and allergen-capturing properties of the air cleaners

Substantial quantities of airborne dust containing cat allergen (Fel d 1) and dog allergen (Can f 1) were captured in the filters of the air cleaners. The sham air cleaners captured relatively small amounts of allergen, as shown in Table II. In 12 of the 20 houses, at least 1 dog was present, and in 10 homes a cat was present; in 2 homes both a dog and a cat were present. Significantly greater amounts of cat and dog allergen were captured by the active air cleaners in living rooms than in bedrooms (Table II), even when these values are corrected for the difference in capturing capacity between the 2 models used in these locations. In 8 of the 20 living rooms, a form of carpeting was present, whereas in bedrooms this number was 10 of 20.

The amount of airborne cat and dog allergens captured with the active air cleaners was associated with the level of these allergens in reservoir dust (floors in living rooms and bedrooms), as shown in Table III. Animal allergen levels in floor dust did not change during the interventions.

Effects on clinical parameters

Lung function and airway hyperresponsiveness. Intervention with air cleaners did not change lung function, as

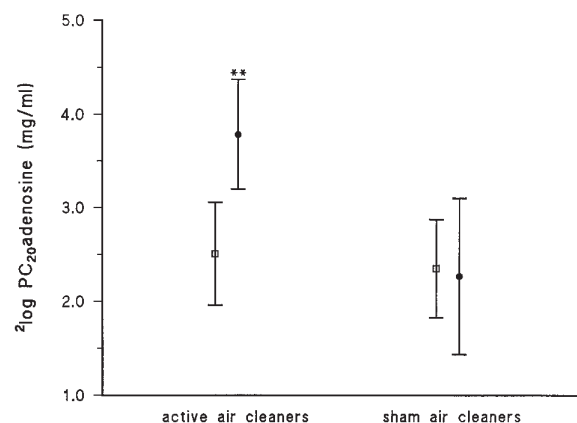


FIG 1. Changes in airway hyperresponsiveness after intervention with air cleaners in living rooms and bedrooms of asthmatic children sensitized to cat or dog allergens. *Open squares*, baseline mean value; *filled circles*, after 3 months. Error bars, SEM; ***P* = .003.

TABLE III. Spearman correlation coefficients between the amount of captured airborne allergen in active air cleaners and allergen levels in floor dust from living rooms and bedrooms

Floor dust	Captured airborne allergen			
	Fel d 1-LR	Fel d 1-BR	Can f 1-LR	Can f 1-BR
Fel d 1-LR	0.543*			
Fel d 1-BR		0.715†		
Can f 1-LR			0.810†	
Can f 1-BR				0.784†

LR, Living room; BR, bedroom.

**P* < .05.

†*P* < .005.

expressed by the FEV₁ predicted value. Airway hyperresponsiveness, however, significantly improved (higher PC₂₀adenosine) after intervention with active air cleaners, showing an increase of 1.2 doubling doses in PC₂₀adenosine (Fig 1). The geometric mean of PC₂₀adenosine increased from 5.69 to 13.01 mg/mL (*P* = .003). In the subgroup of patients who started with active air cleaners, the improved PC₂₀adenosine deteriorated again to baseline after application of sham air cleaners. Sham air cleaners did not affect airway hyperresponsiveness. The observed changes in airway hyperresponsiveness were not influenced by passive smoking, the type of animal present, the use of mattress encasings, or a sensitization to pollen.

Changes in peak flow and peak flow variation. Peak flow values, measured in the morning or evening, did not change. Peak flow variation, however, expressed as peak flow amplitude, decreased statistically significantly (*P* = .045) after 3 months of intervention with active air cleaners, as shown in Fig 2. Peak flow variation, expressed as the lowest peak flow value as percentage of the best response, was not changed.

Urinary EDN. EDN in morning urine did not change after intervention with air cleaners. Also, after correction for creatinine, no changes were observed.

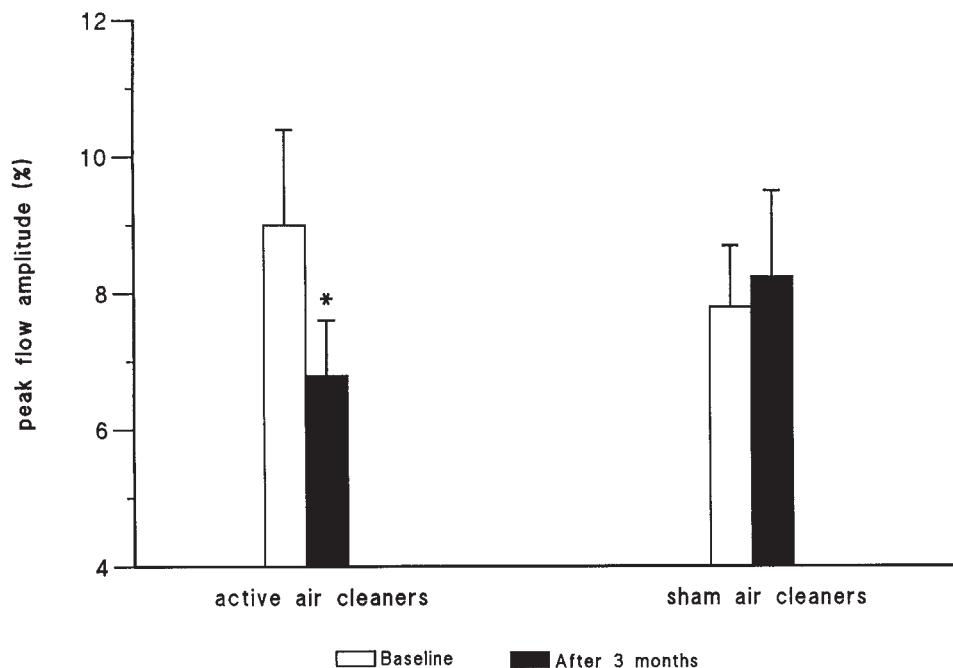


FIG 2. Changes in peak flow variation, expressed as amplitude percent of mean value, after intervention with air cleaners in living rooms and bedrooms of asthmatic children sensitized to cat or dog allergens. Means $\pm$ SEM; * $P = .045$.

Medication and symptoms

Seventy percent of the patients (14 of 20) used inhaled corticosteroids as maintenance therapy. All patients were asked not to change their medication during the study. However, of the original 22 patients, one patient started with inhaled steroids (after physician consultation) after 3 months of intervention with sham air cleaners, and a second patient stopped the use of inhaled steroids after intervention with active air cleaners. Data from neither patient were used for the calculations. The symptom score (wheezing and shortness of breath) did not change during intervention with active or sham air cleaners. Most patients, however, had few or no symptoms at all (baseline median = 7, which corresponds to no symptoms).

DISCUSSION

In asthmatic patients sensitized to pet allergens and with pets at home, removal of the animal is generally recommended as the first choice for reduction of symptoms. However, even after such removal, it can still take months before a beneficial reduction of animal allergens has occurred.¹⁸ Moreover, many patients insist on keeping their pets, and other measures need to be considered.⁸ Although washing the pet has been shown to be effective in reducing the amount of allergens recovered from the animal, it is cumbersome and often not feasible, especially with cats.

In this study substantial amounts of airborne cat and dog allergens were captured by air cleaners in living

rooms and bedrooms of asthmatic children with pet allergies who own a cat or dog. After a relatively short period of intervention (3 months) with active air cleaners, airway hyperresponsiveness, expressed by PC₂₀adenosine, was significantly diminished compared with baseline values.

In a recent study by Wood et al,¹⁹ application of air cleaners in the bedrooms of adult asthmatic patients sensitized to cats with a cat in the home had no clinical effect after a study period of 3 months. Differences in the study population (adults vs children in this study) may be one explanation for the dissimilarities between the 2 studies. There is evidence that the airways of asthmatic children are more susceptible to intervention measures (medication and allergen avoidance) than adult patients.²⁰⁻²² Application of air cleaners in both living rooms and bedrooms, as in this study, may be more advantageous in reducing exposure to pet allergens than application in bedrooms alone. Significantly higher amounts of airborne pet allergens were captured by air cleaners in living rooms than in bedrooms. Lastly, the pharmacologic agent used for assessment of airway hyperresponsiveness (methacholine vs adenosine in our study) may also contribute to the different results in both studies. It has been suggested that airway hyperresponsiveness, as determined by adenosine-monophosphate challenge, differs from airway hyperresponsiveness assessed by histamine or methacholine challenge, in which responsiveness to adenosine monophosphate might be a better marker for allergic inflammation.²³⁻²⁵ However, the literature is not consistent on this subject.²⁶ Regardless of the particular agent, airway hyperresponsiveness seems to be sensitive to changes in allergen exposure in sensitized asthmatic

patients.^{20,27,28} The use of inhaled steroids in 70% of the patients in our study probably minimized the beneficial effects of air cleaners on airway hyperresponsiveness. The acquired improvement in airway hyperresponsiveness by inhaled steroids leaves less space for improvement by allergen avoidance measures. Because all patients were sensitized to house dust mites, the beneficial effects of air cleaners in this study may also be underestimated by an ongoing exposure to mite allergens.

The amount of pet allergen captured by active air cleaners correlated with the concentration of animal allergen in floor dust (Table III). Custovic et al¹³ did not find a correlation between settled dog allergen in floor dust and airborne dog allergen, as measured by a cascade sampler. The difference in sampling time (8 hours vs 3 months in our study) may explain this apparent discrepancy.

Although air cleaners do not affect dust and allergen reservoirs (eg, in carpets and upholstered furniture), they can help to reduce levels of airborne pet allergen. In combination with other avoidance measures, air cleaners may play a beneficial role in the treatment of asthmatic patients with animal allergies who want to keep their pets.

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