

# Effects of HEPA Air Cleaners on Unscheduled Asthma Visits and Asthma Symptoms for Children Exposed to Secondhand Tobacco Smoke

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## KEY WORDS

asthma, children, secondhand smoke, air cleaner, randomized controlled trial, unscheduled asthma visits, exacerbations

## ABBREVIATIONS

HEPA—high-efficiency, particle-arresting  
SHS—secondhand smoke

This trial has been registered at [www.clinicaltrials.gov](http://www.clinicaltrials.gov) (identifier NCT00006565).

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**WHAT'S KNOWN ON THIS SUBJECT:** Exposure to secondhand smoke (SHS) is associated with asthma exacerbations in children. Anticipatory guidance has failed to reduce SHS in controlled trials. It is not known whether high-efficiency, particle-arresting (HEPA) air cleaners can reduce SHS or improve asthma symptoms in children.



**WHAT THIS STUDY ADDS:** HEPA air cleaners led to reductions in unscheduled asthma visits and fine airborne particle levels but not asthma symptoms or cotinine levels. HEPA air cleaners may be useful as part of a multifaceted strategy to reduce asthma morbidity among children.

## abstract



**OBJECTIVE:** The goal was to test the effects of high-efficiency, particulate-arresting (HEPA) air cleaners on unscheduled asthma visits and symptoms among children with asthma exposed to secondhand smoke.

**METHODS:** We enrolled 225 eligible children who were 6 to 12 years of age, had physician-diagnosed asthma, and were exposed to  $\geq 5$  cigarettes per day. We conducted a double-blind, randomized trial. Children were assigned randomly to receive 2 active or inactive HEPA air cleaners.

**RESULTS:** Of 225 enrolled children, 110 (49%) were assigned to the intervention group and 115 (51%) to the control group; 215 (95%) completed the trial. During the trial, there were 42 fewer unscheduled asthma visits among children in the intervention group (18.5% [95% confidence interval: 1.25%–82.75%];  $P = .043$ ), compared with those in the control group, after adjustment for baseline differences. There was a significant difference in the reductions of levels of particles of  $>0.3 \mu\text{m}$  according to group assignment; there was a 25% reduction in particle levels in the intervention group, compared with a 5% reduction in the control group ( $P = .026$ ). There were no significant differences in parent-reported asthma symptoms, exhaled nitric-oxide levels, air nicotine levels, or cotinine levels according to group assignment.

**CONCLUSIONS:** These results hold promise for using HEPA air cleaners as part of a multifaceted strategy to reduce asthma morbidity, but further research is necessary before they can be recommended routinely for the medical management of asthma. *Pediatrics* 2011;127:93–101

Exposure to secondhand smoke (SHS) is associated with wheezing and asthma exacerbations in children.<sup>1-7</sup> Children who are exposed to SHS are ~1.5 times more likely to have physician-diagnosed asthma or wheezing than are unexposed children, which accounts for 130 000 excess cases of asthma among US children.<sup>3,7</sup> The mechanism for asthma exacerbations resulting from SHS is not clear, but cigarette smoke is the major source of airborne particles in households with smokers.<sup>8</sup> Indeed, concentrations of airborne particles of <2.5  $\mu\text{m}$  are 2 to 3 times higher in households with smokers than in households without smokers.<sup>8-10</sup> More than 20% of US children are exposed to household SHS.<sup>11</sup>

Numerous studies have tested the efficacy of anticipatory guidance to reduce SHS exposure for children, but the majority failed to show significant reductions in children's SHS exposure by using measurements of cotinine, a metabolite of nicotine, or improvements in asthma symptoms.<sup>12-23</sup> This problem might be overcome if there was a technology to reduce SHS exposure passively, such as high-efficiency, particulate-arresting (HEPA) air cleaners.

There are limited data on the efficacy of HEPA air cleaners in reducing asthma symptoms. More than 10 trials have tested the effects of HEPA air cleaners, but the largest involved 45 subjects; only 2 studied children exclusively.<sup>24,25</sup> None of those trials tested HEPA air cleaners among SHS-exposed children with asthma, but HEPA air cleaners can reduce levels of airborne particles and nicotine.<sup>26,27</sup> Reisman et al<sup>26</sup> reported a 73% reduction in the level of airborne particles of  $\geq 0.3 \mu\text{m}$  with HEPA air cleaners. Bascom et al<sup>27</sup> reported 50% reductions in levels of airborne particles and nicotine. Other trials incorporated HEPA air cleaners

to reduce environmental triggers among children with asthma, but it was not possible to quantify the specific contribution of the air cleaners because the studies involved multiple environmental interventions.<sup>28,29</sup> We speculated that children with asthma who were exposed to SHS would particularly benefit by using air cleaners. The purpose of this double-blind, randomized trial was to test the efficacy of HEPA air cleaners in reducing unscheduled asthma visits, asthma symptoms, and SHS exposure among children with asthma.

## METHODS

### Study Design

The Cincinnati Asthma Prevention Study was a randomized, double-blind trial to test the effects of HEPA air cleaners, in the homes of 225 SHS-exposed children with physician-diagnosed asthma, on unscheduled asthma visits and symptoms. Families assigned to the intervention group received 2 active HEPA air cleaners (Austin Healthmate [Buffalo, NY]), that is, HEPA air cleaners surrounded by a carbon-potassium permanganate-zeolite insert, whereas families in the control group received 2 inactive (placebo) air cleaners. For both groups, 1 air cleaner was installed in the main activity room and the other was installed in the child's bedroom at the baseline home visit. The air cleaners were equipped with monitors to measure the number of hours they operated. There were no attempts to reduce tobacco use or other asthma triggers.

HEPA air cleaners are certified to remove >99% of airborne particles of  $>0.3 \mu\text{m}$  in a 1500-ft<sup>2</sup> room. The carbon-potassium permanganate-zeolite filter insert was designed to absorb odors and gases. The inactive air cleaners, which were indistinguishable from the active HEPA air cleaners, contained 3 layers of prefilter cloth (a

blend of cotton and polyester fibers), which also were present in the active air cleaners. At the end of the trial, we offered to install HEPA filters in the air cleaners for families assigned to receive inactive air cleaners during the trial.

The Cincinnati Children's Hospital Medical Center institutional review board approved this study. Parents or legal guardians provided written consent before enrollment.

### Study Participants

We screened children and their families for eligibility from May 31, 2001, through March 27, 2003, by using a sampling frame of children who had received treatment for asthma at a clinic, emergency department, or hospital affiliated with Cincinnati Children's Hospital Medical Center or Group Health Associates. Initially, we mailed letters to families. Potential participants were able to decline any further involvement or telephone contact by returning a prepaid postcard or by telephoning our research coordinators. If the family did not decline participation within 10 days, then a research coordinator contacted the family to describe the study, to determine eligibility, and, if the family was eligible, to invite the members to participate in the trial.

Children were eligible if they were 6 to 12 years of age at enrollment, had physician-diagnosed asthma in the previous 12 months, according to International Classification of Diseases, Ninth Revision, billing codes (from hospital records, emergency department visit records, or primary care physician records), experienced  $\geq 1$  exacerbation requiring an unscheduled visit in the past year, were exposed to the smoke of  $\geq 5$  cigarettes per day in and around the house, and lived within a 9-county area surrounding Cincinnati. Children were excluded if they were al-

ready using an air cleaner, if their home lacked electricity, if they had co-existing medical problems (eg, mental retardation, congenital heart disease, or cystic fibrosis), or if their family planned to move in the next year.

### Random Assignment

Children were assigned randomly to receive active HEPA air cleaners or inactive air cleaners. Allocation concealment was performed by using opaque envelopes, which were opened by a research assistant immediately before the baseline home visit was conducted. With the exception of the serial numbers, the active and inactive HEPA air cleaners were indistinguishable. All of the investigators, research staff members, and participants were masked to group assignment until the end of the trial, except for the biostatistician (Dr Hornung), who was responsible for random permutation of the air cleaners by using serial numbers.

### Outcome Measures

We conducted extensive surveys at baseline to characterize the children, their families, and the home environment. Research assistants surveyed the children's parent or guardian at baseline and at 3-month intervals about unscheduled asthma visits, asthma symptoms, therapy, and tobacco exposure. Our primary outcome measure was asthma exacerbation, defined as any unscheduled visit to a health care provider (clinic visit, emergency visit, or hospitalization). We selected unscheduled asthma visits as our primary outcome measure a priori because it was the most-objective measure of asthma exacerbation. We estimated that, to detect a 20% reduction in unscheduled visits attributable to asthma exacerbations with  $\geq 80\%$  power, we would require a sample size of 110 children per group, or a total of 220 children ( $\alpha = .05$ , 2-tailed test). This calculation assumed that we

would have a rate of attrition of  $< 10\%$ . Secondary outcome measures included asthma symptoms assessed with the Child Health Asthma Survey (an instrument shown to be reliable, internally consistent, and able to distinguish levels of asthma severity<sup>30,31</sup>), tobacco smoke exposure, indoor airborne particle levels, and exhaled nitric-oxide levels.

Air nicotine levels, which provide an objective measure of ambient tobacco smoke exposure, were measured in each subject's home by using nicotine dosimeters.<sup>32-34</sup> For standardization, the dosimeters were housed in a metal compartment on the air cleaner that was located in the main activity room. Dosimeters were placed at the baseline and 6-month visits and were retrieved at the 6- and 12-month visits, respectively. The dosimeters, which have a limit of detection of  $0.01 \mu\text{g}$  per filter, were analyzed by using a standardized protocol.<sup>32-34</sup>

To test the efficacy of the HEPA air cleaners in reducing children's SHS exposure, we measured cotinine levels in children's serum and hair at baseline and at 6 and 12 months.<sup>35</sup> Serum samples were analyzed at the National Center for Environmental Health, Centers for Disease Control and Prevention (Atlanta, GA), by using high-performance liquid chromatography linked to atmospheric pressure chemical ionization/tandem mass spectrometry.<sup>36</sup> The detection limit for cotinine in serum was  $0.05 \text{ ng/mL}$ . We collected 20 strands of hair from the occipital region of the scalp. The hair samples were analyzed for cotinine at the Hospital for Sick Children (Toronto, Ontario, Canada), by using a radioimmunoassay.<sup>37</sup> The detection limit for cotinine in hair was  $0.005 \text{ ng/mg}$ .<sup>37</sup>

To test the effect of the HEPA air cleaners on airborne particles, we used a GT-321 particle counter (Met One Instruments, Grant Pass, OR) to measure

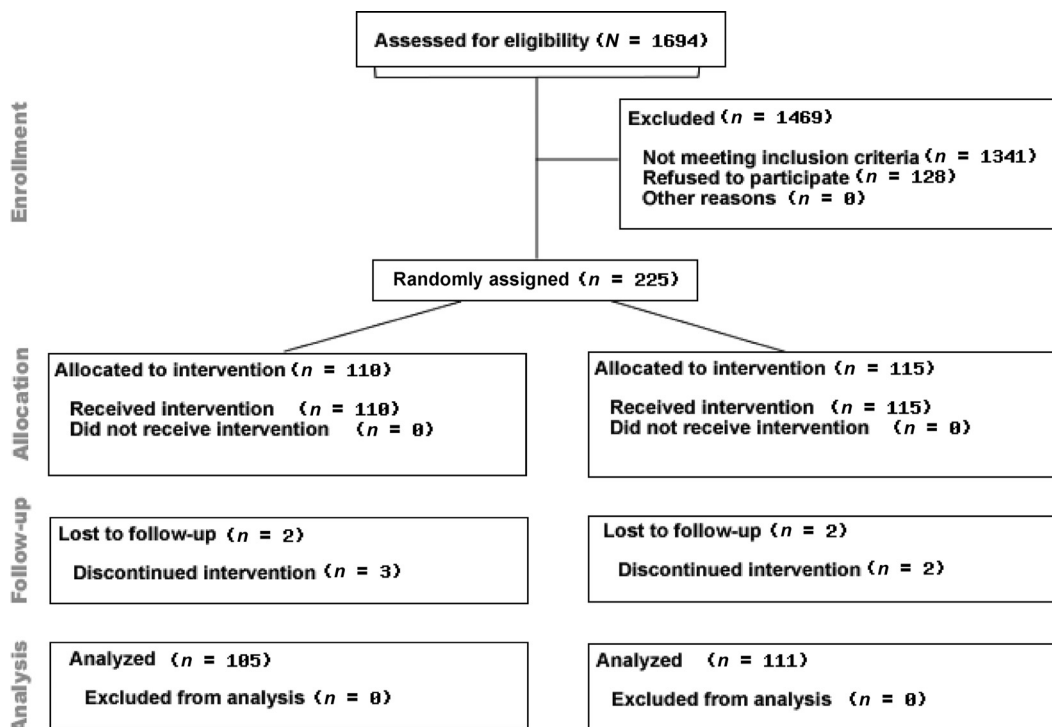
concentrations of indoor particles (particles per cubic foot) at the baseline and 6- and 12-month visits. We took measurements of the numbers of airborne particles of  $> 0.3 \mu\text{m}$  and  $> 5 \mu\text{m}$ ; each reading was the average of ten 6-second measurements taken over 1 minute in 3 different locations in each housing unit. The data used in the analysis are the mean of 3 readings from the main activity room, the child's bedroom, and the kitchen, taken at the beginning of each home visit.

We assessed nitric-oxide levels in exhaled air at the baseline and 6- and 12-month visits. Exhaled air was collected in Mylar balloons from each participant by using a validated offline technique to assess the effect of HEPA air cleaners on airway inflammation.<sup>38,39</sup> A model 280i nitric-oxide analyzer (Sievers Instruments, Boulder, CO) was used for nitric-oxide analysis. As described previously, exhaled nitric-oxide concentrations were imputed when the exhaled nitric-oxide analysis did not occur within 24 hours after collection.<sup>40</sup>

Serum samples were obtained at the baseline visit by a trained pediatric phlebotomist, for determination of allergen-specific immunoglobulin E by using the ImmunoCap test (Pharmacia Diagnostics, Portage, MI). Children with class I or higher immunoglobulin E levels ( $\geq 0.35 \text{ kU/L}$ ) for dust mite, dog, cat, or cockroach allergen were considered to have atopy.

### Statistical Analyses

We calculated descriptive statistics according to group assignment. For continuous variables, we calculated means, SDs, and ranges. For categorical variables, we calculated frequencies and proportions. All analyses were performed according to the intention to treat. For continuous variables, we used multivariate regression analyses for either the untransformed



**FIGURE 1** Enrollment, random assignment, and retention of Cincinnati Asthma Prevention study participants.

or logarithmically transformed outcome, as appropriate. For repeated-measures analyses over the 12 months of the study, we used mixed-effects linear models with an autoregressive covariance structure. The interaction of group assignment and time was tested as the primary hypothesis of an intervention effect. When the outcome was a rate or count (eg, unscheduled asthma visits), the generalized estimating equation version of Poisson regression was used for repeated measures, in a manner similar to the mixed-effects linear model. In secondary a priori analyses, we tested the efficacy of the HEPA air cleaners for families who used either HEPA air cleaner for >6130 hours (ie,  $\geq 70\%$  of the entire trial).

## RESULTS

Of the 2240 children in the sampling frame who were 6 to 12 years of age, had physician-diagnosed asthma according to International Classification

of Diseases, Ninth Revision, billing codes, and resided in a 9-county area surrounding Cincinnati, we screened 1694 (76%) for eligibility between May 31, 2001, and March 27, 2003. Of these children, 353 (21%) were eligible to participate (Fig 1). Of the 353 eligible children and their families, 225 (64%) agreed to participate in the trial. There were no significant differences in children's age, gender, asthma severity, or race, parents' education, marital status, household income, or health insurance, or number of cigarettes smoked in or around the house per day for families that chose to participate versus those that chose not to participate. Of the 225 families that agreed to participate, 110 (49%) were assigned randomly to the intervention group and 115 (51%) to the control group. At baseline, the mean age of the children was 8.6 years (range: 5.3–11.7 years); 62% of the children were male. Chil-

dren were exposed to a geometric mean of 13 cigarettes per day. Numbers of unscheduled asthma visits and airborne particle levels were significantly greater in the control group. Some other measures of asthma severity tended to be greater in the control group, but these differences were not statistically significant (Tables 1 and 2). Of the 225 children enrolled in the trial, 215 (95%) completed the study (Fig 1).

In unadjusted analyses, there were fewer unscheduled asthma visits at follow-up assessment in the intervention group (189 vs 274 visits;  $P = .046$ ). This difference persisted after adjustment for baseline differences in the multivariate analyses. With adjustment for baseline differences, there was a significant difference in the rate of decrease in the number of unscheduled asthma visits among children in the intervention group, compared with the control group (Fig 2). The adjusted

**TABLE 1** Baseline Characteristics of Study Population According to Group Assignment

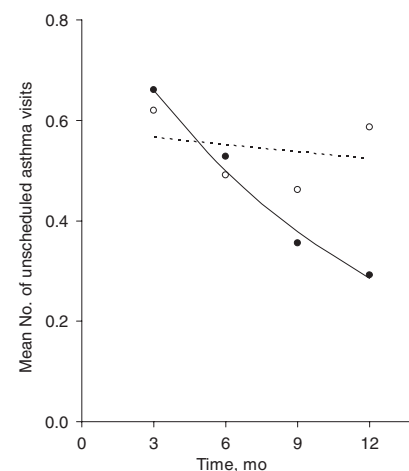
Characteristics	Intervention Group (N = 110)	Control Group (N = 115)	P
Age, mean ± SD, y	8.8 ± 1.8	8.4 ± 1.8	.160
Male, n (%)	74 (67)	65 (57)	.097
Race, n (%)			.565
Black	65 (59)	60 (52)	—
White	43 (39)	52 (45)	—
Other	2 (2)	3 (3)	—
Annual household income, mean ± SD, \$	30 524 ± 24 416	29 595 ± 21 649	.767
No. of unscheduled asthma visits in previous 3 mo, mean ± SD	0.6 ± 1.0	1.0 ± 1.4	.013
Measures of asthma severity, n (%)			
Allergy severity (moderate to very severe)	47 (43)	55 (48)	.443
Shortness of breath (moderate to very severe)	46 (42)	61 (53)	.104
Tightness in chest (moderate to very severe)	29 (27)	37 (33)	.317
Wheeze (moderate to very severe)	44 (40)	46 (40)	.955
Difficulty sleeping (moderate to very severe)	42 (38)	53 (46)	.208
Steroid therapy in previous 3 mo	30 (27)	37 (34)	.305
Long-acting steroid therapy	58 (53)	60 (52)	.877
Duration of asthma, mean ± SD, d	9.8 ± 18.7	10.2 ± 11.7	.841
Serum immunoglobulin E levels of ≥0.35 kU/L for common allergens, n (%)	74 (67)	70 (61)	.310
Exhaled nitric-oxide level, mean ± SD, ppb	14.7 ± 10.0	16.3 ± 12.3	.302

**TABLE 2** Baseline Exposure to Environmental Tobacco Smoke and Indoor Airborne Particles According to Group Assignment

Characteristics	Intervention Group (N = 110)	Control Group (N = 115)	P
Tobacco exposure			
No. of cigarettes smoked around house per d, mean ± SD	12.9 ± 1.8	13.3 ± 2.2	.716
Serum cotinine level, mean ± SD, ng/mL	1.18 ± 3.9	1.23 ± 3.3	.622
Hair cotinine level, mean ± SD, ng/mg	0.14 ± 3.8	0.14 ± 3.5	.970
No. of airborne particles, mean ± SD, 10 <sup>6</sup> /ft <sup>3</sup>			
Particles of >0.3 μm	4.0 ± 2.56	4.7 ± 2.58	.003
Particles of >5 μm	0.003 ± 2.31	0.004 ± 2.14	.154

mean number of unscheduled visits for the intervention group decreased by 8.9% per month, compared with a decrease of 0.9% per month in the control group. With adjustment for baseline differences, there were 185 unscheduled asthma visits among children in the intervention group, compared with 227 unscheduled asthma visits among children in the control group, a reduction of 42 visits (95% confidence interval: 1.25–82.75 visits;  $P = .043$ ). This is equivalent to a reduction of 18.5% (95% confidence interval: 1%–36%) in the number of unscheduled asthma visits during the study (Table 3).

In a secondary analysis, developed a priori, we examined the effect of HEPA air cleaners among 141 (68%) of 207 families with functioning monitors who used 1 or both air cleaners >70% of the time. With adjustment for baseline differences in unscheduled asthma visits, the rate of reduction in the number of unscheduled asthma visits over time was significantly greater in the intervention group, compared with the control group ( $P = .006$ ). The number of unscheduled asthma visits for the intervention group decreased by 12.7% per month, compared with an increase of 0.7% per month in the control group.

**FIGURE 2**

Mean numbers of unscheduled asthma visits in the previous 3 months, reported at quarterly intervals during the trial, according to group assignment, with adjustment for differences in the numbers of unscheduled asthma visits at baseline. The solid line and closed circles indicate the intervention group; dashed line and open circles, control group.

There was a significant difference in the reductions in the numbers of airborne particles of >0.3 μm according to group assignment ( $P = .026$ ) (Table 4). The absolute mean reduction in levels of airborne particles of >0.3 μm during the trial was  $1.1 \times 10^6$  particles per ft<sup>3</sup> for the intervention group, which was equivalent to a 25% reduction in airborne particle levels. In contrast, there was a reduction of only  $0.3 \times 10^6$  particles per ft<sup>3</sup> (5%) for the control group. There was no significant difference in levels of airborne particles of >5 μm according to group assignment (Table 4).

There were no significant differences between groups with respect to severity of asthma symptoms, medication use, exhaled nitric-oxide levels, air nicotine levels, serum cotinine levels, or hair cotinine levels during the trial (Table 3). There were no significant group-season ( $P = .328$ ) or group-allergy severity ( $P = .583$ ) interactions for unscheduled asthma visits.

To validate parents' reports of unscheduled visits, we examined the rate

**TABLE 3** Numbers of Unscheduled Asthma Visits, Asthma Symptoms, Reported Exposure to Tobacco Smoke, and Exhaled Nitric-Oxide Levels According to Group Assignment

Characteristics	3 mo	6 mo	9 mo	12 mo	P
No. of unscheduled asthma visits in previous 3 mo, mean					.043 <sup>a</sup>
Intervention group (n = 110)	0.7	0.5	0.4	0.3	
Control group (n = 115)	0.6	0.5	0.9	0.6	
Moderate/severe allergy in previous 3 mo, %					.618
Intervention group (n = 110)	35	32	40	33	
Control group (n = 115)	38	40	34	34	
In previous 2 wk, how much of time has <child's name> had					
Shortness of breath (some, most, or all of time), %					.415
Intervention group (n = 110)	34	28	29	19	
Control group (n = 115)	36	27	24	28	
Tightness in chest (some, most, or all of time), %					.612
Intervention group (n = 110)	22	16	18	14	
Control group (n = 115)	22	10	16	17	
Wheeze (some, most, or all of time), %					.168
Intervention group (n = 110)	32	15	22	13	
Control group (n = 115)	25	20	15	19	
Difficulty sleeping (some, most, or all of time), %					.299
Intervention group (n = 110)	26	21	27	21	
Control group (n = 115)	27	18	16	18	
Prescription for steroid therapy in previous 3 mo, %					.811
Intervention group (n = 110)	19	13	16	19	
Control group (n = 115)	27	25	18	27	
Prescription for long-acting steroid therapy in previous 3 mo, %					.135
Intervention group (n = 110)	36	43	42	39	
Control group (n = 115)	46	39	30	37	
No. of episodes of asthma, mean					.294
Intervention group (n = 110)	8.9	4.3	6.5	4.5	
Control group (n = 115)	9.3	6.0	6.3	6.8	
Exhaled nitric-oxide level, mean, ppb					.313
Intervention group (n = 110)	—	16.4	—	16.1	
Control group (n = 115)	—	15.0	—	16.8	
No. of cigarettes smoked around house per d, mean					.977
Intervention group (n = 110)	7.5	11.2	7.5	9.5	
Control group (n = 115)	7.5	10.6	7.1	9.5	

<sup>a</sup> Test of group difference in trends over time (group-time interaction), adjusted for differences in the number of baseline visits.

**TABLE 4** Exposures to Tobacco and Indoor Particles, According to Group Assignment, During Study

Characteristic	Baseline	6 mo	12 mo	P
Serum cotinine level, mean, ng/mL				.738
Intervention group (n = 110)	1.1	1.1	1.1	
Control group (n = 115)	1.2	1.1	1.0	
Hair cotinine level, mean, ng/mg				.984
Intervention group (n = 110)	0.1	0.12	0.15	
Control group (n = 115)	0.1	0.11	0.15	
Air nicotine level, $\mu\text{g}$				.191
Intervention group (n = 110)	—	3.1	2.5	
Control group (n = 115)	—	2.5	2.7	
No. of particles of $>0.3 \mu\text{m}$ , mean $\pm$ SD, $10^6/\text{ft}^3$				.026 <sup>a</sup>
Intervention group (n = 110)	4.0	2.5	3.0	
Control group (n = 115)	4.7	4.6	4.4	
No. of particles of $>5 \mu\text{m}$ , mean $\pm$ SD, $10^6/\text{ft}^3$				.219 <sup>a</sup>
Intervention group (n = 110)	0.0033	0.0029	0.0027	
Control group (n = 115)	0.0037	0.0028	0.0024	

<sup>a</sup> Test of differences in group means, including baseline particle levels.

of agreement of parent-reported unscheduled asthma visits by using medical billing records from the Cincinnati

Children's Hospital Medical Center. We found that 87% of parent-reported unscheduled asthma visits (714 of 824

visits) were in agreement with billing records for each 3-month interval.

## DISCUSSION

We found, in a randomized, double-blind trial, that HEPA air cleaners led to an 18.5% reduction in unscheduled asthma visits. The differences in unscheduled asthma visits were apparent only at 9 and 12 months. We also found a significant difference in the reduction of levels of airborne particles of  $>0.3 \mu\text{m}$  in the intervention group, compared with the control group. In contrast, there were not significant reductions in levels of the gaseous phase of SHS exposure, asthma symptoms, or exhaled nitric oxide. These data suggested that HEPA air cleaners reduced unscheduled asthma visits for children by reducing exposure to airborne particles of  $>0.3 \mu\text{m}$  but without a corresponding reduction in the gaseous phase of tobacco smoke.

Although these results are somewhat paradoxical, our results are consistent with other controlled trials of environmental interventions. In a multifaceted trial to reduce indoor pollutants that included portable HEPA air cleaners, Morgan et al<sup>28</sup> reported a 13.6% reduction in the number of unscheduled visits attributable to asthma and a significant reduction in asthma symptoms. In a trial of multiple environmental interventions that included HEPA air cleaners, Eggleston et al<sup>29</sup> reported a significant improvement in asthma symptoms but no difference in unscheduled asthma visits according to group assignment. In a trial to reduce exposures to indoor asthma triggers among inner-city children that did not include portable air cleaners, Krieger et al<sup>41</sup> reported a 15% reduction in unscheduled asthma visits but no significant improvement in asthma symptoms. It is not clear whether the differences across these studies are attributable to the type or intensity of

the environmental intervention, sample size, or eligibility criteria. Collectively, however, these trials provide evidence that environmental interventions can reduce asthma morbidity in children.<sup>42</sup>

Results of studies that have examined the contribution of SHS exposure to asthma exacerbations in children >3 years of age have been inconsistent. Several studies found that SHS was associated with asthma exacerbations or bronchial hyperactivity in older children, whereas others did not.<sup>3,6,7,43,44</sup> The vast majority of studies relied on parents' reports of smoking behavior to quantify the risk of asthma, wheezing, or diminished pulmonary functions associated with SHS exposure; fewer studies used objective biomarkers such as cotinine levels.<sup>7,43,44</sup> Although we found a significant reduction in the number of unscheduled asthma visits among children, there was not a corresponding reduction in the gaseous phase of tobacco smoke, as assessed with objective measures of air nicotine levels and biomarkers of internal doses. In contrast, there was a reduction in the levels of fine indoor particles, the predominant size generated by tobacco smoke. Therefore, this study provides some evidence that airborne particles from SHS or other pollutants represent a risk factor for asthma exacerbations in children.

More than 10 trials have tested the efficacy of anticipatory guidance regarding children's exposure to tobacco smoke, by using cotinine as an objective biomarker of exposure.<sup>12–23</sup> Only from 1 of those studies was a sustained reduction in exposure to environmental tobacco smoke, measured

as cotinine levels, reported, and from another study a significant reduction in the number of unscheduled asthma visits was reported.<sup>12,13</sup> Collectively, these trials raise serious questions about whether it is prudent to continue to rely on anticipatory guidance to reduce children's exposure to tobacco smoke. Our failure to show a reduction in the gaseous phase of children's exposure to SHS by using a passive environmental intervention provides additional support for regulations to ban smoking in public places and residential settings to reduce children's exposure to tobacco smoke.

There are some limitations of this study. First, our primary outcome measure, that is, numbers of unscheduled asthma visits, and airborne particle levels were not equally distributed in our 2 treatment arms at baseline; although the decreases in the number of unscheduled asthma visits and levels of airborne particles of  $>0.3 \mu\text{m}$  remained statistically significant after adjustment for baseline differences, this suggests that the 2 groups were not equivalent. Second, we examined many relevant end points and our primary result, that the air cleaners led to a significant reduction in the number of unscheduled asthma visits, might have been spurious. This is unlikely, however, because we observed a larger effect among the families who used the air cleaners consistently. Third, use of a different HEPA air cleaner might have led to different results. Fourth, we used only 2 HEPA air cleaners in each housing unit. A portable HEPA air cleaner is certified to clean 1 average-sized room and not an entire house. Fifth, the air nicotine dosimeters, which were placed on the

HEPA air cleaners in the main activity rooms, might not have provided representative measurements of household exposure. Finally, by focusing on older children, who are less vulnerable to SHS exposure,<sup>7,43,44</sup> we might have decreased our chances of showing an effect of HEPA air cleaners.

## CONCLUSIONS

Our ultimate goal should be to eliminate tobacco use and SHS exposure for children. Despite efforts to reduce exposure, >20% of US children are exposed to SHS in their homes.<sup>11</sup> Moreover, air quality in housing often is inadequate.<sup>10</sup> Therefore, it is critical to identify ways to reduce exposure to SHS and other pollutants, especially for children with asthma. We found that HEPA air cleaners led to significant reductions in numbers of unscheduled asthma visits and levels of fine airborne pollutants but not in parent-reported asthma symptoms, cotinine levels, or exhaled nitric-oxide levels. These results hold promise for using HEPA air cleaners as part of a multifaceted strategy to reduce asthma morbidity, but they also emphasize the importance of finding ways to reduce the sources of exposure further.

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**MISTAKES IN THE HOSPITAL:** *Patients are taken to the hospital to get better. Unfortunately, hospitalization carries with it a significant risk for adverse events. As reported on NewYorkTimes.com (November 16, 2010:1–3), one of every seven hospitalized Medicare beneficiaries is harmed as a result of the medical care received. The report on patient safety from the Inspector General for the Department of Health and Human Services is based on an exhaustive review of a representative sample of 780 patient files. The report estimates that in October 2008 alone, approximately 134,000 hospitalized Medicare beneficiaries experienced at least one adverse event. Events ranged from mild and temporary to severe and permanent including death. Almost 44% of these events were likely preventable. Medication errors leading to such problems as excessive bleeding were the most frequent adverse event. Poor patient management, e.g. leading to fluid overload was also common. Hospital acquired infections continue to be a major issue. Extremely infrequent are problems that should never happen under any condition such as performing surgery on the wrong patient. While physicians and hospitals have designed systems to help prevent errors, errors continue to happen at a distressing rate. The report recommends not only to broaden the definitions of error and harm in the hospital but to give hospitals financial incentives to reduce errors. While pediatricians infrequently take care of Medicare patients, the report emphasizes that we all need to be mindful of a cardinal rule in medicine: first, do no harm.*

Noted by WWR, MD