

Reduced clinic, emergency room, and hospital utilization after home environmental assessment and case management

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ABSTRACT

Allergists often suspect home environmental conditions are contributors to allergic disease. Case management can be an effective tool in managing asthmatic patients. To describe the impact of home environmental assessments and case management on the medical care utilization of patients with allergic disease the following studies were conducted. This study was designed to retrospectively examine health care utilization of pediatric patients that had a home environmental assessment recommended by a pediatric allergist as part of a comprehensive case management program. Subjects were chosen from pediatric patients who received home assessment after referral for case management by pediatric allergy specialists in a hospital-based clinic as indicated by high emergency room (ER) and hospital utilization. Case management included education, clinic visits, environmental assessment, and a single person responsible for following the subject's care. Home assessment included airborne spore collections, surface collections, and dust collection for evaluation of antigens. There were 25 subjects. Seventy-two percent were asthmatic and 12% were diagnosed with allergic rhinitis. In the year before entering the study these subjects experienced 47 ER visits, 22 hospitalizations, and 279 clinic visits. In the subsequent year they underwent 18 ER visits, 3 hospitalizations, and 172 clinic visits. Penicillium/Aspergillus levels were above 100 spores/m³ of air in 94% of homes and above 1000 spores/m³ in 74% of homes. Thirty-six percent of homes had Stachybotrys above 100 spores/m³. Home environmental assessment and case management may reduce medical care utilization for children suffering from allergic rhinitis and asthma.

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Asthma is a reversible chronic inflammatory disease of the airways, leading to hyperresponsiveness to external stimuli including allergens, smoke, volatile organic chemicals, and even cold air.¹ The airway inflammation itself is complex, involving a wide range of cytokine and cell-mediated responses.^{2,3} In many cases it is initiated and maintained in the chronic state by exposure to protein allergens in the environment.^{4,5} For most asthmatic patients the disease course is punctuated with remission and relapse. No current treatment results in a cure. The disease can be controlled with proper medications; however, control often is lost when the medication is stopped.^{6–8}

Residential environmental exposures are significant contributors to the persistence of allergic diseases such as asthma.^{9–11} Significant levels of dust mite, cat, cockroach, and fungal allergens are found in the homes of asthma and rhinitis patients.^{12,13} Numerous private and governmental organizations provide literature and

classes to educate sensitive persons about the potential health impact of indoor allergens and about methods to reduce exposure to these substances.^{14–18} Allergen control has been shown to be a very effective asthma control strategy when properly applied.^{19–21} However, many allergens including cat and cockroach are very difficult to eliminate.^{22,23} Although allergen exposure reduction is very difficult to achieve for cat and cockroach,^{23,24} effective remediation measures have been established for indoor fungi.^{16,25–28} Also, it has been shown that case management is a very effective tool for managing asthmatic patients.^{29,6} To describe the impact of home environmental assessments in the context of a case management scenario on the medical care utilization of patients with allergic disease, the following studies were conducted.

MATERIALS AND METHODS

Patient Selection

Subjects for this study were identified in a retrospective review of all patients who had been referred for home environmental assessment from a pediatric allergy clinic at an academic institution. These subjects also were referred for case management. All patients had a diagnosis of respiratory disease (mostly asthma) for which there was evidence of environmental triggers. All subjects signed an Institutional Review

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Board-approved consent form allowing us to perform the home inspection and keep records of any health care information recorded at that time. Additional Institutional Review Board approval was granted for the retrospective review of medical care utilization.

Sampling Protocols

One airborne sample was taken on at least every level of the home including the basement. In addition, the patient's bedroom was sampled whenever possible. At least one outdoor sample was taken for comparison. These air samples were collected using an Allergenco MK-3 (EMS Sales, Charleston, SC) volumetric sampler that had been calibrated using a Vitalograph spirometer (Vitalograph, Lenexa, KS). The latter had itself been calibrated using a 3-L syringe. The sampler was set to collect air for 10 minutes at a flow of 15 L/minute onto silicon-coated glass slides.³⁰ Once the particles were collected, the glass slides were stained with glycerin jelly containing 1% modified Calberla's stain composed of basic fuchsin and 0.1 mg/mL of phenosafranin. Particles were counted visually using a Zeiss microscope (Zeiss, Thornwood, WY) at 1000 power under oil immersion.³¹ Each vertical lane was counted horizontally a minimum of five times at different locations along the sample. All persons performing spore identification were certified by the national Allergy Bureau for identification of pollen and spores. One composite dust collection was taken in each house from 9 ft² of carpet, throw rug, or floor by vacuuming 1-ft² areas at nine locations. Dust samples were sieved through a 300-mesh brass filter, extracted, and stored at -20°C until analysis.³² Dust collections were analyzed by enzyme immunoassay for total antigen content of eight common allergenic species including: *Felis domestica*, *Canis familiaris*, *Dermatophagoides farinae*, *Periplaneta americana*, *Alternaria alternata*, *Aspergillus fumigatus*, *Cladosporium herbarum*, and *Penicillium notatum*. These assays have a lower level of detection of 0.01 µg of antigen per gram of house dust. Details of the assays have been published previously.³¹

Bulk or tape surface samples were taken of settled dust and areas of suspected fungal presence. Surface samples were obtained using single-stick clear cellophane tape (Scotch Multitask Tape Cat. 25; 3M Co., St. Paul, MN) by gently pressing on suspicious-looking areas. The tapes were placed in labeled plastic bags for transport back to the laboratory. They were then stained similarly to the air samples and were counted visually. Because these samples are not volumetric, they were classified on an ordinal scale from 1 to 5 (none to very heavy) for each spore genus identified.³² In both airborne and surface samples *Aspergillus* and *Penicillium* spores were counted under the single heading of "Pen/Asp." Ascospores and Basidiospores were

also not differentiated but were counted as groups.³³ All mean values given are arithmetic means unless otherwise noted.

Asthma-Managed Care

Asthma-managed care consisted of identification of children with high health care utilization from emergency room (ER) and hospital admission records. Patients who were high utilizers were assigned a management coordinator who was responsible for coordinating hospital care and arranging for postadmission care. Managed care tools included asthma care cards designed to empower caretakers,³⁴ asthma education to ensure understanding of triggers and medication use, and environmental assessment to provide parents, physician, and care coordinators with information about home environmental conditions.³⁴ The elements of the environmental assessments have been published previously.³² All subjects received a written report outlining the findings of the assessment and suggested procedures for remediation. Typical suggestions included moisture control; heating, ventilation, and air-conditioning (HVAC) maintenance; removal of contaminated dry-wall; and general cleaning for dust.

RESULTS

Only pediatric subjects were enrolled. Demographic data included a mean age of 8.6 (SD, 5.3) years with a 3:2 ratio of males to females. The typical dwelling was a self-owned single-family home located in the suburbs. The mean age of the homes was 28 (SD, 19) years, and the typical home was heated by gas-forced air and cooled by central air conditioning. Most families had at least 4 (4.7; SD, 1.2) members and they had lived in the particular home ~3.9 (SD, 3.5) years. The subject diagnosis was mainly asthma (72%). Eighteen of the subjects were diagnosed with asthma, three had rhinitis (12%), two were diagnosed with attention deficit hyperactivity disorder (8%), one had an upper respiratory tract infection (4%), and one had idiopathic pulmonary hemorrhage (4%).

An indication of the atopic status was available for most subjects. Sixteen of the subjects had been skin tested and 15 of them were positive to at least one common allergenic protein. In addition, eight of the subjects had total IgE values. Only two of the subjects had both skin testing and IgE levels and one of those two was negative to the allergens tested. In total, 84% of subjects were therefore confirmed atopic and one-half of the atopic subjects were allergic to at least one fungal allergen. Of the eight subjects who had total IgE testing performed the mean level was 117.3 kIU/L.

Table 1 indicates the total spore counts and the prevalence of different spore types found in the homes of

Table 1 Spore counts by genus for homes that had air collections performed

	Percent of All Collections	Percent of Homes	Mean for All Collections	Weighted Mean for All Houses
Total	100	100	8479	19890
<i>Alternaria</i>	28	56	63	55
Ascospores	56	88	353	421
Basidiospore	28	52	72	80
<i>Chaetomium</i>	8	28	15	7
<i>Cladosporium</i>	80	96	627	584
<i>Drechslera</i>	1	4	1	1
<i>Epicoccum</i>	8	16	13	12
<i>Fusarium</i>	5	12	6	8
<i>Mycelia</i>	6	108	10	4
<i>Myxomycetes</i>	7	24	20	19
Pen/Asp	68	80	2174	2884
<i>Periconia</i>	40	72	245	202
<i>Pithomyces</i>	10	48	32	31
Rust	12	20	96	97
Smut	8	20	20	11
<i>Stachybotrys</i>	19	36	186	159
<i>Stemphyllium</i>	1	4	1	1
<i>Torula</i>	1	0	1	1

Column 1 indicates the percentage of the time that each spore type appeared for all of the collections taken. Column 2 is the percentage of the homes in which each spore type was found. Column 3 indicates the mean value for all collections in spores per cubic meter of air for total spores and each spore type. For column 4 the means of all the collections made in individual houses are averaged together to give a weighted mean. These values are also in spores per cubic meter of air for total spores and each spore type.

these subjects. The weighted mean value (the average of the individual per house means) of the spore counts for all subject homes was nearly 20,000 spores/m³ of air and the mean for all collections was >8000 spores/m³ of air. *Cladosporium*, found in 80% of collections and 96% of homes, was clearly the most prominent spore type. Pen/Asp was the second most common spore type in 68% of collections and 80% of homes. Other spore types such as *Alternaria* found in 56% of homes and *Stachybotrys* found in 36% of homes were significant parts of the collections.

The distribution of the most prominent spore types is shown in Table 2. The highest spore counts in these collections is represented by Pen/Asp, which was >1000 spores/m³ of air in at least one-half of collections with peak levels exceeding 35,000 spores/m³ of air. At least 5% of homes had *Stachybotrys* counts above 200/m³ of air. Because the inspections were performed throughout the year several of the outdoor counts contained no spores.

Table 3 indicates the genus-specific antigen levels in dust collected from these houses. Measurable *Cladosporium* and Cat antigen was found in 82% of homes, and *Penicillium* antigen was found in 53% of collections. The highest mean antigen levels were dog (6.88

µg/g of dust), cockroach antigen (5.02 µg/g of dust), and cat antigen (2.48 µg/g of dust).

The medical care utilization for the study subjects is described in Table 4. In the 12 months before the home environmental assessment there were 47 ER visits, 22 hospital admissions, and 279 clinic visits and in the 12 months after the home environmental assessment there were 18 ER visits, 3 hospital admissions, and 172 clinic visits. The difference is significant ($p < 0.05$) by Student's *t*-test for ER visits and hospital admissions but not for clinic visits.

DISCUSSION

Demographics and Home Inspections

The subject set is fairly typical for a pediatric allergy clinic in the Midwestern United States. The mean age of subjects is almost the middle of the range of patients seen in the pediatric allergy clinic (0–17 years). The housing also is typical for the Midwestern United States, with most homes having a basement, forced-air heating, and air conditioning. The number of persons per home is higher than average probably because single young adults, older adults, or families without children are excluded.³⁵ The time these families had

Table 2 Spore types expressed as percentiles are listed to provide an indication of the distribution of the data

	Lowest	25th Percentile	50th Percentile	75th Percentile	95th Percentile	Highest
Outdoor mean	0	0	4452	12,838	26,058	35,302
Per house mean	597	2368	3413	5568	38,571	34,4000
<i>Alternaria</i>	0	0	12	43	222	512
Ascospores	0	0	114	256	1991	2027
Basidiospore	0	0	43	128	299	427
<i>Chaetomium</i>	0	0	0	0	43	64
<i>Cladosporium</i>	0	142	448	619	2105	2112
Pen/Asp	0	64	1024	2027	6542	37,931
<i>Periconia</i>	0	0	43	192	512	2338
<i>Stachybotrys</i>	0	0	0	24	235	2987

All values are for the per house mean given in spores per cubic meter of air.

Table 3 Concentrations of total antigen in dust ($\mu\text{g/g}$ of dust)

Antigen	Percent of Homes with Detectable Antigen	Mean $\mu\text{g/g}$ of Dust
<i>Alternaria</i>	24	0.40
<i>Aspergillus</i>	35	0.13
Cat	82	2.48
<i>Cladosporium</i>	82	0.33
Dog	59	6.88
Dust mite	24	0.71
<i>Penicillium</i>	53	1.80
Cockroach	24	5.02

lived in the home was slightly shorter than the mean time of occupancy in the area (5 years) but the difference is probably not significant for this study. The major diagnosis was asthma with rhinitis. The asthma case management and home environmental assessment program was initiated to reduce high medical care utilization rates among asthmatic patients. Children who had multiple ER visits or hospital admissions within a short period of time therefore were more likely to be included in the program.

Nearly all of the subjects were atopic. Fifteen of 16 subjects tested were skin test positive. Two of those were also IgE positive and six of the persons who were not skin tested were also IgE positive making the total known atopic subjects to be 21 (84%). One-half of the 16 subjects that were skin tested were positive to one or more fungal extract. This is a considerably higher atopic percentage than the general population.³⁶ The two reasons for this are that the study targets health care utilizers who have asthma and the inspections were ordered to confirm physician-suspected environmental conditions detrimental to health.

The distribution of spore genera in these homes, described in Tables 2 and 3, is about what would be expected for troubled houses.^{37,38} Nearly all of the houses had Pen/Asp spores at a per house mean value of >2000 spores/ m^3 of air. Although there are no officially accepted maximum tolerable levels for these spores, most home assessment experts would be concerned by levels this high.³⁹ These levels are higher than those reported previously for most houses^{37,38,40} and higher than levels previously reported by these investigators.³² Although the absolute levels were not quite as high, there was significant *Stachybotrys* (36%), *Alternaria* (56%), and *Pithomyces* (48%) presence in the houses. In this region there is only a small period of the year when the HVAC unit is not running. This constant air movement may account for the unexpectedly high occurrence of *Stachybotrys*. There was *Alternaria* (57%) in most of the outdoor collections and low levels of Pen/Asp (42%) and *Pithomyces* (14%) in a few outdoor collections; however, no *Stachybotrys* was found in any of the outdoor collections. In this area, outdoor collections during the winter usually have few spores whereas summer and early fall collections can contain $>30,000$ spores/ m^3 of air. *Cladosporium* dominates these outdoor collections in dry climates and Ascospores dominate during wet periods. This is a normal pattern for many cities in the Midwestern United States.⁴¹

The total levels of spores found in these houses varied dramatically (Table 2). The per house mean levels for the sum of all spores present in a collection varied from 597 to 344,000 spores/ m^3 of air with one-half the houses having per house mean levels of >3000 spores/ m^3 of air. Because the top per house mean level at 344,000 is an order of magnitude above the top per house mean spore level for any of the individual spores, it is obvious that houses with high levels had multiple spore types present.

Table 4 Pre- and postremediation emergency room and hospital visits for asthma

	Previous Year	Subsequent Year	Significance <i>p</i>
Emergency room visits	47	18	0.01
Hospital admissions	22	3	0.02
Clinic visits	279	172	0.07

The most frequently found dust allergens are cat and *Cladosporium* both found in 82% of subject homes. Cat allergen is frequently found in all environments,²⁴ and *Cladosporium* is one of the most abundant spores in both outdoor and indoor environments.⁴² Levels of dust-borne allergens are about as expected from previous reports.⁴² There is a positive correlation between allergen measurements and spore counts for *Alternaria* (0.44), *Aspergillus* (0.21), and *Penicillium* (0.50) and a negative correlation for *Cladosporium* (−0.38). These correlations are interesting but not significant because of the low numbers of subjects. Several larger studies have examined this relationship⁴⁰ and concluded that for the most part correlations between airborne spores and fungal allergens in settled dust are not significant. This is most likely caused by the observation that airborne spore counts represent exposure at one instant of time whereas allergen levels in settled dust represent accumulated exposure.

Case Management Elements

All of the asthmatic subjects were being case managed and because the other subjects came to the study through the allergy clinic they were also part of the overall care regime performed by the clinic personnel. Asthma case management at this institution includes the assignment of a person to coordinate all care, family and patient education concerning medications, family and patient education concerning asthma triggers, and asthma action cards to empower caregivers to deal with the many different aspects of the disease.

Health Care Utilization

There was a dramatic difference in health care utilization in the 12 months before the inspection and the 12 months after the inspection. ER visits were reduced 62%, hospital admissions were reduced 86%, and clinic visits were reduced 38%. All of the subjects continued to receive health care at Children's Hospital so we can be confident that none of them left the area. Because the Children's Hospital is the major provider of children's health services in the metropolitan area and many of the families were enrolled in a Medicare HMO, we are reasonably sure that we were able to capture all of the health care utilization. Both the reduction in ER visits and the reduction in hospital uti-

lization are statistically significant and dramatic. There are, however, several extenuating circumstances that should be noted that might reduce the significance. The subjects were identified because of high utilization patterns. This period of high utilization could be as short as 1 month before the subject was seen in the allergy clinic and the subject may have received only emergency treatment during this period. In this case, utilization reduction would be a result of adequate medical care. Additionally, some subjects may have reduced their medical care utilization subsequent to this brief period of high utilization even without medical treatment. However, the marked health care utilization reduction documented for these subjects is truly significant and there is a high probability that the case management and environmental evaluation were major contributors. There was also no difference in medications prescribed before and after home assessment. Additionally, the interventions to remediate poor conditions in the home revealed by the environmental assessment were not consistent and depended on the financial resources of the family. Some homes received full professional remediation while other families were assisted in finding better housing conditions. All families were made aware of the findings of the environmental assessment and furnished with a list of recommended remediations. To our knowledge, none of the included subjects changed homes during the year after their home inspection; however, follow-up studies to determine subsequent improvement in living conditions were not conducted.

From the available data, we are not able to determine the individual contributions of managed care and home environmental assessment to the observed outcomes. Managed care is well documented to be an effective method for reducing health care costs of patients with asthma.⁴³ The contribution of home environmental assessment to asthma care is not as well documented. Information regarding the home environmental exposure can be of assistance to allergists when diagnosing and treating asthma patients.^{39,44} Likewise, this information can help parents and caregivers to reduce exposure and subsequent symptoms. However, many persons in the general public are not aware of the significance of allergen exposures as asthma triggers. Also, many renters or persons of low socioeconomic means are

not able to produce significant alterations in their home environment.¹²

CONCLUSION

The genesis and triggering mechanisms of asthmatic disease are varied and complex. Even in the face of extensive research, the asthma disease process remains poorly understood. The data presented here describe a group of children for whom asthma-managed care including home environmental assessment accompanied decreased health care utilization for asthmatic disease.

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