Mouse allergen. I. The prevalence of mouse allergen in inner-city homes

Wanda Phipatanakul, MD,[a] Peyton A. Eggleston, MD,[b] Elizabeth C. Wright, PhD,[c] Robert A. Wood, MD,[b] and the National Cooperative Inner-City Asthma Study*

Boston and Watertown, Mass, and Baltimore, Md

Background: Although mouse allergen is a well-defined cause of IgE-mediated hypersensitivity in occupational settings, it has not been well studied in the general population.
Objective: We sought to determine the prevalence of mouse allergen in inner-city homes.
Methods: A subset of 608 homes from the National Cooperative Inner-City Asthma Study population had dust samples adequate for analysis of mouse allergen. In addition, data regarding the demographics and housing of the subjects were related to the mouse allergen levels.
Results: Ninety-five percent of all homes had detectable mouse allergen (Mus m 1) in at least one room, with the highest levels found in kitchens (kitchen: range, 0-618 μg/g; median, 1.60 μg/g; bedroom: range, 0-294 μg/g; median, 0.52 μg/g; television-living room: range, 0-203 μg/g; median, 0.57 μg/g). By city, 100% of the kitchens in Baltimore had detectable mouse allergen, with the lowest percentage (74%) in Cleveland. Mouse allergen levels correlated among rooms (R = 0.65-0.75). Forty-nine percent of the homes had reported problems with mice within the last year, and 29% of the homes had evidence of mice in one or more rooms on home inspection and had higher levels of mouse allergen (P = .0001). Higher allergen levels were also associated with evidence of cockroach infestation in any room (P = .006). None of the other subject or housing demographics evaluated were associated with a higher prevalence or level of mouse allergen.
Conclusions: We conclude that mouse allergen is widely distributed in inner-city homes and that cockroach infestation is associated with high mouse allergen levels. (J Allergy Clin Immunol 2000;106:1070-4.)

Key words: *Mouse allergen, indoor allergens, inner-city asthma, sensitization*

Abbreviations used
NCICAS: National Cooperative Inner-City Asthma Study

Morbidity from asthma is disproportionately high among inner-city children.[1] Although a complete understanding of the cause is not known, possible explanations include increased exposure to allergens,[2] poor air quality,[3] psychosocial problems,[4] and less access to quality medical care.[4] Recently, the National Cooperative Inner-City Asthma Study (NCICAS) reported a relationship between cockroach allergen exposure and sensitivity with asthma morbidity in inner-city children with asthma.[5] The same study also found that cockroach allergen exposure and atopy were important risk factors for cockroach sensitization.[6]

Although mouse and rat allergens are well-documented causes of IgE-mediated hypersensitivity in occupational settings,[7] they have received only limited attention in other settings.[8] It is common for patients from inner-city environments to report significant mouse and rat infestation in their homes and neighborhoods. Realizing how potent these allergens can be in occupational settings, we were interested in studying their distribution and clinical significance in the homes of inner-city patients with asthma. In this study dust samples obtained in the NCICAS were used to determine the prevalence of mouse allergen in inner-city homes. Then we sought to relate the prevalence and magnitude of mouse allergens in these homes with the demographic features of these children and their specific housing characteristics.

METHODS

The NCICAS population consisted of 1528 children aged 4 to 9 years from 8 major inner-city areas (Bronx, NY; East Harlem, NY; St Louis, Mo; Washington, DC; Baltimore, Md; Chicago, Ill; Cleveland, Ohio; and Detroit, Mich). As previously described, these children had a diagnosis of asthma and lived in neighborhoods where 30% or more of the households had incomes below the 1990 poverty level.[9] The child and primary caretaker had a baseline evaluation, which included extensive medical, environmental, demographic, and psychologic interviews.[9,10] From these subjects, dust samples were collected from the homes of the first 663 children recruited into the study. Of these samples, 608 had sufficient dust for analysis of mouse allergen.

The methods for determining the psychosocial characteristics of the households have been previously described.[11] A measure of social support had a scale of 0 to 9, with a score below 7 considered to indicate inadequate social support for the family in dealing with

From [a]the Department of Pediatrics, Division of Allergy and Immunology, Children's Hospital, Harvard University School of Medicine, Boston; [b]the Department of Pediatrics, Division of Allergy and Immunology, Johns Hopkins University School of Medicine, Baltimore; and [c]the New England Research Institutes, Watertown.

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*The Study investigators are listed in the Appendix.

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Reprint requests: Robert A. Wood, MD, CMSC 1102, Johns Hopkins Hospital, 600 N Wolfe St, Baltimore, MD 21287-3923.

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TABLE I. Characteristics of the study population*

Characteristic	Study sample (n = 608)	NCICAS (n = 1528)
Mean ± SD age (y)	6.15 ± 1.69	6.16 ± 1.69
Male sex	383/608 (63%)	954/1528 (62%)
Race or ethnic group		
Hispanic	115/599 (19%)	295/1512 (20%)
Black	450/599 (75%)	1111/1512 (73%)
Other	34/599 (6%)	106/1512 (7%)
Annual income <$15,000†	345/540 (64%)	835/1364 (61%)
At least one smoker in home	348/602 (58%)	889/1513 (59%)
Family history of asthma	341/596 (57%)	868/1512 (57%)
Inadequate social support	250/595 (42%)	637/1499 (42%)
Large No. of stressful life events	346/606 (57%)	893/1515 (59%)
Psychopathology in child	218/602 (36%)	531/1509 (35%)
Psychopathology in caregiver	287/581 (49%)	732/1470 (50%)

*Totals are for the numbers of children for whom data were available.
†$P < .05$.

the child's asthma. Life events were measured with the Psychiatric Epidemiology Research Interview Life Events scale, with scores ranging from 0 to 46. A score above 5 was considered to indicate a substantial number of stressful life events in the previous 12 months. The Child Behavior Checklist for children and the Brief Symptom Inventory for caregivers are tests in which high scores indicate the presence of substantial psychologic problems. The mean normalized score (T score) on these tests was 50; we used the standard cutoff of 63 or greater as the criteria indicating the presence of substantial psychologic problems.

In the NCICAS study all families were asked for permission for home visits as they entered the study; 837 agreed, and visits were done in 663 homes within a month of the baseline evaluation. At each visit, personnel inspected the home according to a standardized protocol, documenting construction, environmental conditions, and evidence of cockroach, mouse, and rat infestation. Direct inspection also determined general information, such as the state of repair of the home and the presence of carpeting, mattress covers, and pets. Study personnel also interviewed the family regarding characteristics such as laundry facilities, smoking habits, and infestations, as previously described.[10]

Dust samples were collected from the home with a hand-held vacuum (Redivac 6735, Douglas Manufacturing Co). Samples were collected from 3 rooms, the child's bedroom, the television-living room, and the kitchen by using standardized methods, as previously described.[10] In the bedroom the sample was collected from a 1-m^2 area near, underneath, and on the bed for 2 minutes. In the television-living room, samples were collected for 2 minutes each from any stuffed furniture and from a 1-m^2 area next to the furniture. In the kitchen the entire floor was vacuumed for 4 minutes. Dust samples were removed from the vacuum, sieved, and then stored at –30°C until they were extracted.

An aqueous extract of 100 mg of sieved dust was prepared in 2 mL of borate-buffered saline. The extracts were stored at –30°C until they were assayed for mouse allergen Mus m 1. A sandwich ELISA with an affinity-purified monospecific anti-Mus m 1 antibody was used to determine the concentration of Mus m 1.[12]

All of the children in the study received standard skin testing to a predefined set of aeroallergens, which included cockroach, dust mite, cat, mouse, and rat, as previously described.[6] Mouse and rat allergen skin testing concentrations were 1:20 wt/vol. There were a total of 499 children who had both valid skin test data and an adequate dust sample for mouse allergen analysis. For the purposes of this article, we analyzed data for the entire 608 homes available for mouse allergen analysis.

The comparison of the study sample with the remainder of the NCICAS population was based on an analysis of variance or a Mantel-Haenszel χ^2 test stratified by city. Spearman rank correlation coefficients were used to measure the association between levels of mouse allergen in the rooms and between mouse and other allergens. The Mantel-Haenszel χ^2 test stratified by city and adjusted for covariates was used to assess the relationship between demographic or housing characteristics and the presence of high levels of mouse allergen, which were considered for this analysis to be any level above the median level for that room. The Wilcoxon rank-sum test was used to compare distributions of allergen levels among groups of patients. A P value of less than .05 was considered to be significant.

RESULTS

The children had a mean age of 6.2 years (range, 4-9 years). Sixty-three percent of the children were boys. The study families were primarily black (77%) or Hispanic (17%), and 66% of the families had an annual income of less than $15,000. There was a family history of asthma in 57% of the children, and 58% had at least one smoker in their home. Overall, the families had a significant number of psychosocial problems. Forty-two percent of the subjects had inadequate social support, and 57% of the caretakers had a large number of stressful life events measured by using the Psychiatric Epidemiology Research Interview Life Events Scale. Thirty-six percent of the children had scores indicating the presence of substantial psychologic problems by using the Child Behavior Checklist, and 49% of the caregivers of the child had high scores on the Brief Symptom Inventory scale. The study group and the total study population of the NCICAS were similar, with the only significant difference occurring in annual income (Table I).

Table II depicts housing characteristics for the 608 children. Forty-one percent of the children lived in apartments less than 4 stories tall, 24% lived in row-duplex homes, 19% lived in single homes, and 16% lived in high-rise apartments. Forty-five percent of the children lived in housing that was more than 50 years old, and evidence of disrepair was seen in 48% of the homes. Evidence of mice in any room was seen in 29% of the homes, and 27% of

the homes had evidence of mice in the kitchen. By history, 49% of the families reported a problem with mouse infestation within the year before evaluation. Furthermore, 66% of the homes had evidence of cockroaches during the home visits, and 68% reported a problem with cockroaches within the year before evaluation.

Ninety-five percent of all homes had detectable mouse allergen in at least one room, and 87% of the samples from each room had detectable mouse allergen (Table III). The highest levels were found in kitchens, with a median level of 1.60 μg/g (range, 0-618 μg/g). The median levels were 0.52 μg/g for the bedrooms (range, 0-294 μg/g) and 0.57 μg/g for the television-living room (range, 0-203 μg/g).

Analysis of individual cities revealed that 100% of the homes in Baltimore and St Louis had detectable mouse allergen in at least one room. All of the cities had a high percentage of kitchens with detectable mouse allergen, with the lowest percentage in Cleveland at 74% and the highest in Baltimore at 100%. Table IV shows the percentage of kitchens with detectable mouse allergen by city. Allergen levels ranged from the lowest in Cleveland, with a median of 0.30 μg/g and a range from 0 to 362 μg/g, to the highest in Baltimore, with a median of 7.87 μg/g and a range from 0.06 to 205 μg/g.

The levels of mouse allergen among the 3 rooms were highly correlated (R = 0.65-0.75, $P < .0001$ for each room). Although there were statistically significant correlations between mouse allergen and cat (Fel d 1) and cockroach (Bla g 1) allergens, the highest correlation coefficient was only 0.18 between Mus m 1 and Bla g 1 in the bedroom.

Demographics of the subjects and their housing characteristics were analyzed to determine which variables might predict higher levels of mouse allergen (Table V). Sixty-eight percent of the homes with reported mice problems in the past year had allergen levels above the median compared with 32% of the homes with no reported mice problems (odds ratio, 4.64; $P = .0001$). Similarly, evidence of mouse droppings in the kitchen or any room on inspection was significantly associated with higher mouse allergen levels (kitchen OR, 5.01; $P = .0001$). Evidence of cockroaches in any room or the kitchen was also associated with higher mouse allergen levels (kitchen OR, 1.80; $P = .01$). None of the other housing variables were significantly related to high mouse allergen levels.

TABLE II. Housing characteristics

Characteristic	No.	%
Type		
Single	115/608	19
Row-duplex	144/608	24
Apartment	252/608	41
High rise	97/608	16
House >50 y old	259/580	45
Evidence of disrepair	292/607	48
Forced air heat	136/606	22
Working vacuum in home	277/608	46
Wall-to-wall or large carpet		
Televison-living room	326/604	54
Bedroom	235/608	39
Any room	360/608	59
Trash or dirty dishes in kitchen	307/608	50
Evidence of mice		
Kitchen	163/607	27
Television-living room	87/604	14
Bedroom	60/606	10
Any room	174/608	29
Problem with mice in past year	292/602	49
Problem with rats in past year	45/602	7
Evidence of cockroaches		
Kitchen	393/608	65
Television-living room	195/604	32
Bedroom	168/606	28
Any room	400/608	66
Problem with cockroaches in past year	413/603	68
Evidence of mice or cockroaches	421/608	69
Problems in past year with mice or cockroaches	465/602	77
Problems in past year with mice, rats, or cockroaches	469/602	78
Pets in home		
Cat	70/608	12
Dog	71/608	12
Rodent	14/608	2
Any pet	141/608	23

DISCUSSION

This is the first report describing the prevalence and distribution of mouse allergen in inner-city home environments of asthmatic children. Mouse allergen was found to be strikingly prevalent among these inner-city homes, with allergen being detected in over 95% of the homes studied. These results confirm those of a prior study that found mouse allergen in air samples taken from 5 inner-city homes.[8] In comparison with other allergens, cockroach allergen was also highly prevalent in these same inner-city homes, with 85% of bedrooms having detectable cockroach allergen, and 50% of the bedrooms having levels above the proposed threshold of 8 U/g.[5] On the other hand, cat and dust mite allergens were detected in 50% and 60% of bedrooms, respectively, and only 13% of the bedrooms for cat and 10% for dust mite had levels considered to be above their respective thresholds.[5] Mouse allergen is therefore more prevalent in inner-city homes than dust mite or cat allergens, raising the possibility that mouse allergen may join cockroach allergen as a uniquely important indoor allergen in this population.

The median levels of mouse allergen were 1.60 μg/g in the kitchen, 0.52 μg/g in the bedroom, and 0.57 μg/g in the television-living room, with ranges from 0 to the highest level of 618 μg/g in a kitchen. Levels varied in different cities from the lowest median kitchen level of 0.30 μg/g in Cleveland to the highest in Baltimore of 7.87 μg/g. In comparison with other animal allergens, the levels and ranges for mouse allergen are overall similar to those found in homes for cat and dog allergens.[13,14]

TABLE III. Mouse allergen by room

	n	% of samples >0	Median (μg/g)	Range (μg/g)
Kitchen	506	87.2	1.60	0-618
Bedroom	608	87.5	0.52	0-294
Television-living room	559	86.9	0.57	0-203

TABLE IV. Mouse allergen in kitchen samples

City	n	% homes detected	Median (μg/g)	Range (μg/g)
Baltimore	57	100	7.87	0.06-205
Bronx	62	94	3.93	0-191
Chicago	49	82	0.38	0-198
Cleveland	76	74	0.30	0-362
Detroit	63	87	3.02	0-474
Harlem	59	88	1.34	0-172
St Louis	79	91	1.86	0-618
Washington, DC	61	84	0.70	0-377
Total	506	88	1.60	0-618

TABLE V. Percentage of homes with kitchen allergen levels above the median by housing characteristics

	% with Mus m 1 levels above median			
Characteristic	Without characteristic	With characteristic	Odds ratio*	*P* value*
House >50 y old	44	55	1.20 (0.80-1.82)	.38
Evidence of disrepair	50	50	1.08 (0.71-1.63)	.73
Working vacuum in home	53	46	0.74 (0.51-1.08)	.13
Large carpet in any room	56	45	0.71 (0.48-1.07)	.10
Trash or dirty dishes in kitchen	57	43	0.80 (0.52-1.22)	.30
Evidence of mice				
Kitchen	40	75	5.01 (3.11-8.06)	.0001
Any room	39	76	5.11 (3.23-8.10)	.0001
Problem with mice in past year	32	68	4.64 (3.10-6.93)	.0001
Evidence of cockroaches				
Kitchen	42	54	1.80 (1.14-2.85)	.012
Any room	41	54	1.90 (1.08-2.78)	.006
Problem with cockroaches in past year	46	52	1.53 (0.99-2.39)	.058

*Mantel-Haenszel χ^2 test stratified by city. Numbers in parentheses represent 65% confidence limits.

Wood et al[13] measured cat and dog allergens in dust samples from 106 homes in Baltimore and found levels ranging from 2 to 130,000 ng/g for cat (median, 90 ng/g) and from 112.5 to 585,000 IU/g for dog (median, 2719.5 IU/g). Although allergen levels were significantly higher in homes with animals, 100% of homes had detectable cat and dog allergens. Ingram et al[14] analyzed dog and cat allergen exposure among asthmatic children in Los Alamos, New Mexico, and found levels in homes with cats and dogs of up to 1000 μg/g. In another study of inner-city homes, Gelber et al[15] found that all of the homes with cats had levels above 8 μg/g, although the majority of the homes in their study did not have cats and had levels below 8 μg/g. Data from the NCICAS population showed a relatively low frequency of pet ownership and overall lower allergen levels. This again suggests that although animal allergens are widespread, mouse and cockroach allergens may be more concentrated and more clinically relevant in urban areas. Furthermore, the mouse allergen levels in inner-city homes are comparable to cat and dog allergen levels in homes containing those pets, which are well known causes of allergic disease.

Mouse allergen levels were highly correlated by room, suggesting that mouse allergens are widely disseminated in homes with mouse infestation. There were no striking associations between mouse allergen levels and cat or cockroach allergens, with the highest correlation occurring between mouse and cockroach allergens in the bedroom ($R = 0.18$). There was also a significant association between evidence of cockroach infestation on inspection with elevated mouse allergen levels. These data suggest that there is an increased likelihood of mouse infestation in homes with cockroach infestation, which may place some patients at particular risk. Further study will be required to determine what factors may underlie these homes with particularly high allergen loads.

With regard to personal, housing, and demographic variables, it was not surprising to find a strong relationship between both a history of mouse problems and visible evidence of mouse infestation and elevated allergen

levels. However, other variables, such as the type or age of the housing, evidence of disrepair, the presence of trash or dirty dishes in the home, the presence of carpeting, and the lack of a working vacuum, were not associated with elevated mouse allergen levels. Similarly, no associations were detected between any personal or demographic characteristics and elevated mouse allergen levels.

Previous studies have demonstrated the clinical efficacy of environmental control measures in homes to lower dust mite allergen levels.[16,17] For cockroach allergen, studies with a combination of cleaning and extermination also resulted in lower allergen levels, although the levels after intervention frequently remain above those that have previously been shown to be clinically significant.[18] Further study will be required to determine both the factors that promote mouse infestation and the measures that may be useful in reducing mouse allergen exposure.

In conclusion, we have found an extraordinarily high prevalence of mouse allergen in inner-city homes of children with asthma. The levels of allergen were substantial and similar to those seen in other studies for cat and dog allergens. We found that homes with recent evidence of mice and cockroach infestation had higher levels of mouse allergen. Further study is urgently needed to assess the true clinical significance of this potentially significant and heretofore underrecognized indoor allergen.

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APPENDIX

In addition to the authors, the following investigators from the NCICAS participated in this study. Albert Einstein School of Medicine, Bronx, NY: D. L. Rosenstreich, E. Crain, and L. Bauman; Children's Memorial Hospital, Chicago, Ill: R. Evans III, J. Lavigne, Y. D. Senturia, C. M. Weil, K. K. Christoffel, and H. J. Binns; Cook County Hospital, Chicago, Ill: M. Sullivan, J. H. Mayefsky, and M. F. McDermott; Rainbow Babies and Children's Hospital, Cleveland, Ohio: C. Kercmar, S. Redline, and S. Wade; Henry Ford Hospital and Medical Center, Detroit, Mich: D. Ownby, J. A. Anderson, F. E. Leicky, C. L. M. Joseph, and C. Johnson; Mount Sinai School of Medicine, New York, NY: M. Kattan, C. Lamm, M. T. Tin, G. Butts, E. Luder, and D. Baker; Washington University Medical School, St Louis, Mo: H. J. Wedner and G. Evans; St Louis University School of Medicine, St Louis, Mo: R. G. Slavin; Howard University, Washington, DC: F. Malveux, A. Thomas, S. Molock, and M. Richard; National Institute of Allergy and Infectious Diseases, Program Office, Bethesda, Md: P. Gergen, E. Smartt, K. Weiss, and R. Kaslow; Center for Occupational Environmental Health, Irvine, Calif: D. Baker; New England Research Institutes, Watertown, Mass: H. Mitchell, K. McNiff-Mortimer, H. Lynn, and S. Islam.