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The effect of air filtration on airborne dog allergen

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Background: Effective methods of reducing dog allergen are required to help alleviate symptoms in asthmatic patients sensitized to dog who refuse to part with their pet. The aim of this study was to investigate the use of the high efficiency particulate air (HEPA) filter air cleaner to reduce airborne Can f 1 in homes with a dog.

Methods: The effect of a HEPA air cleaner was investigated in nine homes with a dog. Samples were collected from two rooms of each house concurrently, one of which contained the dog, on two separate days (active day – HEPA air cleaner on – and control day). Eight consecutive 1-h samples were collected from each room with a high-volume air sampler (airflow rate 60 l/min). Can f 1 was determined by monoclonal-polyclonal antibody-based ELISA.

Results: Baseline airborne Can f 1 levels were 3.8-fold greater when sampling was performed with a dog in the room (GM 27.1 ng Can f 1/m³, range 2.63–329) than when the dog was elsewhere in the house (GM 7.1 ng Can f 1/m³, range 0.69–27.2). When the dog was elsewhere in the house, airborne Can f 1 levels fell on both active and control days, but the magnitude of the reduction was significantly greater on the active days ($P<0.05$), and was approximately 90% from baseline. With the dog in the room, a significant fall in airborne Can f 1 was observed only on active days (75% from baseline), but not on control days (active vs control $P<0.001$).

Conclusions: HEPA air cleaners reduce airborne Can f 1 in homes with dogs. Furthermore, preventing the access of the dog to the bedroom and possibly the living room may reduce the total allergen load inhaled.

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Sensitization to house-dust mites is recognized as a major risk factor for asthma worldwide. However, in areas where mite-allergen levels are low, it is becoming clear that asthma is associated with sensitization to other indoor allergens, such as cat, dog, or cockroach (1, 2).

A major dog allergen, Can f 1, has been purified and a sandwich ELISA has been developed, enabling measurement of allergen levels in dust and air samples (3, 4). We have previously shown that Can f 1 is readily detectable in the air in homes with dogs and also in approximately one-third of homes without a dog (5). A significant proportion of the airborne allergen is carried on small particles ($<5\ \mu\text{m}$ in diameter) which, when inhaled, may penetrate deep into the human respiratory tract and cause asthma symptoms in sensitized patients (5). Exposure to airborne dog allergen in dog-allergic asthmatics may cause severe symptoms. Despite this, many dog-sensitized asthmatics refuse to part with their pets even when this is strongly recommended by their physician. Therefore, effective environmental strategies need to be developed in order to reduce exposure to dog allergen while keeping the dog.

As airborne Can f 1, carried on respirable particles, is often found in very high concentrations in homes with dogs, the primary goal of effective allergen control should include removal of the allergen from the air. This study aimed to investigate the use of the high efficiency particulate air (HEPA) filter air cleaner to reduce airborne Can f 1 in homes with a dog.

Material and methods

The effect of the HEPA air cleaner (Enviracaire 1540) on airborne Can f 1 levels was investigated in nine homes with one dog. Samples were collected from two rooms of each house concurrently, one of which contained the dog, on two separate days. All doors and windows were closed, and the sampling was performed in the absence of artificial disturbance. To quantify airborne Can f 1 during the course of each day, eight consecutive 1-h samples were collected from each room. The sampling pumps (60 l/min high-volume air samplers – Rotheroe-Mitchell, Greenford, UK) were placed in the centre of the room 0.75–1 m above the floor, and the air sample was collected onto a 37-mm Whatman GFA micro-glass fibre filter. The volume of air sampled was calculated by multiplying flow rate by sampling time. On the “active” day, the HEPA air cleaner was placed in the corner of each room 0.5 m above the floor, and was left running for 7 h (starting after the baseline 1-h

sample had been collected). On the “control” day, the sampling procedure was performed in the same rooms and under the same conditions, but without the HEPA air cleaner. The test days were randomized and carried out at least 24 h between each other.

Processing of samples and allergen assays

Each filter was cut into four pieces, and then placed into a syringe with 1 ml of 1% bovine serum albumin in phosphate-buffered saline with 0.1% Tween 20 (BSA PBS-T). After overnight extraction at 4°C, the extraction liquid was aspirated backward and forward several times through a three-way stop lock into a second syringe, and then transferred into a test tube and centrifuged at 3000 rpm for 30 min at 4°C. The supernatant was stored at –20°C.

Can f 1 was measured by monoclonal/polyclonal antibody ELISA, as previously described (2, 5). Air samples were assayed neat and at two- and fourfold dilutions. For concentrations lying off the linear portion of the standard curve, the assays were repeated at an appropriate dilution.

The assay was quantitated with doubling dilutions of dog allergen standard (UVA 94/02) from 500 IU/ml to 1 IU/ml Can f 1. The UVA 94/02 (10000 IU Can f 1/ml) was substandardized against the WHO/IUIS international reference preparation of dog hair and dander (NIBSC 84/685), which contains 100000 IU/ml Can f 1. One international unit is approximately 1 ng Can f 1 protein, and this value was used to calculate the results.

Statistical analysis

For all air samples, the allergen levels in ng/m^3 were calculated taking into account the total amount of allergen recovered, the length of collection period, and the airflow rate of the device. The results, expressed as $\text{ng Can f 1}/\text{m}^3$, were found to follow a log-normal distribution. The geometric means under each of the study conditions at each time point were calculated. These were then converted to percentage changes from baseline. Changes over the study periods were evaluated with a mixed design analysis of variance (ANOVA) including between-group factors (“active” and “control”) and repeated-measures factors (hours 1–8). Statistical significance was set at the conventional $<5\%$ level.

Results

In homes with dogs, baseline airborne Can f 1 levels were 3.8-fold greater when sampling was performed with a dog in the room (GM 27.1 ng Can f 1/m³, range 2.63–329.59 ng Can f 1/m³) than when the dog was elsewhere in the house (GM 7.1 ng Can f 1/m³, range 0.69–27.22 ng Can f 1/m³). There was no significant difference (paired *t*-test) in the baseline Can f 1 levels between the active and control sampling days for each individual room (*P*=0.3 dog in room; *P*=0.6 dog elsewhere in house).

The effect of HEPA filtration on airborne Can f 1 is shown in Fig. 1. In addition, GM and 95% CI, both in terms of the absolute levels of Can f 1 in the air and the percentage change from the baseline, are shown in Table 1 (for days when sampling was performed with the dog in the room), and in Table 2 (for days when the dog was elsewhere in the house).

When the dog was elsewhere in the house, airborne Can f 1 levels fell significantly and immediately, relative to baseline, on both active and control days. However, the magnitude of the reduction in airborne Can f 1 was significantly greater on the active days (HEPA air cleaner on; *P*<0.05) and was approximately 90% from baseline.

When the sampling was performed with the dog in the room, a significant fall in airborne Can f 1 as compared to baseline levels was observed only on active days (HEPA air cleaner on), but not on control days (active vs control *P*<0.001). The reduction on active days was approximately 75% from baseline.

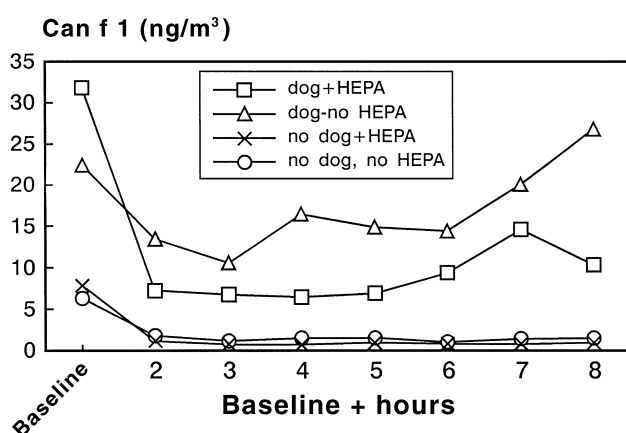


Figure 1. Effect of high efficiency particulate air (HEPA) filter air cleaner on airborne Can f 1 in homes with dogs.

Table 1. Effect of HEPA air cleaner on airborne levels of Can f 1 in houses with dog (geometric means [GM] and ranges for each day and time; ng/m³) when sampling was performed with dog in room. Shown in *italics* are percentage reductions with 95% confidence intervals (CI) for each time point compared with baseline levels for active and control days

	Control	Active
Hour	ng Can f 1/m ³ ; GM (range) % reduction (95% CI)	ng Can f 1/m ³ ; GM (range) % reduction (95% CI)
1	22.42 (4.92–91.11) 40.5% (<i>–40.8% to 74.8%</i>)	31.82 (2.63–392.60) 77.1% (<i>54.1% to 88.6%</i>)
2	13.46 (2.53–54.44) 53.1% (<i>–11.0% to 80.2%</i>)	7.24 (0.54–40.55) 78.9% (<i>57.5% to 89.5%</i>)
3	10.59 (1.89–35.65) 27.0% (<i>–72.6% to 69.2%</i>)	6.75 (0.88–34) 79.9% (<i>59.5% to 90%</i>)
4	16.44 (2.27–304.44) 33.6% (<i>–51.7% to 71.9%</i>)	6.42 (0.50–38.8) 78.2% (<i>56.3% to 89.2%</i>)
5	14.88 (2.68–138.89) 35.5% (<i>–52.5% to 72.7%</i>)	6.89 (0.64–39.40) 70.4% (<i>40.6% to 85.3%</i>)
6	14.44 (0.86–36.67) 10.5% (<i>–112.0% to 62.2%</i>)	9.39 (0.86–177.80) 54.3% (<i>8.21% to 77.3%</i>)
7	20.09 (1.33–92.2) –18.8% (<i>–181.0% to 49.8%</i>)	14.59 (2.61–94.40) 86.1% (<i>36.0% to 84.1%</i>)
8	26.84 (1.83–583.33)	10.38 (0.80–110.20)

The percentage reduction in airborne Can f 1 on active days was significantly greater when the dog was elsewhere in the house than when it was in the room where the sampling took place (*P*<0.05).

Discussion

Many studies have been performed on the effect of avoidance of house-dust-mite allergen on asthma severity in mite-sensitized asthmatics (reviewed in ref. 6). To achieve a clinical benefit, it is necessary significantly to reduce exposure to mite allergens for several months. Effective allergen avoidance carried out for a sufficiently long period may improve asthma control in sensitized patients. This may be achieved only by targeting the allergen-avoidance measures on the aerodynamic characteristics of the specific allergen.

Exposure to dog allergen occurs not only in homes with dogs but also in homes without dogs, in public buildings (e.g., hotels, cinemas, hospitals), and on public transport

Table 2. Effect of HEPA air cleaner on airborne levels of Can f 1 in houses with dog (geometric means [GM] and ranges for each day and time; ng/m³) when sampling was performed with dog not in room, but elsewhere in house. Shown in *italics* are percentage reductions with 95% confidence intervals (CI) for each time point compared with baseline levels for active and control days

	Control	Active
Hour	ng Can f 1/m ³ ; GM (range) % reduction (95% CI)	ng Can f 1/m ³ ; GM (range) % reduction (95% CI)
1	6.30 (0.69–18.33) <i>71.7% (49.7% to 84.3%)</i>	7.85 (1.86–27.22) <i>85.3% (76.9% to 90.7%)</i>
2	1.79 (0.60–13.56) <i>81.1% (65.9% to 89.6%)</i>	1.15 (0.56–5.89) <i>90.3% (84.6% to 93.8%)</i>
3	1.19 (0.56–7.08) <i>76.3% (57.1% to 86.9%)</i>	0.76 (0.56–4.26) <i>90.7% (85.4% to 94.1%)</i>
4	1.49 (0.56–7.08) <i>75.9% (56.3% to 86.7%)</i>	0.73 (0.56–7.14) <i>87.8% (80.7% to 92.2%)</i>
5	1.52 (0.54–19.44) <i>83.6% (70.3% to 90.0%)</i>	0.96 (0.56–7.14) <i>89.9% (83.8% to 93.5%)</i>
6	1.03 (0.56–7.46) <i>77.6% (59.4% to 87.6%)</i>	0.81 (0.56–2.93) <i>89.9% (84.9% to 93.6%)</i>
7	1.40 (0.60–10.23) <i>76.0% (56.5% to 86.7%)</i>	0.79 (0.56–2.40) <i>88.4% (81.7% to 92.6%)</i>
8	1.51 (0.64–7.58)	0.97 (0.56–13.33)

(7–9). Complete avoidance of dog allergens is clearly impossible in developed countries. However, airborne levels in homes with dogs are very much higher and may be sufficient to cause severe asthma symptoms in sensitized patients. High exposure to Can f 1 in dog-allergic asthmatics may be an important determinant of disease severity, contributing not only to the chronic inflammation, but, due to the aerodynamic characteristics of the allergen-carrying particles, also to the continuous symptoms. The dog is clearly the major source of allergen in homes with dogs; therefore, removal of the dog from the home must be recommended by the physicians treating dog-sensitized asthmatics. Previous studies have found high levels of psychosocial morbidity among these patients (10); anecdotally, the experience of many practising physicians is that most pet-sensitized asthmatics (or their parents/relatives) refuse to part with their pets. Therefore, the challenge is now to develop measures that can effectively reduce exposure to dog allergen while enabling the patient to keep the pet in the home. Preventing the access of the dog to the bedroom and possibly the living room of the home may reduce the total allergen load inhaled, as the results of the current study show that when the dog is present in the room,

airborne levels of Can f 1 are much higher than when the dog is elsewhere in the home.

Our results suggest that airborne Can f 1 in homes with dogs can be reduced by the use of the HEPA air cleaner. To meet the criteria to be considered a HEPA filter, a device must have a minimum particle removal efficiency of 99.97% for particles of 0.3 µm diameter, with higher efficiency for both larger and smaller particles. The high flow rate (250 m³/h) of the HEPA air cleaner enabled the air within the tested rooms to circulate through the device about 10 times each hour (the average volume of the rooms in which sampling was performed was approximately 25 m³). It is interesting to note that over an 8-h sampling period, we observed up to 84% reduction in total airborne Can f 1 even without the use of the HEPA air cleaner. This may be due to the air sampler, which effectively filters 3.6 m³ of room air per hour; i.e., approximately 1/6 of the total volume of air in the room through a 0.3-µm filter each hour. In the absence of the dog as the source of allergen and without artificial disturbance, this could have contributed to the observed fall in airborne Can f 1 levels during the control days. With the dog in the room, we did not observe a similar phenomenon, and marked reduction in allergen levels was achieved only when the HEPA air cleaner was on. It is worth noting that the absolute allergen levels in rooms with dogs during the active air filtration were comparable with the baseline levels in the same rooms without active air filtration, but with the dog elsewhere in the house.

Previous studies of the use of HEPA air cleaners have concentrated on seasonal allergic disease caused by pollens and on asthma in patients sensitized to house-dust mite (11, 12). House-dust-mite allergen is largely carried on particles greater than 10 µm in diameter, which quickly fall out of the air within 1 h of disturbance. On the contrary, more than 20% of airborne Can f 1 and Fel d 1 is carried on small particles which remain airborne (4, 13, 14), and we have observed a similar effect of the HEPA air cleaner on airborne cat allergen in homes with cats (14).

The results of this study suggest that the HEPA air cleaner may reduce the levels of Can f 1 in the air in homes with dogs. Further research is required to establish the clinical effectiveness of this avoidance measure, together with others (such as washing the dog and keeping it outside the main living areas) in the management of patients with asthma who are sensitized to their pet dogs.

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