

Strategies for indoor allergen elimination

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During the last decade, major allergens from such indoor sources as animal dander (cat: Fel d I, dog: Can f I) and mite bodies (group II) or mite feces (group I: Der p I, Der f I) have been biochemically analyzed and sequenced. Immunoassays using monoclonal or monospecific antibodies have been developed, so that the individual domestic exposure to indoor allergens can be quantified. Although there is still some debate about sampling procedures, the most appropriate house dust sources (airborn dust, settled dust in carpets or mattresses) and about the most appropriate expression of allergen exposure (amount/g dust, amount/area, etc.), it has generally become possible to investigate allergen exposure in cross-sectional and longitudinal studies as well as to compare values from country to country.

Several groups of investigators have studied allergen exposure in different geographical areas in relation to climatic factors and living conditions (3). It has become quite clear that outdoor climate (38) as well as indoor humidity and temperature (39) are important determinants for dust mite allergen exposure. The most important determinant of pet allergen exposure is the presence of pets in the environment (40). However, high cat and dog allergen concentrations have also been found in apartments without a pet, as well as in day-care centers and schools (4), suggesting that pet allergens may be carried in on the clothes or shoes.

Dose-response relationship between allergen exposure and atopic disease

A number of studies suggest that the indoor allergen exposure, i.e. concentration of allergens over a certain time, is a significant determinant for both the development of specific sensitization and the development of atopic symptoms in genetically predisposed infants (1). Cross-sectional studies suggest a threshold of 2 µg/g or even lower concentrations for the major allergens from house dust mites.

A retrospective study performed in England reports a correlation between house dust mite allergen exposure in households of atopic infants in the first year of life and the time of onset of wheezing (2).

Preliminary results of the German prospective multicenter atopy study (MAS) indicate that sensitization to indoor allergens, especially to house dust mite and cat, occurs at an early stage of development. Exposure to a mite allergen and/or cat allergen at above 2 µg/g dust was found to induce the development of specific sensitization in atopic infants during the first two years of life.

Taking into account typical house dust mite allergen levels found in carpet or mattress dust samples in Central Europe, and accepting 2 µg/g dust as a threshold concentration for sensitization and the induction of bronchial hyperreactivity, preventive and therapeutic elimination procedures should achieve at least a 95% mite allergen reduction in order to be effective.

House dust mite allergen elimination

Better insulation of houses has been associated with less air exchange and has possibly led to an increase of indoor humidity over recent decades. Extensive studies performed by Korsgaard et al. indicate that a reduction of indoor humidity by better ventilation systems may contribute to a reduction of house dust mites and mite allergens (16/17). However, in parts of Europe with a very high mite allergen exposure the 30%–70% reduction of allergen exposure achieved may not be sufficient to reduce mite allergens below the threshold level.

Vacuum cleaning does not achieve significant allergen reduction. Mite allergens are bound to particles > 10 µm which settle quickly after disturbance. Therefore, air filtering is not effective in mite allergen elimination. Thermic treatment above 60°C kills mites, washing of laundry at lower temperatures also reduces mite allergens by up to 80% (8). Major allergens of *Dermatophagoides* show differ-

Table 1. Mite and mite allergen avoidance procedures

Measures	Authors	Allergen reduction effect	Clinical improvement
Vacuuming and removal of carpets and upholstered furniture	Murray & Ferguson 1983 [15]	+	+
	Walshaw & Evans 1986 [16] (plus encasings)	+	+
	Sarsfield et al. 1974 [17]	+	(+)
	Burr et al. 1980 [18]	-	-
	Korsgaard 1982 [17]	-	n.i.
	Carswell et al. 1982 [23]	-	-
Pirimiphos methyl	Heller-Haupt and Busvine 1974 [24]	+	n.i.
Liquid nitrogen	Mitchell et al. 1985 [25]	+n.i.	
	Collof 1986 [26]	+	n.i.
	Dorward et al. 1988 [27]	+	+
Benzyl benzoate impregnated sheets	Burr et al. 1988 [28]	+	n.i.
Allersearch DMS (benzyl derivate + tannic acid)	Green et al. 1989 [29]	+	n.i.
	Price et al. 1990 [30]	+	n.i.
	Tovey et al. 1991 [13]	+	n.i.
	Elixmann et al. 1988 [31]	+	(+)
	Dietemann et al. 1989 [32]	+	(+)
	Dietemann et al. 1993 [33]	+	-
	Lau-Schadendorf et al. 1991 (only carpets) [11]	(+)	n.i.
	Ehnert 1992 [9]	-	-
Polyurethane covered mattresses, comforters	Ehnert 1992 [9]	+	+
	Lau-Schadendorf et al. 1994 [10]	+	+
3% Tannic acid	Miller et al. 1989 [34]	+	n.i.

n.i.: not investigated

ences in heat stability: group I allergen denatures at 56°C, while group II allergen is denatured after a minimum of 15 min at 100°C. Liquid nitrogen effectively kills mites, but requires special equipment and procedures which can only be carried out by specialists.

Acaricides seem to work *in vitro*, but so far *in vivo* data are not very promising. Benzyl benzoate effectively kills mites *in vitro*, but results on mattresses indicate that penetration rates are too low (11).

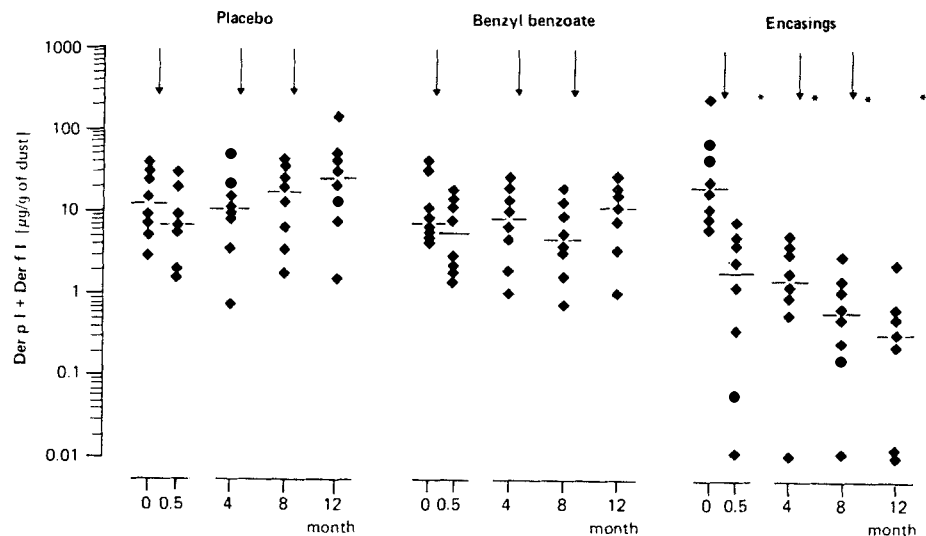
Our group investigated the effect of solidified benzyl benzoate foam and powder on concentrations of the major allergens of *Dermatophagoides* Der p I and Der f I in dust samples from mattresses and carpets in 22 households in a randomized, double-blind placebo-controlled trial (11). All houses had been demonstrated to have significant mite allergen concentrations on mattresses (> 2 µg/g dust). Dust samples were collected from mattresses and carpets before treatment with benzyl benzoate and on Days 10, 30 and 60 after the first treatment. There was a second application on Day 10. We observed a significant reduction of mite allergens in mattresses and carpets in both treated and control groups, but only the results on carpets of the treated group were significantly different from results of the control group on Days 30 and 60 ($p < 0.05$).

Hayden reports that mite allergen reduction can be achieved on carpets if the benzyl benzoate powder remains on the carpet for longer than 12 h (12). Reapplication is suggested every 3 months. However, allergen reduction often does not reach 90%.

Tannic acid denatures proteins. Its effect, which usually lasts 4 weeks, was obviously overestimated because it interferes with enzyme linked immunoassays. An Australian study reported over 90% mite allergen reduction on blankets and carpets with Allersearch DMS, containing tannic acid and a benzyl alcohol (13).

Polyurethane covered mattress and bedding encasings are allergen impermeable but are permeable to perspiration. To study if reduction of mite allergen achieved by polyurethane covered mattress and bedding encasings could reduce bronchial hyperreactivity in sensitive asthmatic patients, 24 children aged 7 to 15 years/median 10 years) with mild or moderate bronchial asthma (definition according to American Thoracic Society) and hypersensitivity to *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* (positive skin pricktest, elevated specific serum IgE [Pharmacia CAP class 3]) were included in a recent study (9). All patients were exposed to high concentration of mite allergen in their mattresses

Fig. 1. Mite allergen levels in three groups before and after treatment (arrows); * $p < 0.05$; bars, median values



(sum of the major allergens Der p I plus Der f I ≥ 2 $\mu\text{g/g}$ of dust).

Patients were randomly allocated to three treatment groups and each patient was studied for 12 months. Patients' homes were visited three times by the same person, who performed the treatment and collected dust samples from mattress and carpet; 16 mattresses were treated with either benzyl benzoate or placebo foam (60 g/m²) in a double-blind fashion on Day 0, at Months 4 and 8. Residues were removed by vacuuming four hours after treatment. For the third group of 8 patients, mattresses, pillows and comforters were covered with cotton encasings coated on one side with polyurethane (Allergy Control, Ridgefield Connecticut USA).

While BB and placebo treatment did not result in a significant reduction of mite allergen, there was a significant decrease in concentration of mite allergen on mattresses covered with polyurethane encas-

ings ($p < 0.005$; Fig. 1). Relative to Day 0 there was already a significant decrease in allergens by Day 14 of 91% ($p < 0.05$), rising to 98% by Month 12.

The degree of bronchial hyperreactivity (PC₂₀FEV₁) in each of the three treatment groups varied widely (Fig. 2). In the placebo group, the median value for PC₂₀FEV₁ decreased from 0.5 mg/ml on Day 0 to 0.27 mg/ml in Month 12 (not significant). BHR in the BB group stayed virtually constant. There was a statistically significant increase of PC₂₀FEV₁ only in the encasing group ($p < 0.01$).

In the meantime, our own results have been confirmed by other investigators. Therefore, it appears that the most efficient procedure to reduce house dust mite allergen exposure below threshold levels for sensitization and bronchial hyperreactivity is the use of encasing for mattresses, comforters and pillows.

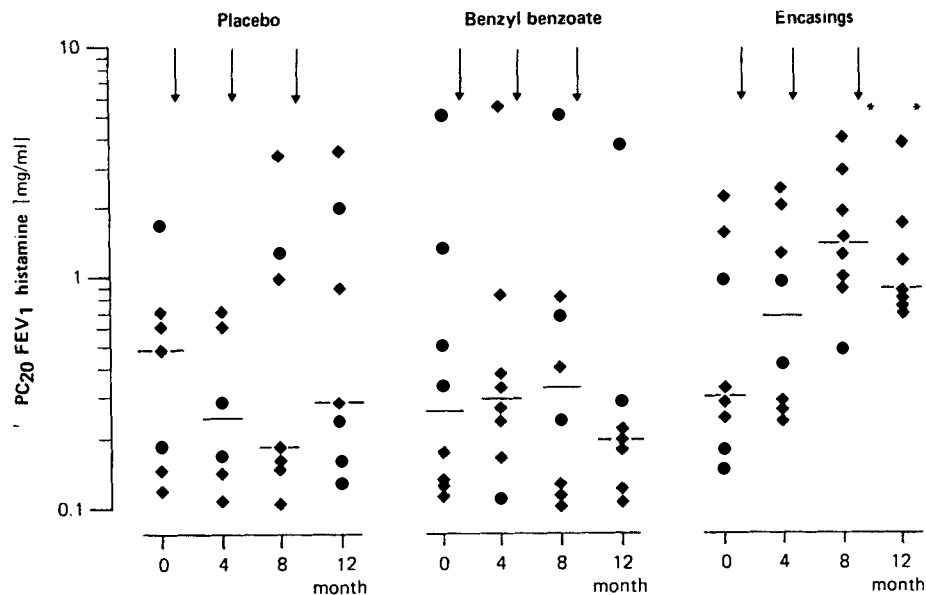


Fig. 2. Bronchial hyperreactivity as measured by provocation concentration causing a 20% fall in FEV₁ (PC₂₀FEV₁ histamine) in three groups before and after treatment (arrows); * $p < 0.05$; bars, median values.

The potential beneficial effect of indoor allergen reduction on atopic eczema has only been studied in a few controlled trials. Most information still is anecdotal. In our own department, patients with atopic dermatitis and specific sensitization to house dust mite allergens already showed clinical improvement with their skin inflammation after eight weeks. This improvement was accompanied by a decrease in serum eosinophil cationic protein, which is considered to be a marker of inflammation (10).

Elimination of pet allergens

Cat and dog allergens seem to be the most important pet allergens in Europe, the USA and Japan. In Sweden over 50% of school children have furred pets at home; 70% of those children suffering from asthma were found to be sensitized to dog or cat dander (4). Allergens of animal dander or urine are bound to small particles (< 5 µm) and remain airborne for prolonged periods and can easily be inhaled. Therefore, in contrast to house dust mite allergens, elimination procedures for allergens from animal dander concentrate on air filtration rather than on carpets, mattresses or upholstery. Dog and cat allergens are also found in houses where no pets live; these sticky allergens are carried into houses on people's clothes. Munir (4) reports finding significant levels of dog and cat allergen in public schools. If a patient is sensitized to animal dander and suffers from associated symptoms, the elimination of the allergen source should be the first line of treatment. There are reports that relevant cat allergen concentrations can be found months after the removal of the cat (5). Vacuum cleaners with HEPA (high efficiency particle arresting) filters can remove cat allergen from air (6), however some authors report less convincing data (7). Unfortunately, clinical data is not yet available. There are also reports that tannic acid can reduce cat and dog allergen in carpets for a week (7).

Preventive elimination

Especially in high-risk babies it is tempting to investigate the effect of preventive reduction of indoor allergen in order to reduce the risk of early sensitization during infancy and early childhood. So far, there has been only one report, from a study performed on the Isle of Wight, where mattress casings were introduced in early infancy together with hypoallergenic dietary regime (15). The results of this study indicate some beneficial effect. Further studies are necessary to find out whether indoor allergen reduction procedures in different parts of the world may contribute to an effective primary prevention of

both atopic sensitization and the development of skin and airway symptoms.

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