

Indoor Allergens: identification and environmental control

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INTRODUCTION

Relationship of environmental indoor allergens to asthma

The association between indoor environmental allergens IgE-mediated hypersensitivity and asthma and/or rhinitis is supported by several findings:

- Numerous studies demonstrate the relation between risk for sensitization and exposure to high concentrations of allergens in homes: a dose-response relationship between the incidence of sensitization to mite and cat allergen and allergen levels during the first 3 years of life was demonstrated by Wahn et al. [1], both in infants with atopic parents and in infants without atopic parents: there seems to be no "safe" minimal level of exposure for atopic individuals; however, an equal rate of sensitization occurs in infants without atopic parents at higher allergen levels (*i.e.*, 25 µg HDM group I allergen per gram of dust versus 0.75 µg/g for 3% sensitization).
- Inhalation of low doses of allergen produces chronic bronchial inflammation and increases bronchial hyperreactivity [2, 3].
- Reducing domestic exposure to dust mite allergens reduces bronchial hyperreactivity in sensitive asthmatic children [4, 5].

– Avoidance of allergen exposure has a preventive effect on the onset of allergic disease: 2 randomized controlled trial of allergen avoidance in the primary prevention of asthma have been published. In the Isle of Wight study, infants with family history of atopy have different rates of sensitization in intervention and control groups (5.2% and 24.2% at 4 years of age) [6]. In the Japanese study [7] reporting the 1-year-follow-up of children post-natally selected on early clinical manifestations of atopy, the rates of sensitization were lower in the active group; they were assessed by measures of specific IgE and positive skin prick tests.

– Avoidance of allergen exposure can induce improvement in asthma severity. Randomized trials have investigated the effects of chemical or physical avoidance measures to control mites, and compared them in asthmatic patients and untreated control groups [8]. A beneficial effect was demonstrated in some trials, while it was not in others. Several problems occur in assessing results of avoidance trials in asthma: a minimal follow-up period of 6 months is necessary, and a successful reduction of allergen exposure should be demonstrated. Heterogeneity of asthma severity, in the patients included in the studies may be an obstacle to evaluate outcomes after avoidance measures and the most effective and

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Table I. – Principal sources of indoor allergens.

Main sources
– Mites (Dermatophagoides, Blomia...)
– Cats and dogs
– Cockroaches
– Moulds
Occasional or anecdotal
– Other animals (rodents, birds...)
– Plants (ficus, flowers...) Fish foods (chironomides...)

efficient methods of achieving indoor allergen avoidance have still not been determined. This should balance the results of the recent meta-analysis of house dust mite control measures in asthma [9]. In a personal one year study, we only demonstrate a reduction in medication intake during the mite season in the active group [10].

IDENTIFICATION OF INDOOR ALLERGENS

The major indoor allergens associated with the risk of allergic diseases differ between and within habitations, depending essentially on climatic factors, characteristics of homes and individuals' lifestyles. The principal sources of indoor allergens are indicated in table I.

Allergen producers in the home can be identified easily when they are visible, *f.i.* cockroaches, pets, or moulds growing in damp buildings. A first step of identifying the most clinical significant world-wide allergen source, *i.e.* the house dust mite is based on house dust sample analysis with binocular magnifiers and microscopes which allow mite counts (per gram of house dust) and species determination. Indoor exposure to moulds can be assessed by identification and counting of fungies in mould cultures of dust samples or air sampling.

The recent availability and use of immunoassays for several indoor allergens has provided more quantitative data on the effective allergen contaminations in homes, and allows identification of the reservoirs of allergens in carpets, furnishings, clothing... The guanine test which is based on the quantification of guanine in mite faeces gives information both on living and dead mites present on the site and also on current colonizations [11]. In a near future, laboratory home tests based on immunochemical identification of mite and cat allergens should be available [12].

The results of measurements of allergens in settled dust may depend on sites, times of

sampling, type and power of vacuum cleaners, seaving of the dust samples. The results can be expressed either in microgram of allergen per gram of dust (*i.e.*, concentration), or micrograms of allergen per unit area (per square meter), which takes into account both concentration and total weight of dust. In temperate climate mean mite (Der p 1) allergen concentrations of 20 to 40 µg of allergens per gram of dust are often observed, but great variations can be observed between different homes; for instance in Strasbourg, among 67 patients with house dust asthma the mean Der p 1 was 28.7 µg/g with a range varying from 0.17 to 176 µg/g (median value: 15.4) [13].

Measurement of allergens can also be performed **on air samplings**, since allergens are carried by a range of particles of different sizes, which affects their ability to remain airborne and to enter the nose or the lung. The amount of airborne allergens is affected by dust disturbance; so, for mite aeroallergen 15 minutes after dust disturbance, only 10 to 20% remain airborne whereas hours later less than 0.1% are still airborne [14]. In contrast, after disturbance, more than 20% of cat and dog allergens associated with particles less than 5 µm in size remain airborne for several days [14, 15]. Cockroach allergens have a similar behaviour after disturbance than mite allergens [16]. Different methods have been proposed to quantify aeroallergen levels:

- Air sampling: area sampling or individual samplings (results expressed in ng or pg of allergen per liter air).
- Collection of settled dust on Petri dishes over one or 2 weeks.
- Nasal air sampler (with impaction sampler onto a protein binding membrane) [17].

The results of these measures depend on the quantity of allergens in dust of different reservoirs in a house, on the level of disturbance and the proximity of the allergen sources; the amount of the aeroallergen is also decreased by air exchange and dilution. With all these parameters taking in account, it appears very difficult to quantify the true individual exposure and further research is needed to obtain data on the relation between the amount of allergens deposited intranasally and/or in the lung, and occurrence of clinical symptoms.

The main current findings concerning indoor allergen measurements are listed below:

Mite allergens:

- Variability from house to house [13].

- No differences in homes of patients and controls [13].
- Beds remain major reservoirs.
- Better identification of other reservoirs in homes:
 - toys (principally old toys) [18],
 - mattress bases [19],
 - carpeted floors (in published studies higher mite levels than smooth floors) [19-21].
- Der p 1 levels in public places lower than in domestic places [23].
- Better knowledge of dust mites prevalences in tropical climate.

Cat allergens

- Present in schools and child care centers (carpeted floors, clothes) [24-26].
- Present in upholstered seats or furniture sampled in public buildings and public transport.
- Airborne Fel d 1 can be measured in some homes without cats.
- Great variability of airborne Fel d 1 in homes with cats [27].

Dog allergens

- High levels of Can f 1 found in almost all homes with a dog, more in living room carpets [15].
- Present in dust samples from public places, especially in upholstered seats [28].
- Dog allergens are airborne in homes with a dog; less than 20% are on small particles (< 5 µm) [15].

Cockroaches

- No difference in homes of patients and controls [29].
- Kitchen is the most infested place [30].
- Cockroach allergens are found in school dust [31].
- No airborne cockroach allergens in undisturbed conditions [16].

ALLERGEN AVOIDANCE

General strategies

The principles of avoidance strategies must be able to address a great variety of patients because ideally avoidance measures should be adapted to each patient's home. The particularity of each home can be determined by specific questionnaires or by a visit of a technician trained in

Table II. – Methods of killing mites and eliminating their allergens.

Methods of killing mites - acaricides - physical methods in order to decrease dwelling humidity - physical active methods: - freezing - steam cleaning - boil washing - dry cleaning
Methods for eliminating allergens - removal of infested reservoirs, - washing, laundry - denaturation of allergens (tannic acid, hot washing > 100°) - establishing barriers to avoid mite and mite faeces getting through → encasing: use of covers

environmental control. Identification of allergen sources within the house should be completed by house dust sample analyses (mattress samples but also samples collected from other places); the proposed avoidance measures should also take into account the personal resources of the patients.

Strategies to address the known sites where the allergens occur combine 3 methods:

- Elimination of reservoirs of settled dust such as bed material, carpets, furnishing, clothing....
- Control of the sources of new allergen (*i.e.*, living mites, residential animals, plants, exceptionally...).
- Cleaning air when allergens are airborne.

Dust mite control

The means available to control dust mite exposure are based on methods which kill mites or eliminate mite allergens, and on strategies for lowering mite colonisation in homes, which affect design and construction of houses [32, 33].

The different procedures involved in killing mites and eliminating allergens are detailed in table II:

The methods aimed at eliminating allergens are not specific to mite allergens. They can be applied to other indoor allergens, especially to allergens from cat and dog.

Mattress covers

Encasing mattresses is an easy and popular method, and justifiably so, since the bed is by far the most important site of allergen exposure, due to the time spent by patients, in or near the

source of allergens. Several trials in which bedding was encased in impermeable covers have shown that the remaining allergen level at the surface of covers is about 2% of the initial allergen concentrations [34]. Persistence of reduction in allergen concentration was demonstrated, except in special climates when levels of house dust mite allergens are exceptionnally high (increasing levels observed after 4 to 5 months in Sydney [35], Melbourne [36]). Plastic covers were used initially, but a real progress was obtained with covers which allow passage of water vapour and yet have small enough pore size to prevent passage of mites and faecal particles. Even fine woven cotton fabrics which allow 50% of air flow restrict allergen passage completely [37].

However, when the mattress is encased, exposure to allergens in other location is not affected; pillows, quilts, over bedding must also be encased. Concerning pillows it was recently shown that synthetic pillows accumulated mite allergens significantly faster than those filled with feather and after a 12 months period contained approximately 5 fold more Der p 1 [38]. Other reservoirs need sometimes to be removed or treated physically or chemically with acaricides for instance carpets, box-springs, soft-furnishings. New unencased mattresses can reach high allergen concentrations within 4 months of use [39]. Clinical efficacy studies with control groups gave positive results when mattress encasing was associated with other methods (acaricides, washing bedding, vacuuming) [40-43]. In short term studies (≤ 3 months) no beneficial effect was observed [44, 45].

Laundry for bedding, carpets, clothing, toys

Washing in cool water will wash out most dust and can remove allergens (> 20-fold reduction) but does not kill mites; living mites cling to the textile. Washing in hot water (60°C) kill mites and removes allergens. By low temperatures, using additives may result in killing mites: 40-60% of living mites survive with detergent, 3% with detergent plus eucalyptus oil 0.2%, no mite survive with detergent plus 0.03% benzylbenzoate [46].

Replacement of carpets with smooth flooring

Carpets contain more dust and it has been shown in several studies that they contain higher allergen concentration than smooth floors [19-22]. Smooth flooring can easily be cleaned by

damp wiping and rendered allergen-free. In some studies use of acaricide such as benzyl benzoate showed positive results but not in others [10, 35]. Carpets incorporating acaricide products are under investigation. At the moment there is a trend to avoid carpets for hygienic reasons [32]. However, for commercial reasons, the carpet industry has put forward arguments pointing out the beneficial aspects of carpets able to grasp aeroallergens and prevent them from becoming airborne. However, no scientific data confirm this assumption.

Vacuuming and vacuum cleaners

It has been demonstrated that dry vacuum cleaners remove mites with difficulties (20% after 40 minutes), especially living mites which are sticking on the deep fibers in carpets [47, 48]. But intensive dry vacuum cleaner can pick up dust and reduce allergen reservoirs in carpets and furnishings. This may be useful to decrease the amount of allergen rendered airborne by disturbances. It has been shown that vacuuming with high frequency vibration system [49], and wet vacuum cleaning [50] can induce better removal of allergens. Steam-cleaning can kill mites, but there is a problem of residual water which can favour humidity and mite colonization [51]. For patients allergic to mite, it is recommended to use vacuum cleaners equipped with a 2 layers' bag and HEPA or electrostatic filtration system on the exhaust air [52].

Air cleaners

Mite allergens settle quickly after disturbance and are certainly not affected by air filters operating at a distance. A recent study [43] showed that use of air cleaners together with covers on mattresses, had a greater effect on peak expiratory flow rate and non specific bronchial hyperreactivity than using covers alone.

Acaricides

Many acaricidal products are available on the market and usually their efficacy is based on laboratory tests and not on domestic trials [53]. Clinical studies including placebo control group are available for benzyl benzoate; positive results have been demonstrated on allergen exposure [4, 54], but a significant clinical benefit was only shown when this acaricide was used together with other avoidance measures [10, 53].

Reduction in indoor humidity

Knowledge of the mechanisms controlling mite survival could lead to better means of controlling mite populations. Up to now, relative humidity has been shown to be the most important factor in mite survival [56, 57]. But mites have biological advantages which permits their survival and the protonymph forms can survive in cold and low relative humidity for months.

Raising indoor humidity can affect mite levels and eliminating indoor humidity sources should never be neglected as an obligatory approach to reduce mite exposure (*i.e.*, reducing humidity sources such as baths, showers, cooking, and avoiding high occupant densities) [58]. Optimization of air exchange rates has been successfully applied in Denmark (1 - 1.5 AC/h) [59] but has not been successful in more humid climates such as U.K. [60, 61]. Building age, dampness, double glazing are factors which can influence mite allergen levels. Air conditioning may be beneficial (continuous use of refrigerative air) [62] or not (evaporative cooling units can increase humidity) [63, 64]. Low allergen level houses should be the aim of an ecological approach of mite avoidance, this implies a comprehensive approach integrating hygienists, medical doctors, architects and building constructors.

Animal allergen control

The optimum strategy is to permanently remove domestic animals; however, this is not always possible for social and psychological reasons. When cats are removed, the allergen levels drop to up 70% but the levels in reservoirs (carpets) decline slowly over months [65]. It is also important to avoid allergen portage from the outside (allergen transfer probably occurs by means of clothing) [26]. If pets cannot be removed, they should be kept outside as much as possible. When they stay in flats they should be kept out of the bedroom, in a separate room with hard surfaces which can be cleaned extensively. Other reducing procedures have been proposed: washing the animal, which achieves a reduction in allergen shedding, use of HEPA filter, air cleaners, mattress encasement, removing of

carpets, all these methods being proposed to remove both airborne allergens and reservoirs [61, 66].

Other indoor allergens

Cockroaches

Methods for decreasing exposure are aimed at reducing exposure by professional eradication procedures and by preventive measures (routine cleaning and elimination of sources of food and water). Recent studies used hydramethylnon or abamectin but did not reduce cockroach allergens after a 6 and 12-month period [68].

Fungi

There are no convincing published data on the importance of exposure to indoor fungi allergens in asthma symptoms. Avoidance methods are mainly based on reduction of indoor humidity and domestic hygiene measures [69].

CONCLUSION

We have more and more adequate tools to identify and quantify the most important indoor allergens. However, many questions remain unanswered. They concern the population who could take a benefit from avoidance measures, and the methods used to decrease total indoor exposure. So far, we have no marker to predict who will benefit by avoidance measures; some studies indicate that primary prevention could decrease the rate of sensitization in atopic children, but the exact benefit on childhood asthma will only be assessed more precisely by the results of extensive primary prevention studies currently in progress in Europe, North America and Australia. It is also highly probable that persistence of allergen indoor exposure is associated with a higher risk of persisting asthma as was shown for occupational asthma. Efficacy of intervention measures certainly also depend on the phenotype and severity of asthma.

Other factors of proven importance include patient compliance with the proposed avoidance measures, the motivation of both the patient and the physician, the acceptability of the avoidance plan, and the help of a technician or nurse specialized in indoor environmental factors.

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