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Indoor allergens: identification and environmental control*

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Summary

The relationship of indoor environmental allergens to asthma, especially in genetically predisposed individuals is better and better established. Knowledge of the principal indoor allergens has so far been secondary to identification of major allergen producers – both animal and vegetable – present in domestic homes. Chemical dosages of the major allergens (mainly allergens from mites and domestic animals) being now available, quantification of the allergens we are exposed to, has become possible: the most meaningful results are reported for each of them. Strategies for indoor allergen avoidance combine three methods: elimination of reservoirs of settled dust such as bed material, carpets, furnishing; control of the sources of new allergens (living mites, household pets, occasionally plants); reduction of airborne allergens. The different procedures involved in eradicating mites and eliminating mite and animal allergens are reviewed in detail. Objective data concerning the effectiveness of environmental control measures in the management of asthmatic patients are difficult to obtain, sometimes giving contradictory results. Further clinical studies are still needed with better designs concerning the most appropriate avoidance methods and criteria of patients' selection.
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allergens control / indoor allergens

Résumé – Allergènes de l'environnement intérieur : identification et contrôle.

Les relations entre l'exposition aux allergènes de l'environnement intérieur et la survenue d'asthme, principalement chez les sujets génétiquement prédisposés, sont de mieux en mieux établis. L'identification des principaux allergènes de l'environnement intérieur a consisté à dénombrer les principaux représentants du monde animal et végétal producteurs d'allergènes dans l'habitat. Grâce au dosage des allergènes majeurs, une évaluation quantitative de l'exposition aux différents allergènes, représentée majoritairement par les allergènes d'acariens et d'animaux, est possible, et les acquisitions les plus récentes sont rappelées pour chacun d'entre eux. Les stratégies d'éviction des allergènes associent trois méthodes : l'élimination des réservoirs d'allergènes accumulés dans les substrats textiles, l'élimination ou au moins la maîtrise des producteurs d'allergènes, la réduction des allergènes aéroportés. Les différentes méthodes d'éviction des acariens et des allergènes animaux, recommandées au cours de la dernière décennie, sont rapportées en détail. Les preuves objectives de leur efficacité dans la prise en charge thérapeutique de l'asthme chronique sont difficiles à apporter et parfois contradictoires. Des études cliniques plus nombreuses, avec une méthodologie d'intervention très précise sur des patients mieux ciblés, sont encore nécessaires. © 2000 Éditions scientifiques et médicales Elsevier SAS

contrôle des allergènes / allergènes de l'environnement intérieur

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Relationship of indoor environmental allergens to asthma

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

- Numerous studies demonstrate the relation between risk of sensitization and exposure to high concentrations of allergens in the home: a dose-response relationship between the incidence of sensitization to mite and cat allergens and allergen levels during the first 3 years of life has been demonstrated by Wahn et al. [1], both in infants with atopic parents and in infants without atopic parents; there seems to be no 'safe' minimum 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 g of dust versus 0.75 mg/g for 3% sensitization).
- Inhalation of low doses of allergens 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 exposure to allergens has a preventive effect on the onset of allergic disease: the results of two randomized controlled trials on allergen avoidance in the primary prevention of asthma have been published. In the Isle of Wight study [6], infants with a family history of atopy have been found to have different rates of sensitization in intervention and control groups (5.2 and 24.2% at 4 years of age). In the Japanese study [7] reporting the one-year follow-up of children postnatally selected for early clinical manifestations of atopy, the rates of sensitization were lower in the active group, and were assessed by means of specific IgE and positive skin prick tests.
- Avoidance of exposure to allergens can bring about an improvement in asthma severity. Randomized trials have investigated the effects of chemical treatment or physical avoidance in the control of house mites, and compared them in asthmatic patients and untreated control groups [8]. A beneficial effect has been demonstrated in some trials, while this was not found to be the case in others. Several problems occur in assessing the results of avoidance trials for

Table I. Principal sources of indoor allergens.

Main sources

Mites (*Dermatophagoides*, *Blomia*)
Cats and dogs
Cockroaches
Moulds

Other sources

Animals other than household pets (rodents, birds)
Plants (ficus, flowers); fish foods (*Chironomides*)

asthma: a minimal follow-up period of 6 months is necessary, and a successful reduction in allergen exposure should be demonstrated. The heterogeneity of asthma severity in the patients included in the studies may be an obstacle in evaluating the outcome following avoidance measures, and the most effective and 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 one-year study carried out by the present group, we were only able to 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 homes, depending essentially on climatic factors, specific characteristics of the home and individual lifestyle. The principal sources of indoor allergens are indicated in *table I*.

The source of allergens in the home can be identified easily when they are visible, e.g., cockroaches (*Blattella germanica*), household pets, or mould present in damp buildings. A first step in identifying the most clinically significant worldwide allergen source, i.e., the house dust mite, is based on house dust sample analysis with binocular magnifying equipment and microscopes which allow mite counts (per g of house dust) and species determination. Indoor exposure to mould can be assessed by identification and counting of fungi 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 allergen contamination in the home, and allows identification of the reservoirs of allergens in carpets, furnishings, clothing, etc. The guanine test which is based on the quantification of guanine in mite faeces provides information on living and dead mites present at the site, and also on current colonizations [11]. In the near future, laboratory tests for the home, based on immunochemical identification of mite and cat allergens, should become available [12].

Measurement of allergens in settled dust

The results of measurement of allergens in settled dust may depend on the site, time of sampling, the type and power of the vacuum cleaner, and the sieving of the dust samples. The results can be expressed either in μg of allergen per g of dust (i.e., concentration), or in μg of allergen per unit area (per square metre), which takes into account both the concentration and total weight of the dust. In temperate climates, mean mite (Der p 1) allergen concentrations of 20 to 40 μg of allergens per g of dust are often observed, but wide 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 $\mu\text{g}/\text{g}$ with a range varying from 0.17 to 176 $\mu\text{g}/\text{g}$ [13].

Measurement of air samples

Measurement of allergens can also be performed on air samples since allergens are carried by a range of particles of different size, 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; 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 dust 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 to mite allergens [16].

Different methods have been proposed to quantify aeroallergen levels: i) air sampling – area samples or individual samples (results expressed in ng or pg of allergen per L air); ii) collection of settled dust on petri dishes over one or two weeks; iii) nasal air sampler (with impaction sampler on a protein-binding membrane) [17].

The results of these measurements depend on the quantity of allergens in the dust from different reservoirs in the 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 taken into account, it appears very difficult to quantify precise 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 the occurrence of clinical symptoms.

CURRENT FINDINGS ON INDOOR ALLERGEN MEASUREMENTS

Mite allergens

Regarding mite allergens, the following findings should be noted: variability from house to house [13]; no differences between the homes of patients and controls [13]; beds remain major reservoirs; better identification of other reservoirs in homes; toys (principally old toys) [18] and mattress bases [19] as a source of allergens; carpeted floors (in published studies higher mite levels have been found in the latter than on smooth floors) [19-22]; Der p 1 levels in public places are lower than in domestic sites [23]; improved knowledge regarding dust mite prevalence in tropical climates.

Cat allergens

Cat allergens are present in schools and child care centres (carpeted floors, clothes) [24-26]; in upholstered seats or furniture in public buildings and public transport; airborne Fel d 1 can be measured in some homes without cats; there is a wide variability of airborne Fel d 1 in homes with cats [27].

Dog allergens

High levels of Can f 1 are found in almost all homes with a dog, with higher levels in living room carpets [15]; they are also present in dust samples from public places, especially in upholstered seats [28]; these allergens are airborne in homes with a dog; less than 20% are found on small particles ($< 5 \mu\text{m}$) [15].

Cockroaches

No difference is found in the homes of patients and controls [29]; the kitchen is the most infested place in the home [30]; cockroach allergens are found in school dust [31]; no airborne cockroach allergens are detected in undisturbed conditions [16].

ALLERGEN AVOIDANCE

General strategies

The principle of avoidance strategy should be to address a wide variety of patients, because ideally avoidance measures should be adapted to each patient's home. The particularity of each home can be determined via specific questionnaires or by the visit of a technician trained in 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 patient.

Strategies to address the known sites where the allergens occur should combine three methods: i) elimination of reservoirs of settled dust such as bed material, carpets, furnishing, clothing, etc.; ii) control of the sources of new allergens (i.e., living mites, household pets, occasionally plants); (iii) cleaning the air when allergens are airborne.

Dust mite control

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

Table II. Methods of exterminating mites and eliminating their allergens.

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1. Methods of exterminating mites
 - Acaricides
 - Physical methods to decrease house humidity
 - Physical active methods
 - Freezing
 - Steam cleaning
 - Boiling washing
 - Dry cleaning
 2. Methods for eliminating allergens
 - Removal of infested reservoirs, washing, laundry
 - Denaturation of allergens (tannic acid, hot washing $> 100^\circ$)
 - Establishing barriers to avoid mite and mite faeces getting through $\rightarrow$ encasing: use of covers
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THE DIFFERENT PROCEDURES INVOLVED IN ERADICATING MITES AND ELIMINATING ALLERGENS

The different procedures involved in eradicating mites and eliminating allergens are shown 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 those 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]. The persistence of reduction in allergen concentration has been demonstrated, except in certain climates where levels of house dust mite allergens are exceptionally high (increased levels observed after 4 to 5 months in Sydney [35] and Melbourne [36]). Plastic covers were used initially, but real progress was obtained with covers which allowed the passage of water vapour and yet had a sufficiently small pore size to

prevent the passage of mites and faecal particles. Even fine-woven cotton fabrics which allow 50% of air flow restricted allergen passage completely [37].

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

Washing of bedding, carpets, clothing and toys

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

Replacement of carpets with smooth flooring

Carpets contain more dust and it has been shown in several studies that they contain higher allergen concentrations than smooth floors [19-22]. Smooth flooring can easily be cleaned by damp wiping and thereby rendered allergen-free. In some studies, the use of an acaricide such as benzyl benzoate has shown positive results, but not in other studies [10, 35]. Carpets incorporating acaricide treatment products are under investigation. At the moment there is a trend towards avoiding carpets for hygienic reasons

[32]. However, for commercial reasons, the carpet industry has put forward arguments on the beneficial aspects of carpets which provide a site for aeroallergens and prevent them from becoming airborne. However, no scientific data have been reported which confirm this assumption.

Vacuuming and vacuum cleaners

It has been demonstrated that dry vacuum cleaners do not effectively remove mites (20% after 40 minutes), especially living mites which stick to the deep fibres in the carpets [47, 48]. But intensive dry vacuum cleaning can pick up dust and reduce allergen reservoirs in carpets and furnishings. This procedure may be useful in decreasing the amount of allergens rendered airborne by disturbance. It has been shown that vacuuming with a high frequency vibration system [49], and wet vacuum cleaning [50] can result in better removal of allergens. Steam-cleaning can kill mites, but introduces a problem of residual water which can favour humidity and further mite colonization [51]. For patients who are allergic to mites, it is recommended to use vacuum cleaners equipped with a 2-layer bag and a HEPA or electrostatic filtration system fitted to the exhaust [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] has shown that the use of air cleaners together with covers on mattresses has a greater effect on peak expiratory flow rate and non-specific bronchial hyperreactivity than using covers alone.

Acaricides

A number of 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 groups have been carried out 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 of indoor humidity

Knowledge of the mechanisms involved in 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 certain biological characteristics which permit their survival, and the protonymph forms can survive in the cold and in low relative humidity for months.

Raising the level of indoor humidity can affect mite numbers, and eliminating sources of indoor humidity should never be neglected as an obligatory approach in reducing exposure to mites (i.e., reducing humidity from sources such as baths, showers, cooking, and avoiding high occupant density in the home) [58]. Optimization of air exchange rates has had successful results in Denmark (1-1.5 AC/h) [59] but has not been successful in more humid climates such as in the UK [60, 61]. Building age, dampness, or 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]. Houses with a low allergen level should be the aim of an ecological approach toward mite avoidance, which implies a combined approach on the part of hygienists, medical doctors, architects and building constructors.

Animal allergen control

The optimum strategy in animal allergen control 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 up to 70%, but the levels in reservoirs (carpets) decline slowly over a period of months [65]. It is also important to avoid allergen transport from the outside (allergen transfer probably occurs via clothing) [26]. If pets cannot be removed, they should be kept outside as much as possible. When they remain in flats they should be kept out of the bedroom, and in a separate room with smooth sur-

faces which can be cleaned extensively. Other allergens reduction procedures have been proposed: washing the animal, which limits the spread of allergens, use of a HEPA filter, air cleaners, mattress encasement, removal of carpets. All these methods have been proposed to remove both airborne allergens and reservoirs [66].

Other indoor allergens

Cockroaches

Methods for decreasing exposure to cockroaches consist of professional eradication procedures and preventive measures (routine cleaning and elimination of sources via food and water). Recent studies have used hydramethylnon or abamectin, but these products did not reduce cockroach allergens after a 6- and 12-month period [68].

Fungi

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

CONCLUSION

We now have an increasing number of adequate tools to identify and quantify the most important indoor allergens. However, many questions still remain unanswered. These concern the patient population which could best benefit from avoidance measures, and the methods used to decrease total indoor exposure. So far, we have no marker for predicting who will benefit from avoidance measures; some studies indicate that primary prevention could decrease the rate of sensitization in atopic children, but the exact benefit regarding childhood asthma can 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 the persistence of indoor exposure to allergens is associated with a higher risk of persisting asthma, as has been shown for occupational asthma. The efficacy of intervention measures certainly also depends on the phenotype and on the severity of the asthma.

Other factors of determined importance include patient compliance with the proposed avoidance measures, the motivation of the patient and physician, the acceptability of the avoidance strategy, and the assistance of a technician or nurse specialized in indoor environmental factors.

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