



Asthma and Indoor Environment: Usefulness of a Global Allergen Avoidance Method on Asthma Control and Exposure to Molds

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Abstract The usefulness and feasibility of a global allergens avoidance method with counselors visiting patients' home for allergens measures and adapted advices were prospectively evaluated through asthma control and environment evaluation. Twenty seven patients were prospectively included and compared to a cohort of 30 control patients. The level of control of asthma at inclusion and after 1 year was evaluated by the clinical signs, the evolution of the FEV1, and the healthcare use. Environmental measurements included the fungal load of 5 surfaces of the dwellings and the evaluation of moisture. A significant clinical improvement in the population that benefited from the home counselors visit was observed compared to the

baseline ($p < 0.0001$), as well as a decreased number of hospitalizations for asthma and of the consumption of anti-asthma drugs ($p < 0.01$). Dampness markers slightly improved with an improvement of the fungal loads in two-third of the dwellings.

Keywords Home intervention · Asthma · Allergens · Pollutants · Molds

Introduction

Asthma is a heavy burden for public health with hundreds of millions of patients in the world for whom optimal preventing strategies are questioned [1].

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Patients with asthma are commonly exposed to multiple indoor allergens, and during large periods of time: individuals usually spend more than 50% of their time at home [2]. These multiple and repeated exposures may contribute to the increased asthma-related complications in this population. Besides pharmacological treatment, healthy home environments may have impact on the morbidity of asthma. Several studies that triggered a single antigen avoidance (mainly mite or pet-derived allergens) have shown limited evidence of their efficacy on the clinical improvement of patients [3]. Interventions for multiple indoor allergens have been attempted using various strategies. An individualized, home-based, comprehensive environmental intervention was shown to decrease exposure to indoor cockroach and dust-mite allergens, resulting in reduced asthma-associated morbidity in a disadvantaged population [4]. Mold sensitization is common amongst patients with severe asthma requiring multiple hospital admissions [5]. More recently, an association between the use of cleaning products and elevated risks for asthma was reported [6], as well as cleaning at home and at work related to lung function decline and airway obstruction [7].

Our work aimed to assess the impact of a global allergen avoidance method implemented by an indoor environment counsellor (IEC) on the clinical improvement of the patients and on multiple indoor environmental risk factors. The intervention of IEC consisted of the evaluation of the allergens in the indoor environment, measurement of physical parameters, sampling for culturable fungi, and providing educational advices to the patients to limit indoor moisture, pollutants such as cleaning agents, and allergens among which fungal allergens, but excluded renovation works. Through specific tools, they advise the patients on the global avoidance method: cockroach, dust-mite, cat and dog allergens, moisture and fungal allergens, and indoor pollutants including tobacco smoke, disinfectants and volatile organic compounds.

Methods

In this pilot study that enrolled 57 asthmatic patients of more than 12 years of age from Brittany, France, 27 patients were prospectively included in the group with intervention on home indoor environment, and

compared to a cohort of 30 control patients that had the standard of care without any intervention. The 27 patients prospectively included in the group with intervention benefited from a 1-year follow-up. The follow-up encompassed a clinical evaluation of signs of asthma according to international GINA (Global Initiative for Asthma) and French HAS (Haute Autorité de Santé) classifications, and the reporting of the numbers of hospitalizations triggered by the asthma, the level of consumption of anti-asthma drugs, up to which point the asthma was under control, and functional parameters such as the forced expiratory volume in 1 s (FEV1) after informed consent was obtained. An increase of $FEV1 \geq 12\%$ was considered as an improvement, and stability was defined by changes between 0 and $+12\%$.

In addition, a baseline visit of patient's home by the IEC was set up to characterize the indoor environment in dwellings, to provide health counseling and to perform several physical measures, among them the estimation of the fungal load on five different surfaces sampled: under the kitchen sink, under the bathroom sink, on the floor of the living room, and on the floor and the wall of the bedroom. A standardized protocol was applied for the sampling using humidified swabs on surfaces of 10 cm^2 , and swabs were inoculated on Sabouraud-Chloramphenicol Agar plates which were incubated at $30\text{ }^{\circ}\text{C}$ for 5 days. A follow-up visit was performed by the same IEC at the end of the study under similar conditions with similar sampling locations.

The fungal load was scored focusing on molds that was the sum of the scores for each of the 5 surfaces (ranked 0 when 0 to 9 CFU/plate; 1 when 10 to 49 CFU/plate; 2 when 50 to 99 CFU/plate; and 3 when count $> 100\text{ CFU/plate}$). Thus an arbitrary score was determined based on the experience of the team on level of contamination of the dwellings, going from 0 to maximum 15. The environmental measurements also included the Acares test, the count of signs of humidity in four classes (no humidity stains on the wall; $> 0\text{ to } \leq 100\text{ cm}^2$; $> 100\text{ to } \leq 500\text{ cm}^2$; $> 500\text{ cm}^2$) and the perception of dampness (arbitrary score taking into account humidity traces, dampness odour and peel off paintings and wall papers).

The level of control of asthma of the 27 patients was evaluated based on the clinical signs according to international GINA and French HAS classifications and compared to a control group of 30 asthmatic

patients that had the standard of care without intervention. All data were anonymised and answering to the survey was voluntary and the completed questionnaire acted as an informed consent. The comparative analysis of data before and after the visit within the intervention group and of pairs of patients between intervention and control groups based on univariate analysis used SAS® software.

Results

At inclusion, 71.4% of the patients were classified as uncontrolled/unacceptable asthma, 23.8% as partly controlled/acceptable asthma, and 4.8% as controlled/optimal asthma (Fig. 1a). The fungal score at baseline was statistically independent from various housing characteristics: geographic location (urban/rural), house age, living level (ground/elevated floors), number of rooms, heating mode, ventilation type, clothes drying type (dryer or not), presence of plants, presence of pets, presence of smokers. By contrast, dampness perception and number of signs of humidity were statistically associated to the presence of molds ($p = 0.02$ and $p = 0.01$ respectively).

At the end of the clinical follow-up (1-year visit), we observed a significant clinical improvement in the intervention group that benefited from the IEC visit compared to the baseline (Fig. 1a, $p < 0.0001$). The FEV1 was increased by more than 12% for 60% of the patients (including 25% for whom the FEV1 increased by more than 36%) (Fig. 1b). During the year of the study, the number of hospitalizations for asthma decreased from 28 to 4, without requiring any admission into the intensive care unit. The consumption of anti-asthma drugs (especially corticosteroids) was also dramatically decreased compared to the year before, by 42% for the inhaled agents, and by 71% for the oral route agents ($p < 0.01$).

Regarding environmental criteria, a good compliance of participants to adopt behaviors susceptible to decrease their exposure to risk factors resulted in a decreased perception of dampness and of signs of humidity (improvement for 1/3 of the dwellings) as well as an improvement of the global indoor fungal load for 62% of dwellings (Fig. 1b). Almost all patients accepted to remove visible molds, to avoid smoking indoor, to ventilate at least 15–30 min the bedroom and the living room, to remove dust reservoir

and use vacuum cleaner with HEPA filters, and to use a mattress cover when Acares test was positive, as suggested by the IEC after the first visit.

The clinical improvement was also significant compared to the control group with 78% of improvement after a 1-year follow-up in the intervention group versus 41% in patients that had the standard of care without intervention ($p < 0.01$).

Discussion

Home interventions by healthcare workers are conducted to decrease the exposure to indoor allergens, to give educational advices on the use of chemical products such as cleaning agents and disinfectants, and counseling on wash machines, dryers, use of boilers etc.... Ultimately the objective is to improve the health status of asthmatic patients.

Few studies have evaluated the changes in patients behavior. Some studies have been conducted that evaluated the impact of a single allergen avoidance, and they showed mixed results. Other studies described global allergens avoidance strategy based on education-based methods, physical methods, or combining both types of methods. The most effective approaches are a matter of debate. Interventions via visits at home by health workers allow to provide patient- and home-adapted recommendations, which are often associated with good compliance. Very few studies adopted this patient-education plus home-intervention approach and none evaluated the impact on patients' health outcome. In this pilot study, this approach was selected to evaluate its feasibility. Our results demonstrate that a larger study should be conducted, and that it might demonstrate measurable health improvements.

Overall, the modification of the indoor environmental risk factors may offer an opportunity for control of asthma severity for some patients [8–10]. The value of home interventions implemented by trained healthcare workers and combining both education-based methods and a global allergen avoidance method warranted in our study a significant improvement of asthma control for most of the patients. For patients who did not benefit from a clinical improvement, other factors than home environment may have accounted such as professional environment, genetic factors and other health conditions. Nevertheless,

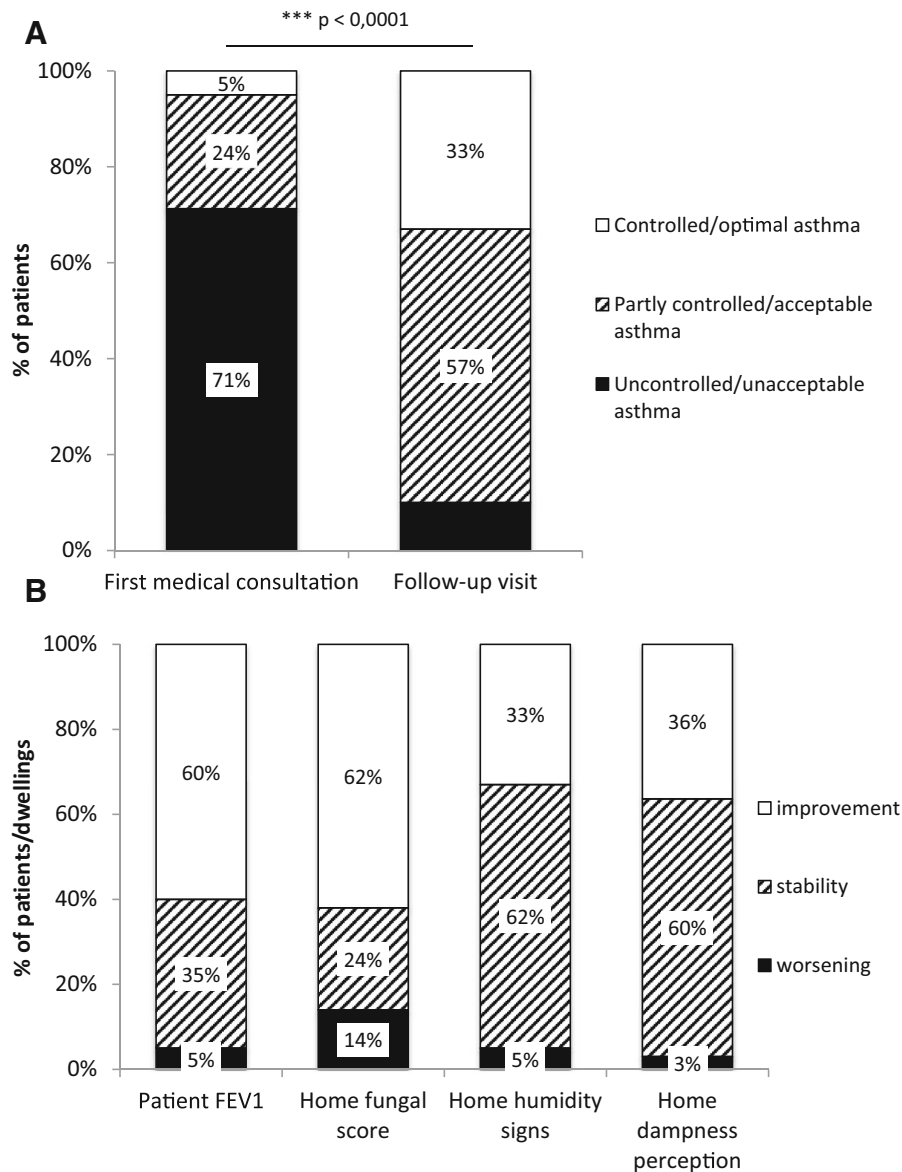


Fig. 1 **a** Level of asthma control according to international GINA (Global Initiative for Asthma) and French HAS (Haute Autorité de Santé) classifications. *** significant improvement between the first medical consultation and the follow-up visit

($p < 0.0001$). **b** Evolution of patients' FEV1 (forced expiratory volume in 1 s), and of home fungal score, humidity signs and dampness perception, between the first visit and the follow-up visit

although preliminary, our data are promising. Some limitations of the study may be underlined such as assessing environmental contamination by Acarex test might be criticized since this test is not quantitatively accurate. Moreover, swabbing surfaces and the use of a unique culture medium may not be sufficient to assess the indoor contamination by molds. In the literature, a wide range of methods for sampling and

analyzing fungal loads in indoor environment are reported, but what is instrumental is to keep a standardized method in case of before-after studies [3]. Air or dust samples are considered by some authors as more representative of indoor mold exposure. Likewise, molecular tools, particularly the Environmental Relative Moldiness Index (ERMI) is a DNA-based metric developed to describe the fungal

contamination in dwellings that showed to be useful in making decisions about reducing fungal exposures in homes [11, 12].

Further studies using a multifaceted approach are warranted to better understand the environmental determinants of asthma and related respiratory diseases in various countries. Following this feasibility study that is evidently limited because of the limited number of patients, a French randomized controlled multicenter study is currently recruiting (NCT02212483) that aims to assess the clinical effectiveness of IEC on the asthma control using various techniques for the evaluation of the fungal load. Importantly, the medico-economic impact of this intervention will be assessed. Indeed, the asthma prevalence is high in France, with about 6.7 to 7.5% of adults older than 45 years suffering from a chronic obstructive pulmonary diseases [13], and about 125,000 individuals suffering from severe asthma with fungal sensitization (SAFS) episodes (189 cases/100,000 adults per year) [14].

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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