EMERGING TECHNOLOGY

Comparison of the efficacy of two airborne disinfection products in reducing the *Aspergillus fumigatus* contamination from hospital false ceiling reservoirs

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ABSTRACT

Objectives: The aim of this study was to compare, in a blinded design, antifungal efficacy of two airborne disinfectants (AD) for *Aspergillus*-contaminated false ceilings of hospital rooms.

Methods: Two types of ADs containing either hydroxyacetic acid (AD#1) or peracetic acid + H2O2 (AD#2) were tested for the disinfection of *A. fumigatus* on false ceiling of four hospital rooms. Airway disinfection involves non-directed spraying of disinfectants reaching all surfaces contained in a given volume.

Results: A total of 11 different false ceiling tiles were sampled before and after disinfection in each of the four rooms tested. Product AD#2 showed a Contamination Rate (CR) of *A. fumigatus* decreasing from 7.2 ± 6.5 colony-forming units (CFU)/m² (mean±SD) before to 2.5 ± 3.4 after disinfection (*adjusted p*=0.05). AD#1 had CR fall from 9.4 ± 8.5 CFU/m² to 7.9 ± 7.3 (*adjusted p*=0.80).

Conclusions: AD#2 is significantly more effective at eradicating *A. fumigatus*, thus representing a good alternative to environmental management of this pathogen in hidden reservoirs.

KEY WORDS

Aspergillosis, airborne disinfection, environment reservoir, hospital

INTRODUCTION

Aspergillus fumigatus is a filamentous, ubiquitous saprophyte fungus that causes invasive infections in immunocompromised patients, often with severe outcomes and 50-90% mortality (1,2). Contamination occurs by inhalation of airborne conidia spores, with various consequences, from allergy to invasive aspergillosis (IA) (3,4). The species evoking IA are mostly *A. fumigatus* (>80%), *A. flavus, A. terreus* and, rarely, *A. nidulans* (3). Incidence of IA has been associated mainly with fungal exposure due to infrastructure work (5-8). Persistence of fungal spores in hospital environment creates reservoirs which directly impact IA incidence (9-11). For several decades we have known that dust above false ceiling is an environmental niche for *Aspergillus* which can be re-suspended in the air when maintenance or renovation work are carried out (12). The most effective way of decreasing IA occurrence is to eliminate those reservoirs and avoid direct patient exposure to environmental *Aspergillus* conidia by an appropriate disinfection (13-14). Airborne disinfection comprises the non-directed spraying of disinfectants onto surfaces within a determined volume, and can be ejected in dry or wet vapor forms. A fine particle aerosol is generated with particles settling onto surfaces and decontaminating them. The usual airborne disinfectant (AD) AD#1 used at our hospital include hydroxyacetic acid for false ceiling disinfection. Lately, another product comprised of hydrogen peroxide (H_2O_2) with peracetic acid has become available. In this study we evaluated the antifungal efficacies of two airborne disinfectants (AD) for decontamination of false ceilings from *A. fumigatus*.

METHODS

The study was conducted in one of the 32 blocks of an 800-bed teaching hospital in Lyon (France) in December 2014. The building was recently closed for subsequent demolition. This was an opportunity to evaluate the extent of contamination with *A. fumigatus*, and to test the technical feasibility of airborne disinfection within false ceilings of partly active medical wards.

Sampling strategy

Four similar rooms of a 24-bed medical unit were randomly selected for the study. The rooms were comparable in volume, location and exposure. Sampled false ceiling tiles were randomly assigned. Top of chosen tiles were entirely sampled with sterile wipes (Biomerieux®) before and a day after AD application (Figure 1). Tiles selected were measured in square meters (a mean of 1,65 m² of tiles located in center and 1,66 m² of tiles located at rooms corners) in order to report the *A. fumigatus* contamination measured to the surface sampled (CFU/m²).

Application of disinfection product

AD#1 contained 4% hydroxyacetic acid (80 mg/m³), and AD#2 contained 3% peracetic acid (~1,200 ppm) and 0.12% H_2O_2. Each AD was assigned to two different rooms out of the four rooms tested and applied by the same operator, as recommended by the supplier. Rooms were emptied and all openings were sealed during the disinfection period. In order to facilitate AD dispersion in false ceilings in the tested rooms, few tiles were slightly displaced just before AD application. Thus, chemical particles could saturate the room entirely and be active on all surfaces.

Plate incubation and reading

Sterile wipes were transferred into stomacher bags filled with buffered peptone water (200 ml) afterwards. For each sample, 1 ml was inoculated on yeast extract glucose chloramphenicol agar. Negative controls were realized with unused sterile wipes. Plates were incubated five days at 37°C and checked every 48 hours to observe *A. fumigatus* colonies growth. *A. fumigatus* colonies were counted, microscopically identified and expressed in colony-forming units per square meter (CFU/m²). Only *A. fumigatus* colonies were considered in this study.

Statistical analysis

Before this study began, preliminary tests were conducted on false ceiling tiles of another medical unit to ascertain the best sampling technique, between sampling by sterile wipes and agar impaction, for evidencing at least 75% of decontamination with a probability of 90% between the two groups (data not shown). Continuous data were reported as mean ± standard deviation (SD) for each condition (after and before disinfection) and each AD (AD#1 vs AD#2). The similarity of contamination distribution before disinfection among the four rooms was checked by the Kruskal-Wallis test. Then, contamination distribution was compared before or after disinfection vs AD#1 or AD#2, by Wilcoxon rank test leading to four statistical tests: i) before AD#1 vs before AD#2, ii) after AD#1 vs after AD#2, iii) before AD#1 vs after AD#1, and iv) before AD#2 vs after AD#2. We reported *p* values for each single test and *p* values adjusted for multiple (i.e., 4) comparisons with the Holm method (15). For all statistical tests, the two-tailed significance level was *p*≤0.05.

RESULTS

A total of 11 different false ceiling tiles were sampled before and after disinfection in each of floor rooms tested leading to
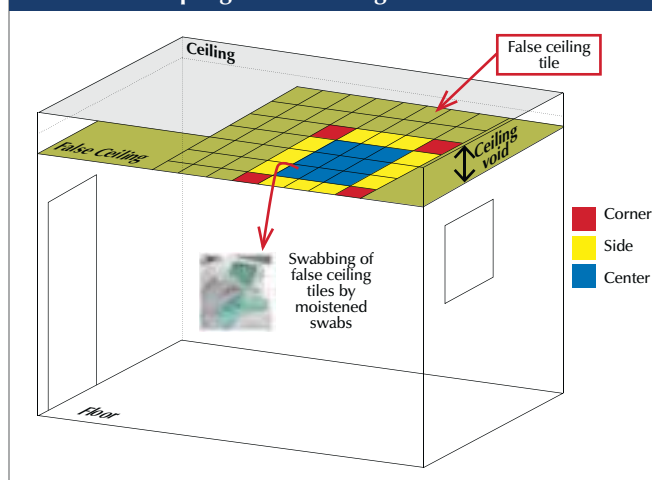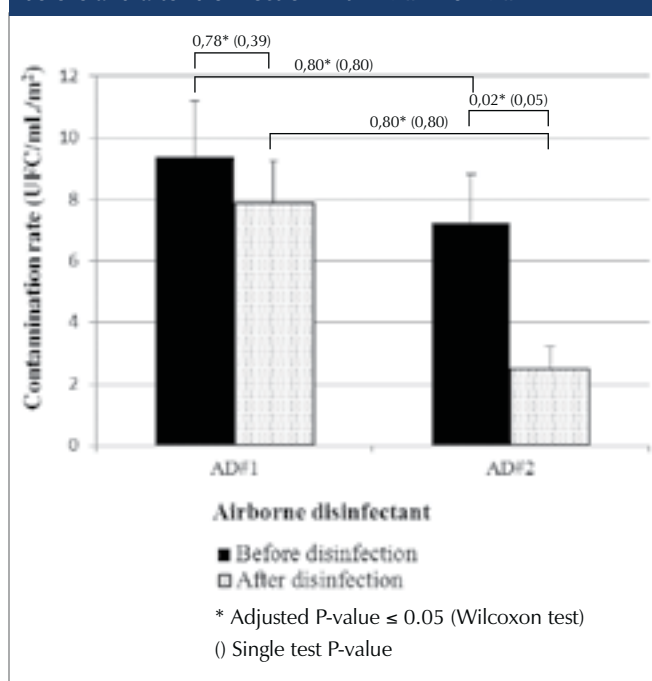

FIGURE 1: Sampling of false ceiling tiles

FIGURE 2: Evaluation of false ceiling tile contamination before and after disinfection with AD#1 vs AD#2

* Adjusted P-value ≤ 0.05 (Wilcoxon test)
() Single test P-value

22 observations per occasion and product, i.e., a total of 88 observations. All 88 environmental samples were collected and processed for isolation of *A. fumigatus* colony.

Comparison of A. fumigatus load before and after disinfection with each AD

No statistically significant difference of *A. fumigatus* contamination was found between corner tiles and center tiles in the four rooms before or after disinfection. Similarly, no difference was found across the four rooms before disinfection (*p*=0.72). Mean values (CFU/m²) before disinfection were: AD#1 vs AD#2: 9.4±8.5 vs 7.2±6.5 (*p*=0.39, adjusted *p*=0.78). The evolution of *A. fumigatus* contamination after AD

application is shown in Figure 2. Significant differences between the two products after disinfection were found. After AD, CFU/m^2 values were: AD#1 vs AD#2 against *A. fumigatus*: 7.9±7.3 vs 2.5±3.4 ($p=0.02$, adjusted $p=0.05$).

Efficacy of AD products on *A. fumigatus* tiles load

Fungal loads of *A. fumigatus* were compared before and after disinfection with AD#1 or AD#2. In the AD#1 group, the *A. fumigatus* contamination rate was 9.4±8.5 before and 7.9±7.3 CFU/m^2 after disinfection ($p=0.80$, adjusted $p=0.80$), whereas in the AD#2 group, the *A. fumigatus* contamination rate was 7.2±6.5 before and 2.5±3.4 CFU/m^2 after disinfection ($p=0.01$, adjusted $p=0.04$) (Figure 2). Reduction rates were 16% for AD#1 and 66% for AD#2 respectively.

DISCUSSION

AD#2, the new tested product, composed of H_2O_2 and peracetic acid vapor was effective against *A. fumigatus* as it delivered 66% reduction of environmental colonization vs. 16% for AD#1. Construction, renovation and maintenance work in healthcare facilities present a challenge to the safety of immunocompromised patients by exposing them to *Aspergillus* conidia re-suspended in the air. This mold is ubiquitous both indoors and outdoors, often growing behind walls and above false ceilings. To ensure safe environment for immunocompromised patients with respect to *Aspergillus*, it is important to reduce the airborne burden of conidia. It has already been demonstrated that IA rates can be decreased by enhancing environmental management around high-risk patients (9). We consider that one of the relevant ways to prevent the spread of these airborne pathogens is to reduce environmental reservoirs by using optimal products to reach this objective. Some have investigated the efficacy of airborne systems for the disinfection of some hospital environments and for infection control, but their antifungal efficacy has not been evaluated on false ceilings which expose high-risk patients to IA during maintenance/renovation work in hospital wards (16-17). Our investigation confirmed the high homogenous presence of *A. fumigatus* on the false ceilings of hospital units. To our knowledge no other study has investigated the contamination rate of *A. fumigatus* on false ceiling of hospital rooms and evaluated disinfection methods *to prevent its* spread during renovation/maintenance. The antifungal efficacy of both of the tested products complied with the French standards for fungicide activity (NF T 72-281). The main difference between the two technologies is the emission of chemical particles. One of the products, (AD#1), ejects particles in dry vapor form, whereas the other product (AD#2) occurs in wet vapor form. These products are used in different fields of work. AD#1 typically disinfects surfaces in the food industry and canteens, whereas AD#2 is mostly confined to medical device disinfection and sterilization in the pharmaceutical industry. AD#1 appears to be the least expensive product available and more suitable for hospital food service areas rather than ward disinfection. For application of these products, rooms need to be vacated and air vents sealed for several hours, depending

of the product applied and the volume of the room. While some studies have shown the effectiveness of those systems as an environmental disinfectant and infection control measure, this has still some limitations for use in real life settings, where wards are occupied by patients and rooms are rarely empty (16). In this study we tested these products in an empty ward in order to evaluate its efficacy for false ceiling disinfection before renovation work. No leakage of product was observed; so it seems that these products could be used in sealed part of wards undergoing renovation work even if the other parts of the wards remain active.

Our study has some limitations. Neither the kinetics of *Aspergillus* colonization on false ceiling tiles, nor the contribution of this source compared to other sources (surfaces, air, water) were estimated. The study focused only on one empty conventional medical ward and cost effectiveness was not assessed for both products which had different purchase prices.

CONCLUSION

This study highlighted the presence of environmental reservoir of *A. fumigatus* on hospital false ceiling. The new product, AD#2 appears to be the most efficient for *A. fumigatus* eradication from room false ceiling. Our data indicate that airborne disinfection devices can help prevent Aspergillosis risk from hidden environmental reservoirs, such as false ceilings in hospitals by lowering the *A. fumigatus* bioburden present on tiles just before removing it for infrastructure facility. Our findings also showed that this protocol seems possible in a sealed part of an active hospital ward undergoing renovation.

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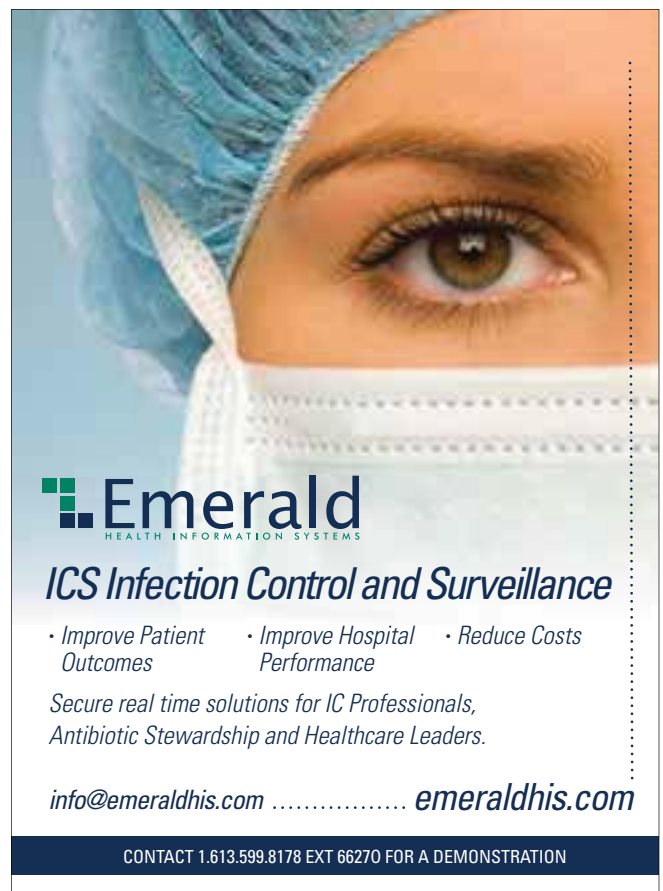
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