Fungal aero-decontamination efficacy of mobile air-treatment systems

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Immunosuppressed patients are at high risk of acquiring airborne fungal infections, mainly caused by *Aspergillus* species. Although HEPA filters are recommended to prevent environmental exposure, mobile air-treatment units can be an alternative. However, many different models of mobile units are available but there are few data on their fungal aero-decontamination efficacy and usefulness in the prevention of *Aspergillus* infections. Thus, we developed a challenge test, based on the aerosolization of $10^6$ *Aspergillus niger* conidia, in order to compare the particle and fungal decontamination efficacy of the following four mobile air-treatment systems; Plasmair T2006, Mobil’Air 1200 (MA1200), Mobil’Air 600 (MA600) combined with Compact AirPur Mobile C250 (C250), and the prototype unit Compact AirPur Mobile 1800 (C1800). The use of all these air-treatment systems was able to significantly decrease the concentration of particles or fungal viable conidia. ISO7 was the maximum particle class reached within 20 min with the Plasmair T2006 and MA1200, 1 h by the combined MA600/C250, and 1 h and 30 min with the C1800. After 2 h, fungal counts were significantly lower with Plasmair T2006, MA1200 and the combined MA600/C250 (2.2 ± 1.9 to 5.0 ± 3.7 CFU/m$^3$) than achieved with the C1800 (23.8 ± 12.8 CFU/m$^3$; $P \leq 6.0E^{-3}$). All the air-treatment systems were able to decrease aerial particle and fungal counts, but their efficacy was variable, depending on the units’ air-treatment modalities and rates of air volume that was processed. This comparative study could be helpful in making an informed choice of mobile units, and in improving the prevention of air-transmitted fungal infections in non-protected areas.

**Keywords** Mobile air-treatment units, *Aspergillus niger*, challenge tests, particle and fungal counts, aero-decontamination efficacy

Introduction

Invasive aspergillosis (IA) is a life-threatening infection in immunocompromised patients, during treatment of hematologic malignancy with prolonged neutropenia, allogenic bone marrow or organ transplantation [1]. The development of new antifungals (newazole drugs and echinocandins), galactomannan and 1,3 beta-D-glucan detection, and early CT-scan-based diagnosis have improved the prognosis of IA patients. However, the high mortality, the increasing incidence of systemic fungal infections and rising medical costs have made prevention of fungal spore exposure by environmental protection a crucial challenge [2].

Guidelines from the National Agency for Health Accreditation and Evaluation (Agence Nationale d’Accréditation et d’Évaluation en Santé [ANAES]) & French Society of Hospital Hygiene (Société Française d’Hygiène Hospitalière [SFHH]) and the Centers for Disease Control and Prevention (CDC) [3–5] recommend the use of high efficiency particulate arrestance (HEPA) air filtration. This has been shown to reduce airborne fungal contamination and decrease IA incidence [6–10], when combined with a
positive pressure (>15 Pa (Pascal) or >2.5 Pa, respectively) and a high rate of air changes per hour (>20 or >12 air changes per hour, respectively). However, the large-scale use of these systems is curtailed due to costs and local configuration of pre-existing hospital buildings.

Mobile air systems can be used as alternatives to improve the protection of patients at risk for fungal infection during their stay in non-protected hospital areas. However, the installation of mobile air-treatment units can also be a challenge, especially during renovation work. In addition, mobile units are still considered to be less efficient than HEPA filtration for fungal aero-decontamination [11] and there is no consensus as to their usefulness in the prevention of IA [3,4]. Many different models, with variable air-treatment modalities and rates of air volume processing, are available but there is little data on their fungal aero-decontamination efficacy and usefulness for IA prevention.

The majority of information on their application has been provided by the manufacturers. Some published data are available but they are based on highly variable sampling methods and strategies and there have been no comparative analyses. For example, a 35% reduction of the Aspergillus fumigatus counts has been reported during a one-year study when results from rooms with the NSA model 7100A/B Environmental Air System (National Safety Association Ltd, USA) (5.3 A. fumigatus CFU/m³; range 0.8–41 CFU/m³) were compared to those without air filtration units (8.1 A. fumigatus CFU/m³; range 0.8–42 CFU/m³) [11]. Similarly, the use of Plasmair (Airinspace, France) in 107 patient rooms of an adult hematology unit during a 13-month surveillance period resulted in a significant decrease in the number of positive air samples and fungal loads (59% and 4.9 CFU/m³ vs. 100% and >39.4 CFU/m³ in rooms without air treatment) [12]. Furthermore, when an Immunair (Airinspace, France) which is a mobile unit that recycles and distributes treated air through a plenum, was investigated through functional tests (27-hour tests, with previous vigorous dry dusting), and clinical trials (in four patient rooms over 15–55 days), airborne fungal levels were systematically maintained below 1 CFU/m³ in the protected zone and were significantly lower than those of the surrounding test room [13]. Lastly, a decrease in the incidence rate of IA, from 34.61/100,000 to 17.51/100,000 patient-days (P < 0.01), has been recently reported in a retrospective 31-month study comparing IA incidence before and after installation of HealthPro 150 units (IQAir, INCEN AG, Switzerland) during a period of major renovation in Singapore General Hospital. These results suggest that mobile units could potentially be used in reducing costs associated with prolonged hospitalization of IA patients [14]. Here, we compared the particle and fungal decontamination efficacy of four mobile air-treatment units or combinations of the equipment using a challenge test, based on the aerosolization of 10⁶ A. niger conidia.

**Materials and methods**

**Experimental procedure**

All the experiments (one control and four test conditions) were performed in the same 42 m³ (17 m²) room, with sealed ventilation systems and neutral air pressure (Fig. 1). Relative humidity, which was measured regularly during the course of the experiments, ranged between 30% and 87% (51–77% before aerosolization, 63–87% after aerosolization, and 30–81% 2 h after aerosolization). Mobile units were placed according to the manufacturer’s instructions, in a corner, in order to optimize room coverage, and at least 1 m from the wall, in order to obtain optimal airflow into and through the unit. Mobile units, aerosolization equipment, and particle/fungal counter positions in the room are described in Fig. 1. C250 was put on the MA600 for the combined MA600/C250.

Room access was limited to one operator wearing protection glasses, and disposable mask, gloves, cap and gown. For safety reasons (limitation of fungal exposure), the operator stood outside the room during the experiment and performed quick opening and closing of the door to come into the room when necessary (e.g., for fungal dispersion, activation of mobile units, particle and fungal samplers). The space under the door, which was the only obvious air intrusion point in the room, was protected using a wet cloth in order to prevent air leakage out of the room or air intrusion from the corridor. Before and after each experiment, a complete bio-cleaning of the room (floor and walls) was performed systematically according to the manufacturer’s instructions using Surfanios at 0.25% in water (Anios, Lille-Hellemmes, France) detergent, disinfectant and decontaminating solution which contains three active ingredients, i.e., an aminoacid chlorhyde (the

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**Fig. 1** Map of the room indicating the localization of mobile air-treatment units, aerosolization equipment (A), particular (P) and air fungal samples (F1 and F2). For the combined MA600/C250, C250 was put on the MA600.

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N-(3-aminopropyl)-N-dodecylpropane-1,3-diamine), the didecylidimethylammonium chloride, and calcium and potassium ion chelators.

For each experiment, $10^6$ A. niger conidia were aerosolized using an Aerosept (Anios) aerosolizer. The A. niger isolate used was a clinical strain (Mycology Department, Lille University Hospital), whose identification was confirmed at the phenotypic and genotypic levels (data not shown). A. niger conidia suspensions were prepared daily in 300 ml of sterile water, from a 5- to 7-day culture on half-diluted agar Sabouraud medium with kanamycin, incubated at 30°C and checked using a counting chamber. Dispersion of the 300 ml challenge was completed within 20 min, using magnetic agitation to avoid sedimentation of the conidia, and total dispersion of the suspension was checked after each experiment.

Once A. niger conidia had been fully dispersed after the 20-min challenge, samplers were activated for one particle and two fungal viable count measurements (T0). Then mobile units were started, and particle and fungal counts were measured similarly after 10 min, 20 min, 40 min, 1 h, 1 h 30 min, and 2 h. For each system, experiments were repeated three times on three consecutive days.

**Particle counts and air sampling methods**

Particles ≥0.5 and ≥5 μm were counted using a Light-house Solair3100 + (Ecomesure, Janvry, France). Particle counts were measured over five 1-min intervals, operating at a flow rate of 28.3 l (1 cubic ft) per minute. Fungal air counts were measured on 1000-l samples, collected using a SampAir MK2 biocollector (AES Chemunex, Bruz, France) on 90 mm diameter Petri dishes containing half-diluted agar Sabouraud medium with kanamycin, incubated at 30°C and read after three and five days to count and identify A. niger and other fungi colony-forming units (CFU) according to their macroscopic and microscopic features. The maximum measurable fungal concentration was limited by the number of impact points of the biocollector, and reached 260 CFU/m³.

**Mobile air-treatment units**

Five mobile air-treatment units were tested – Plasmair T2006 (Airspace, Montigny le Bretonneux, France), Mobil’Air 1200 (MA1200), Mobil’Air 600 (MA600) (Air Medical Program, Bondues, France), Compact AirPur Mobile C250 (C250) and a prototype unit: Compact AirPur Mobile 1800 (C1800) (PhotocleanQuartz, Champagne au Mont d’or, France). Their characteristics are indicated in Table 1. They are all European Community marked mobile air-decontamination units. All except the C250 are higher than 129 cm and deeper than 46 cm, and occupy a great deal of space in a patient room.

Briefly, Plasmair T2006 unit, which is a class II FDA registered medical device and a class I medical device compliant with European Directive 93/42/EEC (1993), is a reactor combining HEPA filtration with microorganism destruction. It accomplishes the latter by a three-step mechanism including exposure to high electric fields that deform and alter their membrane and cell wall, subsequent bombardment with positive and negative ions that destroy the internal structures, and electrostatic nano-filtration. Air output can reach 2000 m³/h and can be adapted to the room volume. Mobil’Air units (MA1200 and MA600), are based on H14 HEPA filtration (according to the criteria of the European Norm EN1822:2000) [15]. Three outputs are available for each unit, but other outputs can be selected if needed. Maximum outputs are 1200 m³/h for MA1200 and 800 m³/h for MA600. Compact AirPur Mobile units (C250 and C1800) are based on photocatalysis with a final destruction of microorganisms by UVC and toxic oxygen radicals on a photocatalytic media. Four outputs are available, with maximum outputs of 360 m³/h for C250 and 1800 m³/h for C1800.

All the units include pre-filtration steps with F or G filters, whose classification is determined according to EN779:2002 [16], from the average filtration efficiency (Em) of 0.4 μm diameter particles and for G filters (whose Em is ≤40%), from the average arrestance (Am) of synthetic dust. These filters are F6 (60–80% Em) filtration and activated carbon medias for Plasmair T2006, G4 (≤40% Em, ≥90% Am) and F7 (80–90% Em) filtration medias for Mobil’Air units, one pre-filer and an activated carbon media for C250, and only a F6 filtration media for C1800.

For the tests, room-size adequate outputs were selected according to the manufacturer’s recommendations. They were similar for Plasmair T2006 (1100 m³/h), C1800 (1100 m³/h) and MA1200 (1000 m³/h), yielding higher than 20 air changes per hour in the 42 m³ room used for the tests (26.19 and 23.81, respectively). MA600 (600 m³/h) was combined with C250 (200 m³/h), which provided the advantage of adding photocatalysis inactivation to filtration. The resulting 800 m³/h output (i.e., 19.05 air changes per hour) was lower than that of the other units but corresponded to a tolerable noise level if this combination had to be installed in a patient room (Table 1).

**Statistical analysis**

The mean particle counts or number of CFU per m³ were evaluated for significance by Student’s $t$-test. A $P$ value equal to or less than 0.05 was considered statistically significant.
Natural sedimentation effect on particle and fungal kinetics

As expected, in the control conditions, particle counts after aerosolization were high, reaching $7.26 \pm 5.81 \log_{10}/m^3$ for particles $\geq 0.5 \mu m$ and $6.63 \pm 5.84 \log_{10}/m^3$ for particles $\geq 5 \mu m$ (Fig. 2). During the 2-h experiment, counts of particles $\geq 0.5 \mu m$ were stable ($7.27 \pm 5.71 \log_{10}/m^3$, Fig. 2a), whereas natural sedimentation of particles $\geq 5 \mu m$ yielded a slight decrease, reaching $6.10 \pm 5.48 \log_{10}/m^3$ at T2 h (Fig. 2b). Fungal counts were higher than the detection limit (260 CFU/m$^3$) until T1 h (251.2 $\pm$ 9.7 CFU/m$^3$, Fig. 3). From T1 h to T2 h, the effect of natural sedimentation yielded a weak but measurable and reproducible decrease of A. niger conidia aerial concentration, reaching $185.2 \pm 31.2$ CFU/m$^3$ at T2 h.

Decontamination efficacy of mobile air-treatment units

When mobile air-treatment units were added, particle and fungal decontamination revealed a two-step kinetics, with an early (\(\lesssim 20\) min) and late phase (T40 min – T2 h).

Firstly, after aerosolization (T0), particle counts were similar to those of the control conditions for all the units, reaching $7.26 \pm 5.72$ to $7.28 \pm 5.91 \log_{10}/m^3$ for particles $\geq 0.5 \mu m$ and $6.49 \pm 5.67$ to $6.63 \pm 5.66 \log_{10}/m^3$ for particles $\geq 5 \mu m$ (\(P \geq 0.225\) and \(P \geq 0.368\), respectively, Fig. 2). However, this high, reproducible initial particular aerosol-contamination, which suggested a negligible experimental variation, could not be confirmed at the fungal viable count level, since initial A. niger concentrations were not measurable (\(> 260\) CFU/m$^3$). Plasmair T2006, C1800, and MA1200 kinetics revealed, after 10 min, a 1 log$_{10}$ and a 2 log$_{10}$ decrease of particles $\geq 0.5 \mu m$ and $\geq 5 \mu m$, respectively, and a substantial decrease of the fungal aerosol-contamination (9.2–19.3 CFU/m$^3$). After 20 min, we observed with the Plasmair T2006 and MA1200 a 1 log$_{10}$ supplementary decrease in particle $\geq 0.5 \mu m$ and $\geq 5 \mu m$, and a slight decrease in fungal aerosol-contamination (2.8–5.3 CFU/m$^3$), but, for C1800, particle $\geq 0.5 \mu m$, $\geq 5 \mu m$, and fungal aero-contamination (15.2 ± 3.3 CFU/m$^3$) only slightly decreased. For the combined MA600/C250, only a slight decrease of particles $\geq 0.5 \mu m$ and a 1 log$_{10}$ decrease of particles $\geq 5 \mu m$ were observed, after 10 min. Fungal aero-contamination decrease was also substantial, but the fungal concentration remained significantly higher than for the other units (72.3 ± 39.4 CFU/m$^3$; \(P \leq 8.9E-3\) (Figs. 2 and 3). After 20 min, a 1 log$_{10}$ decrease in particles $\geq 0.5 \mu m$ and $\geq 5 \mu m$, and in fungal aero-contamination was observed (6.8 ± 2.4 CFU/m$^3$), yielding similar results as the Plasmair T2006 and MA1200 ones (Figs. 2 and 3).
Secondly, in the late decontamination phase (≥40 min), only slight decreases (<1 log_{10}) in particle and fungal counts were observed. For all the units, when particle counts were interpreted according to the ISO 14644-1 airborne particulate cleanliness classes [17], ISO7 (which corresponds to maximal particle/m^3 counts of 352,000 for particles ≥0.5 μm and 2,930 for particles ≥5 μm) was the maximal particle class reached, more or less quickly, i.e., after 20 min for Plasmair T2006 and MA1200, 1 h for the combined MA600/C250 and, after 1 h and 30 min for C1800. Fungal aero-contamination was stable after 20 min for Plasmair T2006 (2.2–4.5 CFU/m^3), MA1200 (3.5–5.3 CFU/m^3), and the combined MA600/C250 (3.2–6.8 CFU/m^3). The C1800 showed no significant supplementary decrease of the fungal aero-contamination after 10 min and exhibited higher concentrations than the other units (15.2–23.8 CFU/m^3).

The lowest particle counts were reached after 2 h for all the units. Particles ≥0.5 μm counts were similar for Plasmair T2006, MA1200, and the combined MA600/

**Fig. 2** Particle counts at the end of the 10^6 A. niger conidia aerosolization (T0), and 10 min, 20 min, 40 min, 1 h, 1 h 30 min, and 2 h after aerosolization. (a) Particles ≥0.5 μm counts; (b) Particles ≥5 μm counts. The discrepancy between initial particles ≥5 μm counts (6.49–6.63 log_{10} /m^3 at T0) and the 4.38 log_{10} CFU/m^3 theoretical concentration of viable CFU obtained by dispersing 10^6 conidia into a 42 m^3 room is probably related to aerosolized water particles counting by the Lighthouse Solair3100+. **ISO7 was the maximal particle class reached by all the units. According to the ISO14644-1 classification, ISO7 corresponds to maximal particles/m^3 counts of 352,000 for particles ≥0.5 μm and 2,930 for particles ≥5 μm [17].**
C250 (Fig. 2, \(P \approx 0.115\)). They were slightly higher for C1800, but this difference was not statistically supported \((P \approx 0.288)\). Particles \(\approx 5\) \(\mu\)m counts were similar for Plasmair T2006 or MA1200 \((P = 0.700)\), significantly lower than for the combined MA600/C250 \((P \approx 1.1E-3)\), and the C1800 \((P \approx 0.036)\). Furthermore, after 2 h, fungal counts were significantly lower for Plasmair T2006, MA1200 and the combined MA600/C250 \((2.2 \pm 1.9\) CFU/m\(^3\), \(4.0 \pm 2.1\) CFU/m\(^3\), and \(5.0 \pm 3.7\) CFU/m\(^3\), respectively) than for C1800 \((23.8 \pm 12.8\) CFU/m\(^3\); \(P \approx 6.0E-3)\).

**Fungal diversity in air samples**

Before aerosolization of *A. niger* conidia, 23–240 CFU/m\(^3\) were detected, including a large variety of fungal species, such as *Penicillium* spp. \((50.7 \pm 72.6\) CFU/m\(^3\)), *A. fumigatus* \((3.5 \pm 4.6\) CFU/m\(^3\)) and *Cladosporium* spp. \((2.2 \pm 2.5\) CFU/m\(^3\)). After aerosolization, as expected, *A. niger* was the main species recovered during the experiment in the control conditions, and the only species isolated in the initial air samples after air-treatment by mobile units. Nevertheless, other fungi from the natural environmental flora of the room were also isolated (Table 2). They were detected after 20 min with the Plasmair T2006 and MA1200, and after 40 min with the combined MA600/C250. Interestingly, for C1800, non-*A. niger* species counts were detected even at T10 min (Table 2).

**Discussion**

Our study reports the first description of challenge tests to compare and evaluate mobile air-treatment units’ ability to eliminate airborne particles and *Aspergillus* conidia. Control conditions revealed that particle aerial concentrations resulting from *A. niger* conidia aerosolization were high, reproducible, and persistent within the 2-h experiment. Counts of particles \(\approx 5\) \(\mu\)m (which were comprised between 6.49 and 6.63 \(\log_{10}\) CFU/m\(^3\)) were much higher than the 4.38 \(\log_{10}\) CFU/m\(^3\) (23,800 CFU/m\(^3\)) theoretical concentration of viable CFU obtained by dispersing \(10^6\) conidia into a 42 m\(^3\) room. This discrepancy, which is too high to result from the basal particle concentration of the room, is more probably related to aerosolized water particles counting by the Lighthouse SolarAir3100. After aerosolization, fungal concentrations were not measurable but this observation was consistent with the 23,800 CFU/m\(^3\) theoretical concentration of *A. niger* conidia. After 1 h, sedimentation of *A. niger* conidia, which are known to be able to concentrate on surfaces and form a reservoir of conidia [7], yielded a decrease in fungal aerial concentrations which became measurable. This decrease was reproducible on the three repetitions of the experiment made for each assay, which supported the validation of the *A. niger* inoculum size and of the experimental conditions.

When we evaluated the air-treatment units (using three repetitions for each experiment), a broad range of particle counts, spanning several logs, was observed. This observation was not unique to any one air-treatment unit, and was also found in the control conditions, and thus would appear to be a phenomenon of the sampling technique. Application equally throughout the experiment enabled a comparison of results. The higher particle and fungal aero-decontamination early efficacy of Plasmair T2006, C1800, and MA1200 was consistent with the higher outputs of these units \((\approx 1000\) m\(^3\)/h – 23.81 air changes per hour versus 800 m\(^3\)/h – 19.05 air changes per hour for the combined MA600/C250), and supported the critical role of airborne particle and fungal levels for the Plasmair T2006, MA1200, and combined MA600/C250. These levels, which were lower than those of the C1800, suggested that features other than the output, such as air-treatment modalities (filtration, or inactivation by photocatalysis or cold plasma), number and type of prefilters/filters, or air flow, influenced equally the performance of the unit when airborne contamination levels were closer to the natural levels. The late efficacy of the combined MA600/C250 were also consistent with previous studies reporting a reduction of the fungal load or the IA incidence by very low output units, such as the NSA 7100A/B (112–168 m\(^3\)/h) or the IQAir HealthPro 150 (40–350 m\(^3\)/h) portable units [11,14]. Nevertheless, the data of these studies should be interpreted carefully because of their design (which resulted in...
frequent windows opening and output reduction or unit stop during the night due to the high noise level) [11] or their retrospective nature (which resulted, for example, in a high variability of immunosuppression levels in included patients, or the absence of information on the antifungal prophylaxis protocol) [14]. It is likely that basic patient room management associated with the mobile unit’s installation contributed to the mobile unit’s efficacy, but this parameter cannot be evaluated separately.

Retrospective comparison of the Plasmair T2006 and MA1200, which are cold plasma inactivation and HEPA filtration-based units yielded similar early, late and maximal decontamination efficacies both at the particle (1 log_{10} decrease after 10 min for particle ≥0.5 μm and ≥5 μm, respectively; ISO7 particle class after 20 min and similar particle counts after 2 h) and viable fungal levels (greater than 1 log_{10} fungal aero-contamination decrease after 10 min; similar fungal counts after 20 min and after 2 h). These results were consistent with the similar outputs of these units. Furthermore, they confirmed Plasmair efficacy on fungal decontamination [12], and suggested that the Mobil’Air HEPA filtration-based systems, which had not been previously evaluated, could have a similar efficacy. The main difference could be the micro-organism destruction by Plasmair T2006, whereas, for MA1200, particles can accumulate on HEPA filters over time, affecting the unit’s performance. Moreover, HEPA filters require restricting maintenance procedures such as regular filter replacement by a qualified operator, which are related to high maintenance costs. Lastly, fungal and bacterial growth could occur on filters [18], and should be further evaluated. In contrast, a disadvantage of Plasmair T2006 could be production of charged air particles by cold plasma, the health consequences of which are unknown, whereas mechanical removal by filters is safe.

Surprisingly, when we compared the C1800 (which is a photocatalysis inactivation-based unit) to the Plasmair T2006 and MA1200, late and maximal decontamination efficacies were significantly lower for particles ≥5 μm and fungal counts. These results suggested that photocatalysis disinfection using TiO₂ photochemical catalysis provided no advantage over conventional HEPA filtration or cold plasma inactivation under the conditions of the tests. Several explanations could be offered to account for this unexpected finding. The lower number of pre-filtration steps (one for the C1800 instead of two for the Mobil’Air units) or their potential lower efficacy could suggest that airborne particles and conidia are less effectively caught or partially released after filtration with this unit. Preliminary tests which had been performed on the C1800 prototype without UV lamps (data not shown) could also have interfered with the data.

For the combined MA600/C250, contribution of HEPA filtration and photocatalysis inactivation could not be evaluated but, even if particle and fungal aero-decontamination were delayed, particle ≥0.5 μm and fungal counts reached a similar level as with the Plasmair T2006 and MA1200 after 2 h, suggesting an effective removal of particle ≥0.5 μm and conidia, but a lower efficacy for removal of particles ≥5 μm.

The detection of species other than A. niger during the course of the experiment suggested a probable interference of pre-existing airborne environmental fungi. In fact, these species, whose concentrations were negligible when compared to the 23,800 CFU/m³ theoretical A. niger concentration after aerosolization, are likely to have become detectable after A. niger decrease. For C1800, the high level of persisting airborne environmental fungi combined with low concentrations of A. niger is difficult to explain. It could be related to a variation of conidia destruction efficacy related to the fungal species or to a releasing of conidia from C1800 filters.

Taken as a whole, challenge tests showed the four air-treatment systems were able to reduce the aerial particle and fungal counts, but they also confirmed that mobile air-treatment units are not able to completely remove conidia.
from the indoor environment [13]. This residual load, which had already been observed in previous clinical studies [19], could be related to the absence of positive pressure in the room, which could facilitate the ingress of airborne contaminants, contributing to the variety of fungal organisms recovered. It is likely that using positive pressure would have been helpful to minimize intrusion of fungal contaminants and obtain lower particle and fungal counts. The efficacy of air-treatment systems was variable, depending on: (i) the selected output (e.g., early particle and fungal aero-decontamination was delayed using the combined MA600/C250); (ii) the air-treatment modalities, e.g., (HEPA filtration alone as with the MA1200 and cold plasma inactivation [Plasmair T2006] were more efficient than filtration with photocatalysis [C1800]); and (iii) the complete conception of the device (e.g., ineffective pre-filtration steps could have decreased C1800 efficiency). The conditions of the challenge tests (high particle and fungal aero-contamination levels and high relative humidity) should also be taken into account to interpret our results.

In clinical practice, the significant diminution of fungal contamination we observed suggests that, even if mobile units cannot reduce the ingress of airborne contaminants by providing a positive pressure in the room, they can approximate additional air changes per hour and enhance a ventilation system’s ability to clean the air, and could reduce fungal exposure of patients, being useful as temporary solutions for hematology or transplant patients or for other immunocompromised patients at risk for IA staying in non-protected areas. They must be associated with: (i) mold source elimination (food and water sterilization; no mold-contaminated food [such as tea, pepper, kiwi]; no potted plants and flowers; material and laundry decontamination; strict hand-hygiene and protective equipment for care workers and visitors; limitation of door opening/closing); (ii) basic patient room management (appropriate construction design; rigorous cleaning and disinfection of environmental surfaces procedures; waste elimination procedures); and (iii) environmental surveillance using particle counts of various size diameters or mycological sampling for routine surveillance, and mycological sampling for outbreak investigations [3–5,20–22]. Mobile units could also contribute to IA prevention by reinforcing existing air-treatment systems during hospital renovation periods.

Regarding the large variety of mobile air-treatment units and their variable installation and maintenance costs, our comparative study based on challenge tests could be helpful to make an informed selection of mobile air-treatment units, and to design a prevention strategy of air-transmitted fungal infections for patients at risk staying in non-protected areas.

Further challenge tests using various units (and taking into account technical improvements, which are regularly added, such as a supplementary filter for the prototype unit C1800), and various outputs, mobile unit placements (to optimize airflow), or A. niger inoculum sizes (closer to the natural airborne concentrations) could be performed. Furthermore, even if the variable natural fungal loads and the rare occurrence of IA make comparative clinical studies difficult and lengthy, a prospective clinical evaluation of these mobile air-treatment units should be completed in patient rooms in order to assess their effect on the reduction of natural fungal loads and IA incidence. Such studies should also take into account other criteria such as noise, which must be tolerable to avoid output reduction or unit stopping by the patient [11,23], and measures for basic patient room management, which must be associated with the installation of the mobile unit and similar in all the rooms tested.

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