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Major Article

Fungal aerocontamination exposure risk for patients in 3 successive locations of a pediatric hematology unit department: Influence of air equipment and building structure on air quality

Anne-Pauline Bellanger PharmD, PhD [a,b,*], Gabriel Reboux PhD [a,b], Florent Demonmerot [b], Houssein Gbaguidi-Haore PharmD [a,c], Laurence Millon PharmD, PhD [a,b]

[a] Chrono-Environnement UMR 6249 Research Team, Bourgogne—Franche-Comté University, Besançon, Doubs, France
[b] Parasitology-Mycology Department, Besançon University Hospital, Besançon, Doubs, France
[c] Infection Control Department, Besançon University Hospital, Besançon, Doubs, France

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Background: Invasive fungal infections (IFIs) play an important role in the mortality of immunocompromised patients. The pediatric hematology department (PHD) at Besançon University Hospital has relocated 3 times: (1) from a building without an air filtration system (B1), (2) to a renovated building with low air pressure (B2), and (3) to a new building with high air pressure and high-efficiency particulate air filters (B3). This study aimed to investigate how these relocations influenced the fungal exposure risk for the PHD's patients.

Methods: Air samples were taken monthly in patient rooms and weekly in corridors. The detection of opportunistic fungi species was used to assess IFI risk. Data were analyzed using univariate and multivariate random-effects negative binomial regression.

Results: A total of 1,074 samples from 29 rooms over a 10-year period showed that renovation of an old building with a basic ventilation system did not lead to a significant improvement of air quality ($P = .004$, multivariate analysis). Among factors linked to higher risk of patient rooms mold contamination was fungal contamination of the corridors ($P < .001$).

Conclusions: This study demonstrates that corridors can be used as reliable sentinel to prevent fungal contamination in patient rooms. Only relocation in building B3, equipped with laminar air flow, achieved adequate air quality.

BACKGROUND

Invasive fungal infections (IFI) play an important role in the morbidity and mortality of immunocompromised patients in hematology units. Preventive measures and especially good air quality are critical to minimize the incidence of IFI. High-efficiency particulate air (HEPA) filtration systems provide an efficient means of obtaining high air quality for patients at risk of developing this infection.[1]

At Besancon University Hospital, the pediatric hematology department (PHD) has relocated 3 times over the last 10 years: (1) from a concrete building with no air filtration system (B1), (2) to an old renovated fine cut stone building with low air pressure (B2), and (3) finally to a new building with high air pressure and HEPA filters (B3).

From 2006-2008, the PHD was located in a building built in the 1960s (a quadrangular concrete construction) (B1) and was part of the pediatric unit. There was no physical separation between the 2 departments. The unit's ventilation system was based on an F5 filter (retaining 40%-60% of 0.4-μm particles; EN 779 2012 [http://www.uniclima.fr/fileadmin/BASE_DOCUMENTAIRE_UNICLIMA/Actualites/2012_11_30_NF_EN_779-2012_et_classification_energetique_Eurovent.pdf]). Five rooms were equipped with a mobile air filtration system (Coolplasmair; airinspace, Montigny les Bretonneux, France), and 2 rooms had laminar airflow with an HEPA filter H13 (retaining 99.75% of 0.3-μm particles). After the discovery of high fungal contaminations in December 2006, the old passive air extraction system using a 15- × 15-cm chimney in each room was discontinued. An additional problem was the absence of airtight doors between the pediatric and hematology parts of the unit. Storage rooms and the playroom were therefore in contact with the

* Address correspondence to Anne-Pauline Bellanger, PharmD, PhD, Parasitology-Mycology Department, University Hospital Jean Minjoz, 2 Bd Fleming, F-25030 Cedex Besancon, France.
E-mail address: apbellanger@chu-besancon.fr (A-P. Bellanger).
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rooms accommodating immunocompromised patients. Surveillance of fungal aerocontamination was irregular in the PHD in B1. Because the housing conditions of patients at risk of IFI were considered inadequate, pediatric patients undergoing hematopoietic stem cell grafts were systematically transferred to the adult hematology department (AHD).

From 2008-2012, the PHD was transferred to an old renovated fine cut stone building with clay roof tiles built in the 1940s (B2). The aim of this relocation, after renovation, was to improve accommodations of patients at risk of IFI. The building had previously housed the hospital pneumology unit and was equipped with a standard filtration system (F7 filters that retain 80%-90% of 0.4-µm particles). The renovation consisted in (1) increasing the positive pressure from 1 to 3 Pa in every room, (2) adding an airlock at the entrance of the unit, (3) equipping 5 rooms with mobile air treatment units (Coolplasmair), and (4) equipping 3 rooms with laminar airflow and HEPA filters. Aerocontamination surveillance was carried out as often as in the AHD (ie, weekly monitoring in corridors and monthly checks in rooms).[2,3]

Since 2012, the PHD has been located in a new building (B3) of Besançon University Hospital, along with the AHD. The PHD location meets the safety norms for patients at risk of IFI (40 volumes per hour, rooms with positive 25-Pa pressure, and HEPA filters). Fungal aerocontamination surveillance is performed weekly in corridors and monthly in patient rooms. The only remaining concern is the presence of 2 emergency exit doors (permeable) at each end of the unit.

The aim of our study was to investigate to what extent these relocations have influenced the fungal aerocontamination exposure risk for patients in the PHD.

MATERIALS AND METHODS

Air sampling

Air sampling was carried out by impaction with an MAS 100 impactor (Merck, Darmstadt, Germany) for 2.5 minutes per sample (250 L of air) weekly in corridors. Two consecutive samples of 5 minutes per sample were taken monthly in the rooms (1 m^3) on dichloran-glycerol 18% culture media (Oxoid, Basingstoke, Hampshire, United Kingdom). In B1, fungal aerocontamination surveillance was irregular and only performed when requested by the medical staff. However, systematic fungal aerocontamination surveillance was applied in B2 and B3. The global analysis presented here takes into account monthly samplings taken simultaneously in rooms and corridors.

Identification of fungal species

Impacted dichloran-glycerol 18% culture media were incubated at 30°C. Cultures were checked after 3 and 7 days of incubation. Fungal species were identified by macroscopic and microscopic examination.

Expression of the results

Results were expressed as mean concentrations of opportunistic fungal species in colony forming units (CFU) per cubic meter. The list of fungal opportunistic species included *Aspergillus fumigatus*, *Aspergillus flavus*, *Mucor* spp, *Rhizopus* spp, *Rhizomucor* spp, *Lichtheimia corymbifera* (syn *Absidia corymbifera*), *Fusarium* spp, and *Scedosporium* spp. The calculation of the mean concentrations of opportunistic fungal species was based on the number of surveillance samplings.

Location and frequency of the sampling

Air samplings were performed weekly in corridors and on a monthly basis in each building (B1, B2, and B3), in rooms equipped with mobile air treatment units (Coolplasmair), rooms with HEPA filters and their corresponding airlock, and also in control rooms (that were not equipped with specific air treatment systems).

Air sampling procedures varied from one building to another.

In B1, air samplings were taken in 3 different corridor locations: one corridor opposite rooms with mobile air treatment units, another corridor opposite rooms with laminar airflow, and the other in front of a treatment room. Fungal aerocontamination samplings were performed at the request of the medical staff.

In B2, air samplings were performed systematically in 4 locations: the entrance corridor, the corridor opposite rooms with mobile air treatment units, a corridor opposite the rooms with laminar airflow, and the airlock between the 2 parts of the unit (airlock toward rooms with laminar airflow).

In B3, air samplings were performed systematically in 6 locations: the entrance corridor, in front of the treatment room, the corridor opposite the patient room, in front of the waiting room, in front of the nurses' station, and the corridor opposite the rooms with laminar airflow.

Clinical data

Since 2006, the parasitology-mycology department has systematically reported all IFIs to the National Reference Center of Mycoses and Antifungal Therapies, to the regional health agency, and to the National Sanitary Survey Institute. Therefore, based on the EORTC/MSG (European Organization for Research and Treatment of Cancer/Invasive Fungal Infections Cooperative Group and the National Institute of Allergy and Infectious Diseases Mycoses Study Group) criteria, each probable and proven IFI was systematically registered.[4,5]

Warning sign management

The results of each survey were sent to the heads of the hematology and infection control departments and to the infection control committee of the health care facility. Warning signs were based on the detection of opportunistic species defined as fungi able to induce an IFI: commonly *A fumigatus*, *A flavus*, *Fusarium* spp, and *Mucorales*. Whenever opportunistic molds were detected, biocleaning was reinforced, and the potential cause of the contamination was sought by discussing any unusual events with the staff and technical services. This specific surveillance in the PHD was completed by surveillance in the general corridors of the university hospital, as previously described.[3]

Statistical analysis

The outcome variable was fungal aerocontamination exposure assessed from repeated (monthly) air samplings (count data, CFU per cubic meter) in patient rooms over a 10-year period and in the 3 building locations.

Independent variables included buildings (B1, B2, and B3), secular trend (years), seasonal trend (quarters), room equipment (Coolplasmair and HEPA filters), and fungal aerocontamination in corridors (CFU per cubic meter). To take into account the clustering of data (repeated measures in each patient room over time), univariate and multivariate random-effects negative binomial regression analyses were performed to determine factors influencing fungal aerocontamination exposure risk for patients in the PHD.

All analyses were 2-tailed, and $P < .05$ was considered significant. We used Stata version 14.1 software (StataCorp LP, College Station, TX) for the analyses.