

Microbiological environmental monitoring in high-risk departments during building activities in a hospital site

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Key words: Building constructions, hospital-acquired infections, microorganisms, environmental control, risk assessment

Parole chiave: Cantiere, infezioni nosocomiali, microrganismi, controllo ambientale, valutazione del rischio

Abstract

Background. This study examines the microbial and fungal contamination associated with the presence of renovation works in a hospital site in Sardinia (Italy).

Methods. Microbiological environmental monitoring was carried out before, during and at the conclusion of the works in the Ophthalmology Department in view of a risk assessment procedure.

Results. Although the median values of microbial and fungal counts were found raised during the works, protective measures set out by the internal procedures limited the contamination level.

Conclusions. This study emphasizes the benefits of environmental surveillance for airborne contamination to help prevent outbreaks of nosocomial mycosis associated with construction work.

Introduction

Construction, demolition, and renovation of a hospital building are normal and foreseeable events that should always be considered in the framework of a risk assessment procedure for infectious diseases. Building work on or near hospital wards causes disturbance to settled spores or the disruption of a locus of growth exposing immune compromised patients to filamentous opportunist fungi, such as the *Aspergillus* species, responsible of infections with high mortality rate (1-3). In addition,

an increased risk of waterborne *Legionella* infections has to be considered, due to lesions to the aqueduct pipes caused by building works (4, 5). *Aspergillus* species are ubiquitous organisms in the environment (6). The relationship between the airborne concentration of *Aspergillus* spp. and the risk of invasive pulmonary Aspergillosis (IA) is unknown; for high-risk individuals, the critical value of air contamination is supposed to range between 0.009 CFU/m³ and 0.2 CFU/m³ (7, 8). Building work is considered a major risk factor as it contributes to increase the contamination of

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Aspergillus spp in both indoor and outdoor environments (2, 9-11). To deal with this risk, hospitals generally set out preventive procedures.

In order to assess the risk due to the construction work it is necessary to know the baseline values of the contamination. In many hospitals microbiological environmental monitoring (MEM) is not carried out on a regular basis, restricting therefore the possibility to quantify the benefits obtained by implementing appropriate preventive measures (12, 13). In this paper, periodic monitoring of microbial concentrations in the air, in the water and on surfaces was carried out in a hospital in Sardinia (Italy) as a baseline, in order to evaluate the effectiveness of these procedures during renovation works (14-16). Environmental control was focused on the Ophthalmology Department (OD) which includes three operating rooms (OR) - A, B, and C.

The health significance of the consequences of such infections, the availability of low-cost, effective preventive measures to be implemented, and the knowledge of the microbiological records of baseline contamination of some hospital wards, provided reasons for this study, which focus on the risk management of infectious diseases associated with construction activity.

Methods

In order to assess the effectiveness of the preventive procedures, taking into account as a baseline the record of the analyses carried out in previous years, sampling was carried out by trained personnel in the OD before (September 2015), during (October-November 2015) and one week after the end of the renovation works. The range of values of microbial counts suggested by the Italian guidelines ISPEL (17) were utilized to pinpoint critical situations and to

evaluate the return to the previous baseline values. A total of 280 samples, 132 of them from indoor air (44 before, 12 during and 76 after) and 148 from surfaces (78 before, 6 during and 64 after) were collected. In the OD, surface samples were collected from walls, the digital vision tables, armchairs, beds, wardrobes and floors, while in the OR samples were collected from the table, automatic respirator, head lamp, mayo instrument stand and floor. Air samples were collected at the center of each room, in the vicinity of the vents and at 260 centimetres from the floor. A volume of 1,000 L of air was aspirated through the DUO-SAS-360 Surface Air Sampler (PBI International), with a flow rate of 180 L/min, which draws it on RODAC plates containing nutrient media for microorganisms (soil Plate Count Agar for the determination of the total bacterial load and Sabouraud dextrose agar plus chloramphenicol for the determination of the charge of yeasts and molds). Surfaces were sampled with RODAC contact plates using the same nutrient media. Samples were transported to the laboratory in refrigerated insulated bags (0-4°). The temperature was monitored via data logger. PCA plates were incubated at 36° ± 1° for 48 h and SDA plates at 25° for 72-120 h. Colonies of bacteria (API Biomerieux) and fungi were then counted, isolated and identified. Sanitary waters were analyzed for total coliforms, *Escherichia coli*, fecal enterococci, *Pseudomonas aeruginosa*, sulfite reducing *Clostridia* spores, and *Legionella* spp.

The volumes of OR ranged from 93 to 113 m³ (Table 4) and the mean number of air changes per hour was 20. The heating, ventilation and air conditioning (HVAC) system distributes air to the three ORs through ducts and diffusers with a strong inductive effect. The cleaning of OR when empty is assured daily by an external cleaning service, according to specific protocols, and regards walls, floors and all the furnishing; cleaning of appliances and all the equipment

is performed by the healthcare workers. The samplings were carried out 30 minutes after the end of the cleaning. Every two weeks the OR is cleaned through compressed air from ceiling to floor. Every 20 days the suspended ceiling is cleaned. In each room two nozzles were placed with absolute filters that are replaced every six months.

Statistical analyses. The SPSS version 8.0 software package was used for statistical procedures. The Mann-Whitney test and Kruskal-Wallis test were used for the statistical analyses of the data in relation to the observed differences in contamination levels at different times.

Results

Median values of the microbial concentrations in the air before the works

Results are shown in Table 1 and 2. In the OD, the median value of the mesophilic count in the air sampled in the vicinity of the air vent was 2 CFU/m³, corresponding to 3 CFU/m³ of yeasts and molds, respectively represented by *Acinetobacter baumannii*, *Cladosporium cladosporioides*, *Paecilomyces variotii*,

Penicillium commune, and *Cryptococcus laurentii*. In the bathroom the median value of the mycetic count was 12 CFU/m³. *C. cladosporioides*, *Paecilomyces lilacinus*, *P. commune*, *Rhizopus oryzae* were isolated. In the ORs, the mesophilic count in the air sampled in the vicinity of the air vent was 30 CFU/m³ and equal to 1 CFU/m³ of yeast and mold represented by *P. variotii*. In the center of the hall, the value of the mesophilic count was 110 CFU/m³, and 2 CFU/m³ of yeasts and molds (*C. cladosporioides* and *Rhodotorula rubra*). At the center of the room and at the exit of the vents of the operating theatres A and B, the median values of the mesophilic count were respectively 31 CFU/m³ and 14 CFU/m³, while those for yeasts and molds were always <1 CFU/m³. In the recovery rooms, air samples presented a median value for the mesophilic count of 18 CFU/m³.

Median values of the microbial concentration in the air during the work

At the center of the OR and at the outlet of the OR nozzles the median values of the mesophilic count were respectively 260 CFU/m³ and 330 CFU/m³. *Acinetobacter lwoffii*, *A. baumannii*, *Acinetobacter junii*, *Staphylococcus aureus* were among the

Table 1 - Median values of the microbial concentration in the air (CFU/m³ before, during and after the works)

Sampling point	Before		During		After	
	CM	LM	CM	LM	CM	LM
Ophthalmology hospital rooms	2 CFU/m ³	3 CFU/m ³	NR	NR	44 CFU/m ³	8 CFU/m ³
Operating theaters ophthalmology room center	30 CFU/m ³	1 CFU/m ³	NR	NR	NR	NR
Operating theaters ophthalmology vents	110 CFU/m ³	2 CFU/m ³	NR	NR	NR	NR
Operating rooms, room center	31 CFU/m ³	<1 CFU/m ³	260 CFU/m ³	71 CFU/m ³	661 CFU/m ³	10 CFU/m ³
Operating theaters Vents	14 CFU/m ³	<1 CFU/m ³	330 CFU/m ³	30 CFU/m ³	660 CFU/m ³	12 CFU/m ³

CM = mesophilic counts, LM = yeast and mold, NR = not detected

Table 2 - Median values of the microbial concentration expressed in CFU / cm² on surfaces (before, during and after the work)

Sampling point	Before		During		After	
	CM	LM	CM	LM	CM	LM
Ophthalmology hospital rooms	1 CFU/cm ²	3 CFU/cm ²	NR	NR	3 CFU/cm ²	1 CFU/cm ²
Operating theaters ophthalmology center room (floor)	*3 CFU/cm ²	*2 CFU/cm ²	NR	NR	NR	NR
Operating theaters	<1 CFU/cm ²	<1 CFU/cm ²	<1 CFU/cm ²	<1 CFU/cm ²	<1 CFU/cm ²	<1 CFU/cm ²

CM = mesophilic counts, LM = yeast and mold, NR = not detected, * precise value

species identified; for yeasts and molds, the counts were 71 CFU/m³ and 30 CFU/m³ respectively (*Alternaria alternata*, *R. rubra*, *Aspergillus brasiliensis*, *P. variotii*).

Median values of the microbial concentration in the air at the conclusion of the works

In the wards of the OD, the median values of the mesophilic counts of the air sampled in the vicinity of the air vent and at the center of the room were 30 CFU/m³ and 44 CFU/m³ respectively, while yeasts and molds showed values of 9 CFU/m³ and 8 CFU/m³ respectively, represented by *A. baumannii* and *P. variotii*, *R. rubra*, *C. cladosporioides*, *A. brasiliensis*, *P. commune*. In the center of the recovery room of the operating block, air presented a median value for the mesophilic count of 680 CFU/m³; the microbial species most frequently isolated were *Burkholderia cepacia*, *R. rubra*, *S. aureus*, and *Acinetobacter radioresistens*. Yeasts and molds showed median values of 20 CFU/m³ with the species *A. brasiliensis*, *R. rubra*, *Aspergillus ochraceus*, *P. commune*.

At the exit of the vents and at the center of the ORs A, B and C, the median values of the mesophilic count were respectively 660 CFU/m³ and 661 CFU/m³ and *A. radioresistens*, *Pseudomonas fluorescens*, *S. aureus* represented the species isolated. For yeasts and molds values were 12 CFU/m³ and 10 CFU/m³ respectively and

the specie isolated were *R. rubra* and *C. cladosporioides*.

Median values of the microbial concentration on surfaces before the works

In the patient rooms of the OD, the median values of the mesophilic count and yeast and mold in the surface sample were 1 CFU/cm² and 3 CFU/cm² respectively. *Aspergillus fumigatus* (wardrobe), *C. cladosporioides* (wardrobe), *P. variotii* (chair), *P. commune* and *P. fumigatus* (chair), *Cryptococcus albidus* (floor) were among the species isolated.

In the OR the value of the mesophilic count on the floor area sampled was 3 CFU/cm², while for yeasts and molds, the value was 2 CFU/cm². Isolated species of *C. cladosporioides* and *P. variotii* were found. The value of the mesophilic count and the yeast and mold in the automatic respirator surface was 1 CFU/cm². Median values of the mesophilic count and yeast and mold in all of the surfaces of operating theatres A and B were <1 CFU/cm².

Median values of the microbial concentration on surfaces during works

During the building activity, departments considered in this study were closed, as a consequence of the precautionary principle adopted by the surgery staff. However, sampling in all the operating theatre surfaces

showed that the median values of the mesophilic count and yeast and mold counts were <1 CFU/cm² (walls, surgical lamp).

Median values of the microbial concentration on surfaces at the conclusion of the works

In patient rooms of the ophthalmology department, the median values of the mesophilic count and yeast and mold were 3 CFU/cm² and 1 CFU/cm² respectively. *R. rubra* (chair), *C. cladosporioides* (chair), and *P. commune* (chair) were among the species isolated. In all ORs, median values of the mesophilic count and yeast and mold were <1 CFU/cm². In the OR 'B', the automatic respirator showed an anomalous value of the mesophilic count of 20 CFU/cm² (outlier).

Statistical analyses. Statistical analyses showed that the differences between the mesophilic and mycotic counts (comparison between ranks) before and at the conclusion of the building works are highly significant ($P < 0.05$). Comparison between the results (Mann-Whitney test) confirmed statistically significant differences for all kinds of environments ($P < 0.05$), except for other workplaces/OR and other workplaces/patient rooms ($P > 0.05$). Comparison of the differences between the air contamination before and after work in all the environments showed that U-value amounted to 884.5 with an approximately normal distribution. The Z-score value was 4.2859, with a P-value of 0. The result is significant at $P \leq 0.05$. Instead, the comparison of the differences between the values of contamination in all surfaces before and after works, showed U-value of 2346 with an approximately normal distribution. The Z-score value was -1.76, with P-value equal to 0.08544. The result was not significant at $P > 0.05$.

With regards to the water, all parameters were found to comply with the limits set by Italian legislation (Decree 31/2001) and

by Italian guidelines for the control and prevention of Legionnaires' disease (18). Results were evaluated according ISPEL recommendations (17).

Discussion and Conclusions

The microbiological environmental monitoring of a hospital site can be considered a valid test of the effectiveness of procedures implemented to prevent and minimize the risk of infection, through the reduction of microbial contamination (19). The knowledge of the level of contamination in some areas within the departments, before building operations began, allowed us to confirm the average critical condition and to get the scientific evidence and necessary support to fulfill improvement activities in relation to risk management (12, 15, 20). As far as risk evaluation is concerned, from a preliminary analysis (Fig. 1, Table 3), the progress in air contamination levels in the building site proved to be limited as a result of the respect of preventive and protective measures shown by the Hospital Guidelines (12, 21). Failure to follow hospital hygiene guidelines in the presence of construction sites can, in fact, determine a significant increase in levels of microbiological environmental contamination, encouraging the spread of pathogenic microorganisms of anthropogenic origin (Fig. 2). Nevertheless, the results of the progressive contamination levels of both sporogenous and mesophilic airborne microorganisms ($P < 0.05$) (Fig. 1) highlighted situations not complying with the expected values of the ISPEL guidelines exclusively referred to operating rooms, as shown in table 1. In addition, the contamination values preceding the construction work induced to take appropriate and corrective measures within the hospital as for instance the complete replacement of the air filtering system and the renovation of the air circulating system. Following

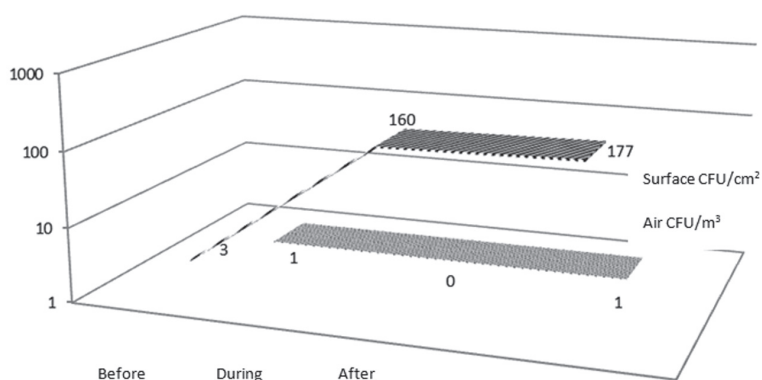


Fig. 1 - Trend of the median values of the air and surfaces samples (before, during, after the works).

this intervention the levels of microbial contamination in the environment were in the range of the baseline values, allowing the resumption of activities in the different departments of the hospital. The results for the microbial air contamination (Table 1) before the works have shown that in the operating rooms, at the center of the room and vents (HEPA absolute filters), all the values were within the limits suggested by the ISPESL document (17) ($\leq 35 \text{ CFU/m}^3$ at rest and $\leq 180 \text{ CFU/m}^3$ in operation, $\leq 1 \text{ CFU/m}^3$ near vents). Also, except for the

automatic respirator, surface samples (Table 2) did not exceed the ISPESL acceptable limits for operating rooms OF 0.5 CFU/cm^2 (17) during the period considered. While sanitization procedures normally adopted in the hospital clearly do work, more attention is needed when proceeding to sanitize the more critical surfaces that are difficult to reach with disinfectants (22, 23), such as the automatic respirator.

In these cases corrective actions should be mainly directed to train the staff, whose professionalism is essential to adequately

Table 3 - Microbial species in the air and surfaces (before, during and after the work)

Microbial species isolated	Before		During		After	
	Air	Surfaces	Air	Surfaces	Air	Surfaces
<i>Acinetobacter spp</i>	2		16*		8	
<i>Burkholderia cepacia</i>					2	
<i>Pseudomonas fluorescens</i>					4	
<i>Staphylococcus aureus</i>			4		18	
<i>Aspergillus spp</i>		2°	2^		2^	
<i>Alternaria alternata</i>			2			
<i>Cladosporium cladosporioides</i>	16	10				6
<i>Cryptococcus spp</i>	2°°	2°°				
<i>Paecilomyces spp</i>	10	10			8	
<i>Penicillium commune</i>	10	8			16	10
<i>Rhizopus oryzae</i>	2					
<i>Rhodotorula rubra</i>			12		52	6

*baumannii (8), lwoffii (4), junii (4); °fumigatus; ^radioresistens, brasiliensis; °°albidus, laurentii

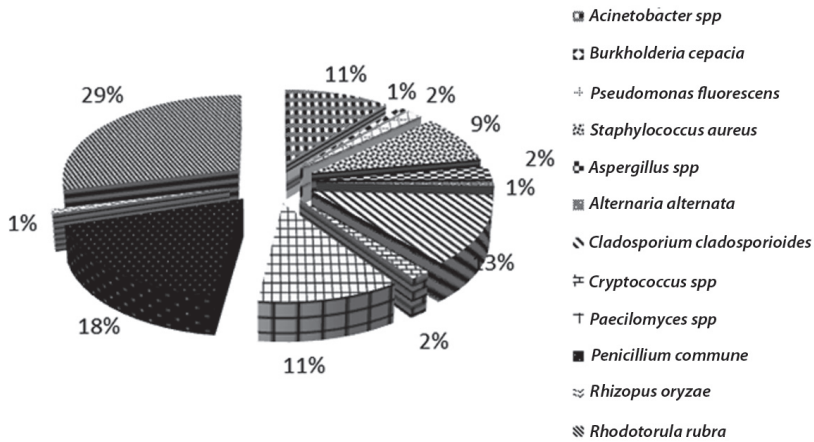


Fig. 2 - Microbial species isolated from the air and the surfaces

sanitize equipment and subsequently store it before reuse. The protection of the environment from airborne microorganisms, as evidenced by the results of temporal air contamination released from the vents at the center of the operating rooms, was not guaranteed by the air conditioning system with HEPA filters in the presence of a construction site, even in the case of a system efficiency $\geq 99,97\%$. With regards to the bacterial species (Fig. 1), the presence of both normal environmental saprophytes and those of human origin were observed with greater frequency, with a wide variability of molds.

This study emphasizes the benefits of environmental surveillance for airborne contamination to help preventing outbreaks of nosocomial mycosis related to construction work. The results of this study reinforce the belief that the hospital safety management

requires an urgent systematic organization model based on HACCP and risk assessment procedures, by identifying the critical limits observed on a periodic basis to assess effectiveness of normally and consistently applied preventive procedures, kept under control with check lists and supervised by the appropriate hospital team.

Riassunto

Monitoraggio microbiologico ambientale nei reparti ad alto rischio di un ospedale in presenza di un cantiere

Introduzione. Questo studio esamina la contaminazione microbica e fungina associata alla presenza di un cantiere in un ospedale della Sardegna (Italia).

Metodi. Il monitoraggio microbiologico ambientale è stato effettuato prima, durante e al termine dei lavori nel reparto di Oftalmologia, secondo una procedura di valutazione del rischio.

Risultati. Anche se durante i lavori sono stati misurati valori mediani di carica microbica e fungina elevati, le misure preventive stabilite dalle procedure interne hanno contenuto il livello di contaminazione.

Conclusioni. Questo studio sottolinea i vantaggi di una sorveglianza della contaminazione aerea ambientale al fine di prevenire focolai di micosi nosocomiale associati alla presenza di cantieri.

Table 4 - Operating rooms dimensions

Operating Room	Surface	Volume
A1	32 m ²	112 m ³
2B	29 m ²	102 m ³
3B	27 m ²	93 m ³

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