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Microbiological assessment of indoor air quality at different hospital sites

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Abstract

Poor hospital indoor air quality (IAQ) may lead to hospital-acquired infections, sick hospital syndrome and various occupational hazards. Air-control measures are crucial for reducing dissemination of airborne biological particles in hospitals.

The objective of this study was to perform a survey of bioaerosol quality in different sites in a Portuguese Hospital, namely the operating theater (OT), the emergency service (ES) and the surgical ward (SW). Aerobic mesophilic bacterial counts (BCs) and fungal load (FL) were assessed by impaction directly onto tryptic soy agar and malt extract agar supplemented with antibiotic chloramphenicol (0.05%) plates, respectively using a MAS-100 air sampler.

The ES revealed the highest airborne microbial concentrations (BC range 240–736 CFU/m^3 CFU/m^3; FL range 27–933 CFU/m^3), exceeding, at several sampling sites, conformity criteria defined in national legislation [6]. Bacterial concentrations in the SW (BC range 99–495 CFU/m^3) and the OT (BC range 12–170 CFU/m^3) were under recommended criteria. While fungal levels were below 1 CFU/m^3 in the OT, in the SW (range 1–32 CFU/m^3), there existed a site with fungal indoor concentrations higher than those detected outdoors. Airborne Gram-positive cocci were the most frequent phenotype (88%) detected from the measured bacterial population in all indoor environments. *Staphylococcus* (51%) and *Micrococcus* (37%) were dominant among the bacterial genera identified in the present study. Concerning indoor fungal characterization, the prevalent genera were *Penicillium* (41%) and *Aspergillus* (24%).

Regular monitoring is essential for assessing air control efficiency and for detecting irregular introduction of airborne particles via clothing of visitors and medical staff or carriage by personal and medical materials. Furthermore, microbiological survey data should be used to clearly define specific air quality guidelines for controlled environments in hospital settings.

Keywords: Airborne microorganisms; Indoor air quality; Hospital

1. Introduction

The complex hospital environment requires special attention so as to ensure healthy indoor air quality (IAQ) to protect patients and healthcare workers from hospital-acquired (nosocomial) infections and occupational diseases [1]. Airborne microorganisms can originate not only from humans (including patients), but can also be spawned by various indoor hospital characteristics and outdoor environmental sources [2–5]. Hospital buildings may be regarded as dynamic environments affected by season, weather conditions, indoor ventilation system design and operation, intrusion of moisture, outdoor microbial load and the number of occupants, visitors and human activities [2]. These factors may be associated with conditions for microbial growth. Achieving satisfactory IAQ in hospitals is

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thus a challenge for health care professionals, hospital managers and engineers. In Portugal, concern about indoor air as a vehicle of pollutants and contaminants assumed such importance in the last few years that a specific law was published [6] to replace a non-specific previous one [7], in order to standardize all procedures related to operation and maintenance of IAQ. Although recommendations exist elsewhere [8,9], there exists a regulatory lacuna of a referential standard for microbiological parameters of IAQ in health care facilities. This gap could be due to the lack of comprehensive studies on the airborne bioburden at several hospital sites, which would enable a broad effective characterization of hospital indoor microbiota. In fact, most available literature the airborne microbiota levels at a specific site of indoor hospital spaces, namely lobbies [2], orthopedic multi-bedroom wards [10], operating theaters [3,4] and surrounding areas [11]. The few studies performed at different hospital areas highlight deficiency in the relationship between these microbiological survey data and their epidemiological implications [12,13].

The aim of the present study was to characterize airborne microbial levels of three different hospital areas and evaluate potential airborne contamination sources. The obtained data are intended to contribute to recommendations for useful guidelines facilitating control and management of hospital IAQ within the scope of the EFICARE project.

2. Materials and methods

2.1. Study design

A prospective study on airborne microbiota was carried out in a 1.8-bed/1000 population community hospital located in the urban area of Setúbal, Portugal. Analyses were conducted in three hospital sites selected as presenting inherent characteristics and different risk classifications: 1) the operating theater (OT): high risk; 2) the emergency service (ES): medium risk (said to be the face of any hospital setup); and 3) the surgical ward (SW): low risk (without a chilling system). Three sampling campaigns were performed in June 2013 (summer; T = 30.1 °C; RH = 43.8%), December 2013 (winter; T = 7.1 °C; RH = 82.7%) and February 2014 (winter; T = 14.7 °C; RH = 80.7%), with specific objectives and methodological approaches. The study design is summarized in Table 1.

The ES is located on the ground floor of the hospital with two outside doors (one for regular entrance and the other for stretchers). The SW is situated in the third floor of the building and the rooms are provided with natural ventilation with windows. Filtered outdoor air is supplied through diffusers above the door room and evacuated by corner outlets at floor level. All OTs (six rooms) located on the first floor of the building have a ventilation system designed to achieve 20 complete outdoor air changes per h and are equipped with 0.3 mm 99.97% HEPA filters. Filtered outdoor air is supplied through diffusers in the ceiling and evacuated by corner outlets at floor level. The OT air pressure is $\geq$ 5 Pa higher than in adjacent rooms. The doors of the OTs are always kept closed during surgical procedures.

No local sources of industrial air pollution were found in the vicinity of the hospital.

2.2. Microbiological air sampling

Microbiological air counts were measured by impaction using an air sampler (MAS100, Merck KGaA, Darmstadt, Germany) with a flow rate of 100 l/min. Air samples of 250 l for ES and SW and of 500 l for OT were collected in culture medium petri dishes. For sampling campaigns in June 2013 (summer) and February 2014 (winter) and whenever possible, samples were collected with equipment approximately 1 m above the floor to simulate the breathing zone.

To assess aerobic mesophilic bacterial counts (BCs) in indoor air, tryptic soy agar (TSA; Oxoid, Hampshire, UK) was used and plates were incubated at 30 ± 1 °C for 7 days. Fungal load (FL) was evaluated using malt extract agar (MEA; Oxoid, Hampshire, UK) supplemented with antibiotic chloramphenicol (0.05%) and plates were incubated at 25 °C ± 1 °C for 7 days. Triplicate samples for each culture medium were collected to ensure sampling accuracy.

Bacterial phenotyping was based primarily on morphology, Gram-staining, endospore formation, catalase activity and oxidase production. Bacteria were grouped into morphological groups as Gram-positive cocci, Gram-negative cocci, Gram-positive rods and Gram-negative rods according to their microscopic morphology as defined by [14]. Some commonly found bacteria were identified using a miniaturized biochemical test (RapID, Remel; Santa Fe, Lenexa, KS, USA). Identification of filamentous fungi was carried out on material mounted in lactophenol blue and achieved through morphological characteristics listed in the illustrated literature [15].

2.3. Data analysis

The number of colony-forming units (CFUs) per petri dish, after appropriate incubation, was corrected using the positive hole correction table MAS-100 provided by the supplier. The air bioburden values were expressed in CFUs per cubic meter (CFU/m^3) and the limit of quantification was 1 CFU/m^3.

Data were managed with Microsoft Excel 2010 and Origin 8.0 (OriginLab Corporation; Northampton, MA, USA). The significance level was $P < 0.05$. The obtained average air bioburden values were compared with referential limits (RLs) defined in [7] for summer samplings and with those recommended in [6] for winter samplings. CFUs at different locations collected in summer and winter were compared using the one-way analysis of variance test with Tukey post hoc comparisons for normally distributed data.

3. Results and discussion

3.1. Seasonal assessment

Air samples were taken in June 2013 (summer) and February 2014 (winter) to characterize airborne microbial concentrations (Figs. 1–3) in three different hospital services