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Concentration and type of bioaerosols before and after conventional disinfection and sterilization procedures inside hospital operating rooms

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ABSTRACT

Operating rooms (ORs) in hospitals are sensitive wards because patients can get infections. This work aimed to characterize the type and concentration of bioaerosols in nine ORs of an educational hospital before and after sterilization and disinfection. During 2017, fungal samples were incubated at 25–28 °C for 3–7 days and bacterial samples at 37 °C for 24–48 h. The study results showed that the concentrations of fungi before cleaning procedures (for both of disinfection and sterilization) were limited from 4.83 to 18.40 CFU/m^3 and after cleaning procedures ranged from 1.90 to 8.90 CFU/m^3. In addition, the concentrations of bacteria before cleaning procedures were limited 14.65–167.40 CFU/m^3 and after cleaning procedures ranged from 9.50 to 38.40 CFU/m^3. The difference between the mean concentrations of airborne bioaerosols before and after sterilization was significantly different than the suggested value of 30 CFU/m^3 ($p \leq 0.05$). The bacterial concentration was higher than the recommended value (30 CFU/m^3) in 41% of the ORs. The main fungal species identified in the indoor air of ORs (before vs. after sterilization) were *A. fumigatus* (25.6 vs. 18.3%), *A. Niger* (11.6 vs. 5.8%), *Penicillium* spp. (5.5 vs. 3.3%), *Alternaria* spp. (2.8 vs. 0.7%), *Fusarium* spp. (9.7 vs. 3.7%), *Mucor* spp. (15 vs. 12.7%), *Cephalotrichum* spp. (1.7 vs. 0.8%), *A. Flavus* (24.6 vs. 18.5%), *Cladosporium* spp. (2.6 vs. 0.8%), and *Trichoderma* spp. (0 vs. 0.9%). The growth of biological species even after sterilization and disinfection likely resulted from factors including poor ventilation, sweeping of OR floors, inadequate HVAC filtration, high humidity, and also lack of optimum management of infectious waste after surgery. Designing well-constructed ventilation and air-conditioning systems, replacing HEPA filters, implementing more stringent, frequent, and comprehensive disinfection procedures, and controlling temperature and humidity can help decrease bioaerosols in ORs.

1. Introduction

Bioaerosol concentrations in indoor air, especially hospitals and their operating rooms (ORs), pose a public health issue in developing countries (Napoli et al., 2012; Nourmoradi et al., 2012; Soleimani et al., 2016). Fungal and bacterial bioaerosols can cause acute diseases, infections, asthma, rhinitis, and allergies in indoor air, such as ORs (Azimi et al., 2013; Dales et al., 1991; Goudarzi et al., 2014; Khan and Karuppayil, 2012; Mandal and Brandl, 2011; Saadoun et al., 2008; Soleimani et al., 2016). Patients may also be a source of airborne microorganisms that can affect other vulnerable patients, personnel, and visitors in hospitals (Qudiesat et al., 2009). Fungal and bacterial bioaerosols, especially in hospitals and clinical settings, cause susceptible patients to be exposed to air pollution during surgery (Napoli et al., 2012).

Previous studies have shown that hospital infections are promoted by fungi such as *Aspergillus species*, *Candida albicans*, *Cladosporium*, *Penicillium*, *Fusarium*, and *Mucorales* (Faure et al., 2002; Sautour et al., 2007; Sohrabi et al., 2014). Faure et al. assessed bioaerosol pollution in ORs in France and reported that the predominant species were *Penicillium* spp., *Cladosporium* spp., *Aspergillus* spp., and *Aspergillus fumigatus* (Faure et al., 2002). Another study evaluated microbe levels in different parts of a hospital and found that the fungal concentration ranged from 0 to 7.33 CFU/m^3 in ORs (Ortiz et al., 2009). Concentrations of fungi

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and bacteria in a hospital in Taiwan ranged between 0 and 319 and 1–423 CFU/m^3, respectively (Li and Hou, 2003). Moreover, fungal bioaerosols can be caused colonizing syndromes, such as nosocomial aspergillosis and allergic bronchopulmonary aspergillosis (Ortiz et al., 2009; Sohrabi et al., 2014). The presence of fungi in hospital wards, particularly ORs, is linked to several factors such as the (i) presence, condition, and activities of patients, (ii) temperature, (iii) inadequate ventilation, (iv) poor air-conditioning systems, (v) humidity, (vi) organic matter (OM) available in materials of walls, (vii) types of surgery, (viii) the season, and (ix) inadequate disinfection (Dharan and Pittet, 2002; Faure et al., 2002; Nourmoradi et al., 2012; Park et al., 2013; Sautour et al., 2007; Wan et al., 2011). The main reason for bacterial contamination in OR air is thought to be surgical site infection after operations (Dharan and Pittet, 2002; Landrin et al., 2005; Napoli et al., 2012).

The goal of this work was to study the type and concentration of bioaerosols in ORs in a major educational hospital in Shiraz, Iran, specifically affiliated with the Shiraz University of Medical Sciences. By comparing aerosol characteristics before and after conventional disinfection and sterilization procedures, a goal of this work is to determine how effective such procedures are in eliminating harmful bioaerosol in the indoor environment of a major hospital.

2. Materials and methods

2.1. Location

Shiraz is in a semiarid area and the capital of Fars province in southwestern Iran (29°36′N, 52°32′ E) with an average elevation of 1500 m above sea level (Dehghani et al., 2018; Delikhoon et al., 2018; Neghab et al., 2017). It is located near Iraq, Saudi Arabia, and Kuwait and has a total population of 1.3 million (Fig. 1). This study aimed to assess the microbial load, including fungi and bacteria, in the indoor air of nine ORs in an educational hospital in Shiraz, Iran in 2017. Furthermore, patients who check into the hospital typically have diseases such as those related to the cardiovascular system, hemic and lymphatic systems, mediastinum and diaphragm, digestive system (stomach / excision, liver / incision and so on),urinary system (kidney, bladder / excision, cystoscopy / urethroscopy / cystourethroscopy and ureter / incision), male genital system, integumentary system,musculoskeletal system, maternity care and delivery, respiratory system, and female genital system. It should be noted that only general and internal surgeries were performed in the ORs under investigation.

2.2. Cleaning operating rooms and ventilation

Before surgery, all OR instruments, including chests, tables, and operation beds, were cleaned and disinfected with a Deconex Surface AF (Aldehyde-Free) solution. The floors and walls of the nine studied ORs were also disinfected with a sodium hypochlorite (NaOCl) solution. During and after surgery, OR floors were cleaned by wet mopping (cleaning tool). In addition, ORs were cleaned every Thursday with the following steps: (i) all mattresses, rolls, logo boards, rims, and stretchers were rinsed with detergent and water and disinfected with Deconex 50 AF; (ii) doors and walls were rinsed with detergent and water disinfected using Deconex 50 AF; and (iii) floors and walls were disinfected with the NaOCl solution. Additionally, after sterilization and disinfection, ORs were sterilized with UV irradiation in a short span of time (< 2 h). In addition, this educational hospital has conventional ventilation with HEPA filters. HEPA-filtered laminar air-flow was supplied vertically and downwards to ORs via ceilings. The air change rate was less than 15 h^{-1} and no recirculation of air occurred.

2.3. Sampling method

A QuickTake-30 sample pump equipped with standard biostage impactor containing 400-holes (BioStage Single-stage Impactor, SKC, Inc., USA) was used for air sampling every twenty minutes at a flow rate of 28.30 L min^{-1}. Relative humidity (%) and temperature (°C) were simultaneously recorded using a portable instrument (Preservation Equipment Ltd, UK) to find the relation between bioaerosol concentrations and environmental conditions. Sabouraud dextrose agar

Fig. 1. Map of Iran and Shiraz indicating the location of the selected hospital.