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Effectiveness of air purifiers in intensive care units: an intervention study

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SUMMARY

Background: Effective design and operation of intensive care unit (ICU) ventilation systems is important to prevent hospital-acquired infections. Air purifiers may contribute.
Aims: To detect the number and types of micro-organisms present in the air and on high-touch surfaces in ICUs, and to evaluate the effectiveness of air purifiers in reducing the microbial load and thus the rate of nosocomial infections in ICUs.
Method: This intervention study was conducted in two similar ICUs between May to November 2020. Novaerus air purifiers were located in the intervention ICU for 2 months. Routine cleaning procedures and high-efficiency particulate air filtration continued in the control ICU as well as in the intervention ICU. After 2 months, the air purifiers were moved to the other ICU for the next 2 months to reduce any possible bias in the results. Air and surface samples were evaluated.
Findings: Evaluation of changes in the intervention ICU over time revealed a significantly lower colony concentration in the air and on surfaces on Day 60 compared with Day 1 ($P_{air}<0.001$ and $P_{surface}<0.001$). There was a significant positive correlation between the number of colonies detected and the rate of hospital-acquired infections in the intervention ICU ($r=0.406$, $P=0.049$) and in the control ICU ($r=0.698$, $P=0.001$).
Conclusion: Using air purifiers in addition to heating, ventilation and air conditioning systems in hospitals may be an effective way to reduce the microbial load in the air and on surfaces, and thus hospital-acquired infections.

Introduction

The key factors that determine the rate of hospital-acquired infections include host susceptibility, types of host diseases/injuries, micro-organisms frequently found in the hospital and other hospital indoor air pollutants, nutrition, handwashing, environmental control and use of immunosuppressive drugs. Although patients treated in intensive care units (ICUs) and

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surgical wards, and immunosuppressed patients, in general, are most susceptible to such infections, hospital staff and people who visit healthcare facilities frequently are also at risk [1]. The most common hospital-acquired infections in Turkey include pneumonia, bloodstream infections and urinary tract infections, with the most common agents being *Pseudomonas aeruginosa, Acinetobacter* spp., *Staphylococcus aureus* and other *Pseudomonas* spp. [2]. When ICU patients are infected with micro-organisms resistant to antimicrobials, their hospital stay may be prolonged and their treatment costs may be increased, eventually causing higher morbidity and mortality rates. Immediate preventive measures to minimize the entry and spread of micro-organisms in hospital settings should be the first step in the fight against these infections [1].

Appropriate and effective operation of heating, ventilation and air conditioning (HVAC) systems is a priority for improving the environmental factors that affect the indoor air quality of hospitals, and high-efficiency particulate air (HEPA) filters are recommended for infection control in high-risk areas. These technologies can efficiently filter all types of aerosol particles, regardless of their biogenic origin, as required by applicable standards [1,3–7]. Many studies have reported that HEPA filters in hospitals can reduce the risk of aspergillus and other fungal infections [8]. The literature also reports that HVAC-integrated air filtration systems (indoor air purifiers) may decrease aerosolized viral loads [1,3,4]. Air filtration studies suggest that HEPA filters can be very useful for reducing airborne levels of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), the cause of coronavirus disease 2019 (COVID-19) [9]. Therefore, by protecting and reinforcing existing ventilation systems by means of hospital environmental and administrative controls, the rates of hospital-acquired infections associated with airborne infectious pathogens can be minimized [8–10]. In the first half of 2019, the rate of hospital-acquired infections in the ICUs at the study hospital was 1.47%. To prevent hospital-acquired infections, ICUs, where high-mortality infections commonly occur, must be appropriately designed, and managed with the cooperation of clinicians and administrative functions of the hospital to ensure effective operation of ICU ventilation systems [10].

This study aimed to determine the indoor microbial loads inside the ICUs and in the immediate surroundings of ICU patients, and to evaluate the effectiveness of air purifiers installed in the ICUs for filtering microbial loads and preventing nosocomial infections.

Methods

Study design

This experimental intervention study was designed prospectively and conducted between 1 May and 30 November 2020. The study sites were two similarly designed ICUs at a tertiary hospital in Western Turkey. The study was approved by the hospital's ethics committee and the local ethics committee (approval dated 5 November 2019, No. 11–12).

ICU characteristics

Two general-type ICUs with similar bed capacities, patient requirements, room areas and hospital-acquired infection rates (based on previous year) were selected for the study. These ICUs shared a central HEPA filtration system, with room temperature maintained at 20–25ºC and relative humidity of 30–60%. Located on the same floor, opposite each other, both ICUs had an area of 105 m^2 and each had eight beds. All staff wore personal protective equipment before entering the ICUs.

The study consisted of two phases. In Phase 1, ICU 1 was the intervention site and ICU 2 was the control site. The air purifiers in the intervention ICU were placed far away from doors, windows and the ventilation system. They were used for 2 months (15th May–15th July 2020). After 2 months, the devices were turned off, followed by a 1-month waiting period (August 2020). The air purifiers were then placed in ICU 2 after replacing the filters, and ICU 1 became the control ICU in Phase 2. Phase 2 of the study lasted for 2 months from 15th September to 15th November 2020. No other air purification systems were used in the control ICU.

In both phases of the study, the facilities were maintained through routine cleaning procedures: the floors and all compatible elevated environmental surfaces were cleaned using 1000 mg/L chlorine-containing disinfectant three times per day, and 70% alcohol was used for chlorine-incompatible surfaces. The central HEPA filtration system was used in both ICUs.

Equipment used

Novaerus (Ireland) air purifiers were used in this study. Novaerus NV800 and NV1050 air purifiers are filtration devices similar to air conditioners used in $\leq$35 m^2 and $\geq$72 m^2 rooms, respectively. The Novaerus Defend 1050 has been cleared by the US Food and Drug Administration as a 510(k) Class II medical device to filter out and inactivate airborne virus and bacteria within large rooms and indoor spaces. It is a free-standing, portable recirculating air cleaning system with dimensions of 92 cm (h) $\times$ 49 cm (w) $\times$ 58.9 cm (d) and weight of 53 kg. It has five different airflow speeds ranging from 107 to 533 m^3/h, with a noise level ranging from 48 to 78 dB. The device has ultra-low energy plasma technology – a highly powerful yet extremely gentle method of rapid pathogen destruction – combined with a high-performance multi-stage filter system from Camfil which consists of three filters. A powerful multi-speed fan pulls indoor air through a Camfil pre-filter, capturing large particles, protecting the internal NanoStrike plasma coils and extending the life of the HEPA filter. A Camfil G4 carbon/molecular filter neutralizes volatile organic compounds, odours and impurities. A Camfil HEPA H13 filter, which is certified in accordance with EN-1822, traps bacterial debris and particles as fine as 0.12 μm. Six NanoStrike plasma coils provide a deadly strike, made up of multiple concurrent inactivation processes, which work to destroy airborne pathogens rapidly. The source of plasma is the coil assembly that is surrounded by atmospheric plasma discharge [11]. The Defend 1050 has been independently tested and shown to be effective against MS2 bacteriophage virus, a surrogate for SARS-CoV-2, reducing the virus by 99.99% in 15 min. Many air cleaning methods in use in healthcare facilities rely on filters to capture pathogens. However, without deactivating those pathogens first, the filter can allow viable pathogens to colonize. The Novaerus plasma technology solves that problem by killing airborne pathogens before they become trapped in the filter [12,13]. NV800 is a free-standing or wall-mounted device with dimensions of 36.6 cm (h) x 36.5 cm (w) x 11.4 cm (d) and weight of 4.7 kg. It has two speeds – 220 m^3/h

and 260 m^3/h – with noise levels of 40 dB and 45 dB, respectively [14]. This study used one NV1050 device at speed level 3 with air flow of 267 m^3/h and noise level of 67 dB, and two NV800 devices at speed level 2. The washable filters were cleaned every week. When transitioning to Phase 2 of the study, the filters were replaced.

Microbial load concentrations in the air were measured using the bioMérieux AIR IDEAL 3P air sampler (bioMérieux, Marcy l'Etoile, France). This device is a simple, manually operated mobile device. Complying with ISO 14698-1, it collects between 85% and 139% of particulate matter measuring 2–14 μm [15].

Sample collection: air–surface samples

Microbiological samples were collected from indoor ICU air and the immediate surroundings of ICU patients in the intervention and control ICUs. All samples were collected when the staff were least active in their regular functions (cleaning, patient examinations, performing imaging scans, etc.).

The air samples were collected at five different designated points inside the ICU (from the room floor, in the middle of the room, around the ceiling, on the right side and on the left side). In total, 500-L air samples were collected using the sampler at a steady rate of 100 L/min in each sample, with 100 L collected at each point. Five percent sheep blood agar was used for sampling, and an aerobic bacteria colony count was performed. Quantitative results were provided in terms of number of colony-forming units (CFU) per 500 L of air.

Swab cultures were collected simultaneously from an area of 10 cm^2, including the bed armrests, bed headboards, bedside monitors, overbed table, nurse desk and medical cabinet in the ICUs, using Dacron swabs moistened with phosphate-buffered saline with 0.04% Tween 80 which has proven efficiency of 60–98% for bacterial recovery from surfaces [16]. An aerobic bacteria count was performed, and the results were presented as CFU/10 cm^2.

Samples were collected in the same way before the device was turned on (Day 0), as well as on Days 7, 14, 30 and 60 of operation. The same procedure was followed to collect samples in Phase 2 of the study. In total, 120 air samples and 240 surface swab samples were collected from the ICUs during each phase of the study over 4 months.

The number of patients with diagnosed hospital-acquired infections and the rates of hospital-acquired infections during the study were calculated for the intervention and control ICUs. Data collected at the visits with the doctor responsible for monitoring infections between April and December 2020 and the patients' culture results were evaluated. The same infection control doctor, who was not involved in the study, conducted the routine surveillance for hospital-acquired infections throughout the study period. Hospital-acquired infection diagnoses were made based on European Centres for Disease Control and Prevention criteria [17]. The rate of hospital-acquired infections was calculated using the following formula: infection rate = number of infections in the ICU/number of patients admitted to the ICU × 100. The incidence density of hospital-acquired infections was calculated using the following formula: number of infections developing in the ICU/total number of hospital days for patients admitted to the ICU × 1000.

Laboratory analysis

A 5% sheep blood agar medium was incubated at 36°C for 24–48 h to identify the indicator micro-organisms in the collected air. After micro-organisms that grew in the blood agar were Gram-stained, the bacteria were identified by conventional microbiological methods. The presence of any indicator micro-organisms causing hospital-acquired infections in the ICUs, including *S. aureus*, *Enterococcus* spp., Enterobacterales, *Pseudomonas* spp., *Acinetobacter* spp., other non-fermenting Gram-negative bacilli, *Candida spp.*, *Aspergillus* spp. and moulds, was investigated. The presence of any specific antibiotic resistance, such as meticillin resistance in *S. aureus*, vancomycin resistance in enterococci, and carbapenem resistance in Enterobacterales, was examined by the disk diffusion method using cefoxitin 30 μg, vancomycin 5 μg, ertapenem 10 μg and meropenem 10 μg antibiotic disks. Five percent sheep blood agar was inoculated with the swab

Table I
Distribution of pathogenic micro-organism species detected in the intervention and control intensive care units (ICUs) on the sampling days in Phases 1 and 2

Phase 1	Micro-organism species		
	Days	Intervention ICU	Control ICU
Air	1		
	7		
	14	*A. baumannii*	
	30		*A. baumannii*
	60		*A. baumannii*
Surfaces	1	*S. aureus*	*A. baumannii*
	7		*A. baumannii*
	14	*A. baumannii*	*A. baumannii*
	30		*A. baumannii*
	60		*S. aureus*
Phase 2			
Air	1	*K. pneumoniae*	
	7	*P. agglomerans*	*S. aureus*
			A. baumannii
	14	*S. aureus*	*S. aureus*
	30	*A. baumannii*	
	60	*K. pneumoniae*	
Surfaces	1	*K. pneumoniae*	
		A. baumannii	
	7	*A. baumannii*	*A. baumannii*
	14	*A. baumannii*	*A. baumannii*
	30	*A. baumannii*	*A. baumannii*
		E. cloacae	
	60	*K. pneumoniae*	
		S. aureus	
		A. baumannii	

A. baumannii, *Acinetobacter baumannii*; *S. aureus*, *Staphylococcus aureus*; *K. pneumoniae*, *Klebsiella pneumoniae*; *E. cloacae*, *Enterobacter cloacae P. agglomerans*, *Pantoea agglomerans*.

cultures collected from the immediate surroundings of patients. Incubation and other microbiological procedures were performed as described above.

Data analysis

The data were evaluated using SPSS (IBM Corp., Armonk, NY, USA). Descriptive and inferential analyses were performed using non-parametric tests. The Kruskal-Wallis test was used to compare the number of colonies detected according to sampling day, the Mann-Whitney *U*-test was used to compare the number of colonies detected in the intervention and control ICUs, and Spearman's analysis was used to analyse correlation of measurable values. $P<0.05$ was considered to indicate statistical significance for all comparisons.

Results

Table I shows the distribution of pathogenic micro-organism species detected in the intervention and control ICUs on the sampling days in Phases 1 and 2.

All *Acinetobacter baumannii* strains isolated from the air and surfaces in the intervention and control ICUs during both phases of the study were found to be resistant to carbapenems and tigecycline, and susceptible to colistin. *S. aureus* strains isolated from both ICUs were susceptible to meticillin. *Klebsiella pneumoniae* strains isolated from both the air and surfaces in the intervention ICU were resistant to carbapenems and, with the exception of one, were susceptible to colistin and tigecycline. Carbapenem- and tigecycline-resistant but colistin-susceptible *A. baumannii* and carbapenem-resistant *K. pneumoniae* were the primary pathogens causing hospital-acquired infections according to the infection control surveillance data.

Comparison of the number of colonies identified in the intervention and control ICUs by day revealed no difference between the two ICUs in terms of colony concentrations in the air on Days 1, 7 and 30 ($P=0.062$, 0.154 and 0.261, respectively).

The colony concentration in the air in the intervention ICU on Day 14 was significantly higher compared with the control ICU ($P<0.001$). A significantly higher colony concentration was found in the control ICU on Day 60 ($P<0.001$).

The colony concentration on surfaces was significantly higher in the intervention ICU on Days 1 and 7 ($P<0.001$ and <0.001, respectively). A significantly higher colony concentration was found in the control ICU on Days 14, 30 and 60 ($P<0.001$, <0.001 and <0.001, respectively).

Evaluation of changes in the intervention ICU over time revealed a significantly lower colony concentration in the air and on surfaces on Day 60 compared with Day 1 ($P_{air}<0.001$ and $P_{surface}<0.001$). An evaluation of changes in the control ICU over time revealed a significantly higher colony concentration in the air and on surfaces on Day 60 compared with Day 1 ($P_{air}<0.001$ and $P_{surface}<0.001$) (Figure 1).

Comparison of the number of colonies in the intervention and control ICUs by day revealed no difference between the two ICUs in terms of the colony concentration in the air on Days 14 and 30 ($P=0.090$ and 0.435, respectively). The colony concentration in the air in the control ICU on Days 1, 7 and 60 ($P<0.001$, <0.001 and <0.001, respectively) was significantly higher compared with the intervention ICU.

The colony concentration on surfaces was significantly higher in the intervention ICU on Day 1 ($P<0.001$). While there

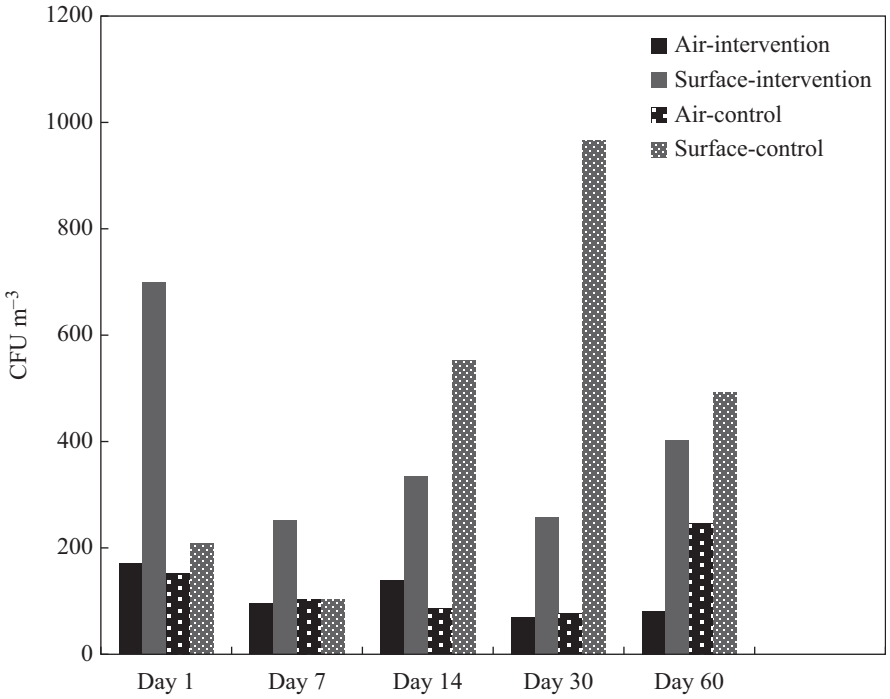

Figure 1. Distribution of the number of colonies detected in the air and on surfaces in the intervention and control intensive care units by sampling days during Phase 1. CFU, colony-forming units.

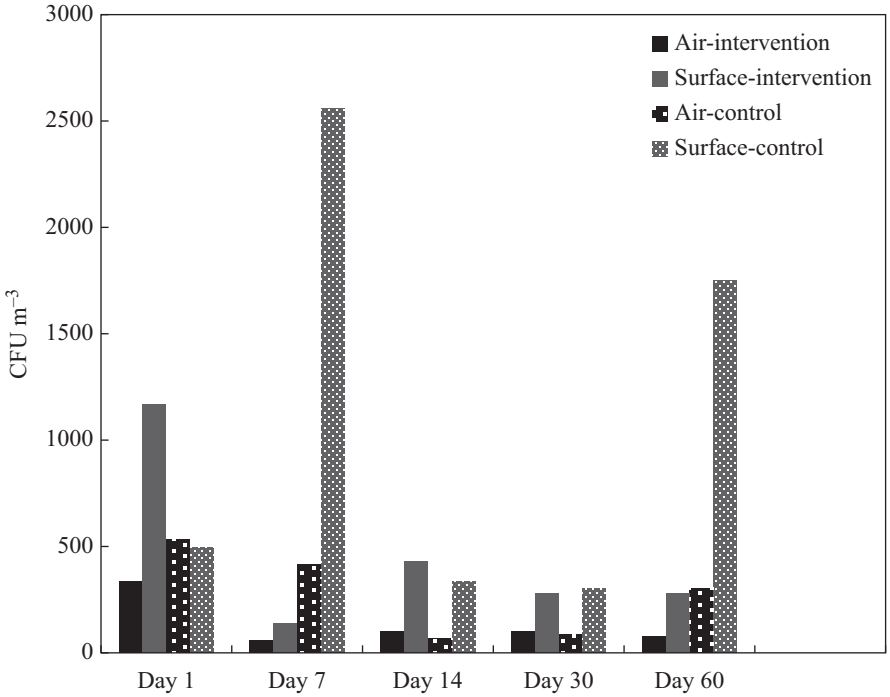

Figure 2. Distribution of the number of colonies detected in the air and on surfaces in the intervention and control intensive care units by sampling days during Phase 2. CFU, colony-forming units.

was no difference between the colony concentrations on surfaces in the intervention and control ICUs on Days 14 and 30 (P=0.071 and 0.321, respectively), a significantly higher colony concentration was found in the control ICU on Days 7 and 60 (P<0.001 and <0.001, respectively).

Evaluation of changes in the intervention ICU over time revealed a significantly lower colony concentration in the air and on surfaces on Day 60 compared with Day 1 (P_{air}<0.001 and $P_{surface}$<0.001). Evaluation of changes in the control ICU over time revealed a significantly lower colony concentration in the air and a significantly higher colony concentration on surfaces on Day 60 compared with Day 1 (P_{air}<0.001 and $P_{surface}$<0.001) (Figure 2).

Over the total study period, regardless of sampling days, in Phase 1, CFUs in the air and on surfaces were found to be higher in the control ICU than in the intervention ICU (P<0.001 and <0.001, respectively). CFUs on surfaces were higher than in air in the intervention and control ICUs (P<0.001 and <0.001, respectively). The same results were found in Phase 2 (Table II).

Figures 3 and 4 show the distribution of the rate of hospital-acquired infections in the intervention and control ICUs, and the incidence density rate of hospital-acquired infections by study time in both phases of the study.

There was a significant positive correlation between the rate of hospital-acquired infections and the incidence density rate of hospital-acquired infections in the intervention ICU during the study (r=0.935, P=0.006). The same result was also observed in the control ICU (r=0.928, P=0.008).

There was a significant positive correlation between the number of colonies detected and the rate of hospital-acquired infections in the intervention ICU during the study (r=0.406, P=0.049). The same result was also observed in the control ICU (r=0.698, P=0.001) (Figure 5).

Discussion

Factors that may affect the transmission of airborne diseases include particle size, particle type, microbial load, distance travelled, micro-organism lifespan and host risk factors [18,19].

Table II
Distribution of the number of colonies detected in the air and on surfaces in the intervention and control intensive care units (ICUs) during Phases 1 and 2

	CFUs	Intervention ICU (mean±SD)	Control ICU (mean±SD)	Statistical evaluation (P)
Phase 1	Air	126.16±38.27	161.98±68.66	<0.001
	Surfaces	460.53±183.39	658.00±282.86	<0.001
Statistical evaluation (P)		<0.001	<0.001	
Phase 2	Air	213.00±125.41	401.37±144.41	<0.001
	Surfaces	750.32±428.01	1854.75±829.39	<0.001
Statistical evaluation (P)		<0.001	<0.001	

CFU, colony-forming units; SD, standard deviation.

Physical factors such as indoor air and environment, room design, patient density and hospital design should also be considered [20]. Additionally, the distribution and complexity of the equipment around ICU hospital beds may increase the number of hospital-acquired infections as well as medical errors. Therefore, it is important to position such equipment carefully [21].

The aim of this study was to identify the microbial load in ICU air, and evaluate the effectiveness of the air purifiers used in addition to the HVAC system. Three air purifiers were used to match the capacity of the room (m^2), and were positioned at a distance from the windows, doors and the ventilation system for higher efficiency and in places where staff activities would not be restricted.

Effective functioning of HVAC systems used in hospitals contributes to a safer environment for patients, hospital staff and visitors, and lower air contamination. Once allergens, bacteria and moulds enter a building, HVAC systems control their transmission and help remove them from indoor air [18–20]. Keeping indoor air clean is an important strategy in reducing infections, especially in ICUs, where hospital-acquired infections are common [20–22]. A systematic compilation has reported that the total cost of hospital-acquired infections is close to $10 billion [23]. Moreover, a study conducted in Turkey showed that these infections increased the length of stay and patient costs [24]. Studies have shown that the reasons why the air in a hospital room is contaminated with micro-organisms include staff activities and the number of staff members inside the room [25]. Some studies have also reported that *Acinetobacter* and *Aspergillus* spp. as well as *Clostridium difficile* spores are transmitted through air conditioners in ICUs, and that these organisms are further disseminated by the movement of heavily contaminated hospital bed curtains [21,26–28].

Although the ICUs in this study were selected so that both had the same characteristics, and the authors aimed to collect microbiological samples when there was no activity (e.g. cleaning, changing sheets, patient visits, etc.), some situations were beyond the authors' control such as staff activities, consulting physicians' activities, patient movements, curtain movements during emergency procedures, and the fact that, during some procedures, air purifiers were behind curtains. These factors were excluded in Phase 2, and the control and intervention ICUs were swapped, operating the devices for another 2 months during Phase 2. In Phase 1, the colony concentration found in the air and on surfaces in the intervention ICU decreased significantly, and the colony concentration in the control ICU increased significantly during the second month. In Phase 2, the same was observed for the intervention ICU, while the colony concentration in the air in the control ICU decreased significantly, but the surface colony concentration increased. Decreased microbial load over time in the intervention ICU suggests that the devices may be effective. During Phase 2, the authors believe that microbial load in the air settled on to surfaces, increasing the load, in the control ICU. Although the measurements were taken simultaneously, it should be noted that these samples were collected instantaneously and there may be instantaneous differences in ICUs. Phase 1 of the study was in the summer and Phase 2 was in the autumn, so the effect of seasonal air should not be overlooked.

The conditions in the ICUs, such as the COVID-19 pandemic, patient turnover, staff numbers and movements, seasons, and unintentional prevention of air filtration device flow by curtains, patient's bed position or extra devices used for the patient were totally uncontrollable. Under controlled circumstances, the results may have been different. Rapid turnover of the patients could not be prevented due to the high need for ICU beds. Rapid turnover creates additional movement in ICUs, causing an increase in particles in the air that may include micro-organisms. Due to the pandemic, the study had to be reduced to a period of 2 months, rather than 3 months as planned. A longer study may have given better statistical results. Searching for all types of micro-organisms, including fungi and anaerobes, could be interesting, but the authors

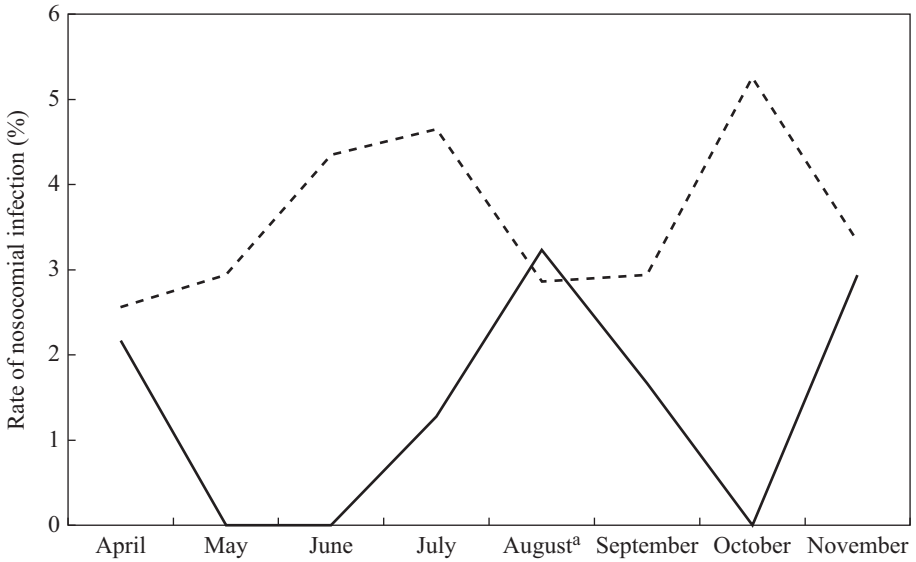

Figure 3. Distribution of the rate of hospital-acquired infections by study period in the intervention (solid line) and control (dashed line) intensive care units in both phases of the study. [a]August was the period without air purifiers. Phase 1, 15th May–15th July 2020; Phase 2, 15th September–15th November 2020.

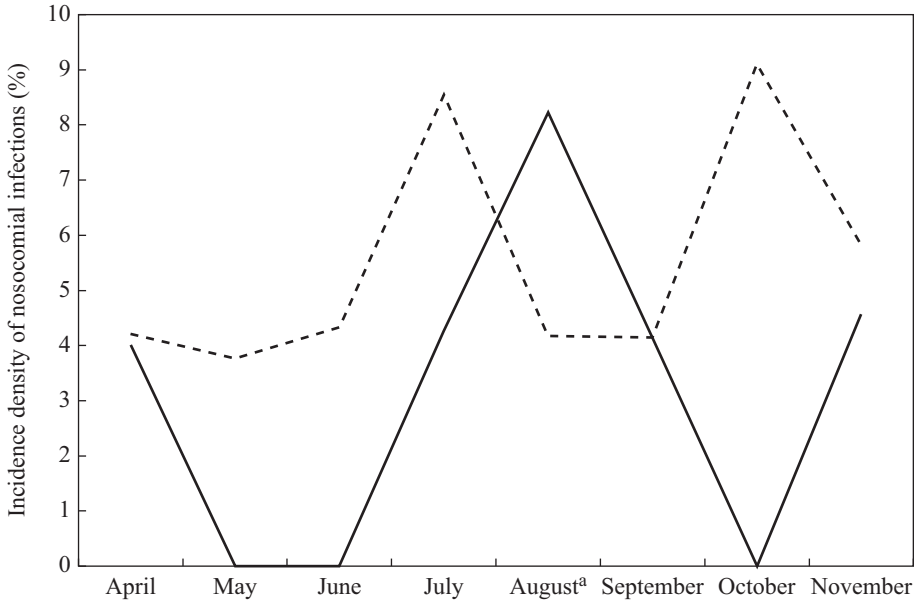

Figure 4. Distribution of the incidence density rate of hospital-acquired infections by study period in the intervention (solid line) and control (dashed line) intensive care units in both phases of the study. [a]August was the period without air purifiers. Phase 1, 15th May–15th July 2020; Phase 2, 15th September–15th November 2020.

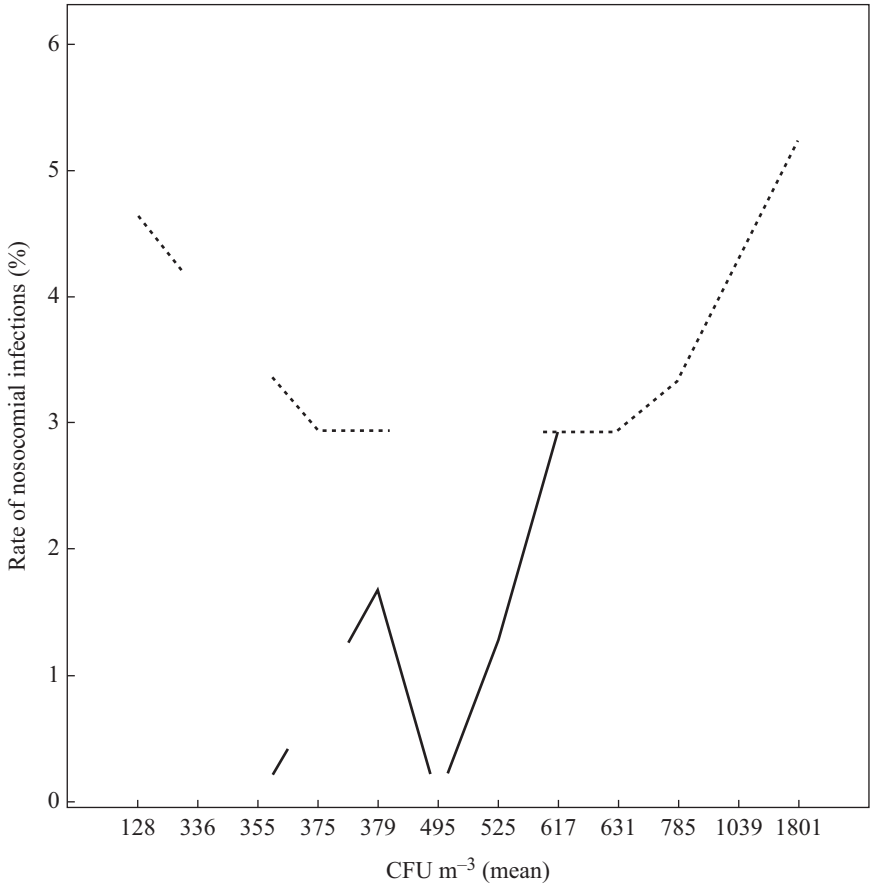

Figure 5. Distribution of the rate of hospital-acquired infections and colony concentration in the intervention and control intensive care units in both phases of the study. CFU, colony-forming units.

preferred to focus on indicator micro-organisms for hospital-acquired infections.

Hand hygiene compliance is audited and reported regularly by infection control nurses at the study hospital. Compliance was reported to be >90% in both ICUs from May to November 2020. The differences cannot be explained by differences in hand hygiene compliance rates. Nonetheless, it should be kept in mind that hand hygiene compliance is audited regularly but not continuously, which can still leave instantaneous failures open for discussion.

Compliance with cleaning/disinfection procedures is audited regularly by infection control nurses at the study hospital, and all failures are reported using a corrective action form. No failures were reported between May and November 2020. The same staff performed cleaning and disinfection during this period in both ICUs. The differences cannot be explained by thoroughness of cleaning and disinfection.

A. baumannii, *S. aureus* and *K. pneumoniae* — indicator micro-organisms associated with hospital-acquired infections — were isolated in the air and surface samples collected on different days. *A. baumannii* strains were found to be resistant to carbapenems and tigecycline, and susceptible to colistin. *S. aureus* strains were found to be susceptible to meticillin, whereas *K. pneumoniae* strains were found to be resistant to carbapenem and, with the exception of one, susceptible to colistin and tigecycline. Strains of this antibiotype are the most common infectious agents in the ICUs at the study hospital, and patients who had these bacterial infections were monitored in respective ICUs when their samples were collected. However, they could not be examined on a patient basis.

Hospital-acquired infection rates may wax and wane over time due to hyperendemic rates, but according to the hospital infection control surveillance data, no hyperendemic rates were reported in any ICUs during the study period.

Most hospital-acquired infections are from endogenous microbes, but the contribution of air and surfaces should not be underestimated. The indicator micro-organisms causing the most hospital-acquired infections in the study ICUs were found in the air and on surfaces, confirming the importance of air and surfaces. They can either be the reason or the consequence of the infection, but the finding that higher colony concentrations in the air and on surfaces were associated with higher infection rates in ICUs confirms the hypothesis. According to the study data, the density of the micro-organisms was approximately four times higher on surfaces than in the air in both the intervention and the control ICUs. If it was possible to exclude other factors related to the patient, healthcare staff, hand hygiene, etc., it might be possible to hypothesize that 20% of hospital-acquired infections come from the air and 80% from surfaces.

The prevalence of viral infections that could cause epidemics, as reported in a hospital in China, correlated with the building design attributes that facilitated air transmission. In China, correlation was reported between the incidence of viral infections that may cause a hospital outbreak and building factors that may facilitate airborne transmission [29]. Additionally, functional aspects of HVAC systems, such as relative humidity and temperature, were found to be significantly correlated with the rates of nosocomial infections, particularly in ICUs [19,29].

There was a significant positive correlation between the rate of hospital-acquired infections and the incidence density of hospital-acquired infections identified in the ICUs during the study. The rate of infection was found to increase in proportion to the length of stay in the ICU. Similarly, the rate of infections identified in the ICUs increased as the number of colonies found in both ICUs increased. The micro-organism concentration detected in the intervention ICU was lower than that in the control ICU.

During the COVID-19 pandemic, the patients in these two ICUs remained isolated from the other pandemic patients in the study hospital, being the only tertiary healthcare facility in the region. In this respect, there were some challenges but also some advantages which enabled the authors to make better observations. It is important to ensure that the ICU is well designed, the number of staff members in patient rooms is low, the length of a patient's stay is kept to a minimum, and ventilation systems operate effectively in order to lower the microbial load in indoor environments.

In conclusion, the micro-organism concentration decreased more rapidly during the first week when the air purifiers were installed in the ICUs. There was no difference compared with the control ICU at the end of the first month, and the microbial load decreased in the intervention ICU, while it increased in the control ICU, at the end of the second month.

Using air purifiers in addition to the hospital HVAC system may be an effective way to reduce the microbial load in the air. However, it should be kept in mind that filtering capacity and environmental factors may, at times, cause contamination. As this study reports the results from 2 months, further prospective studies on long-term effectiveness are recommended.

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Air purifiers and air sampling devices were provided by Novaerus (Ireland) for the study. After the study, all devices were returned to the company.

Conflict of interest statement
None declared.

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