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TANAFFOS

Investigating the Ventilation System of an Intensive Care Unit in the COVID-19 Crisis: A Study in a Hospital of Tehran, Iran

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Background: Ventilation system besides other prevention strategies such as surface disinfecting and personal protective equipment (PPE) decrease the risk of coronavirus disease 2019 (COVID-19) infection. This study aimed to examine the ventilation system of an intensive care unit (ICU) in a hospital in Tehran, Iran to evaluate the potency of heating, ventilation, and air conditioning system (HVAC) for COVID-19 spread.
Materials and Methods: Contamination of air turnover caves was evaluated in supplier diffuser and extractor grills of negative pressure HVAC by ten samples. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the samples was evaluated by the real time reverse transcription-polymerase chain reaction (PCR). Moreover, air conditioning and sick building syndrome (SBS) was assessed according to MM040EA questioning from health care workers.
Results: In the health care workers, respiratory effects were more prevalent compared to other signs. Despite suitable air conditioning, this study highlighted carrier potency of ICU workers for SARS-COV-2.
Conclusion: According to our results, although the HVAC of ICU ward had an appropriate air movement, it was not safe enough for health care workers.

Key words: Health care workers; HVAC system; Intensive care unit; SARS-CoV-2; Sick building syndrome

INTRODUCTION

In December 2019, a coronavirus was identified in Wuhan, one of the main transportation center in China (1). The first cases of coronavirus disease 2019 (COVID-19) were related to a large seafood market in this city. The most common symptoms of COVID-19 are fever, cough, and fatigue (2, 3) and other symptoms include sputum, headache, diarrhea, and indigestion (4). Respiratory droplets from coughing, sneezing, and talking have important role in the virus transmission through the respiratory tract (5). Infection can also occur by touching contaminated surfaces (6). Although different prevention strategies such as social distancing, surface disinfecting, and personal protective equipment (PPE) have been suggested for the spread of COVID-19 (7), these protocols are not adequate for health care workers in the time of outbreak (8). Transmission of droplet contamination could be reduced by suitable ventilation system in the patient room (9).

The Centers for Disease Control and Prevention (CDC) recommended that COVID-19 patients should be admitted to an airborne infection isolation room (AIIR) connected to a heating, ventilation, and air conditioning (HVAC) system by negative air pressure (8). By performing a higher ratio of air extractor than air supplier, infection of indoor air is decreased in negative air pressure system (10). Air filtration in the patient room reduces the viral load in the surfaces and airborne (11, 12). The HVAC system can also decrease the airborne particles and released contamination from surfaces by continuously ventilating of patient room (9). High-efficiency particulate absorbing (HEPA) filtration is one of the most important parts of the HVAC system, which captures particles by diameter higher than 0.3 micron (13). It is expected that the HEPA filter will be able to capture the SARS-CoV-2 (14).

The preparation of AIIR for COVID-19 patients is impossible in many countries due to the severity of pandemic. Hence, the patients confirmed by medical strategies are referred to intensive care unit (ICU) of hospitals (15). HVAC is one of the most important equipment of ICU ward in the hospitals (16). Performance of HVAC system has been confirmed for the control of nosocomial infections (17).

Furthermore, air quality has been related to sick building syndrome (SBS), which is defined as symptoms in indoor environments, including headache, fatigue, irritation of eyes, nose, and throat, and dry/itchy skin (18). Many studies on SBS have been performed (19). SBS symptoms have been reported to be associated with personal and indoor environmental factors (20).

However, the stay of infected patients in the ICU instead of AIIR is still an unanswered question. Currently, there is no experimental study to examine HVAC of ICU ward in the contaminated area with the virus. Moreover, given that prevalence of nosocomial infected cases in the ICU was reported higher than 20% (21), the air quality by SBS was evaluated in the ICU ward. Hence, we assessed the reduction of COVID-19 spread in ICU ward by evaluating SARS-CoV-2 in the air turnover locations of HVAC system.

MATERIALS AND METHODS

Experimental Design

This study was conducted on April 2020 in the time of COVID-19 spread in Tehran, Iran. Tehran is a critical point for the spread of SARS-CoV-2 since it is the highest populated city in Iran. One of the hospitals in Tehran for the admission of COVID-19 patients is Shohada-E-Tajrish Hospital, and critical patients are referred to the ICU ward of this hospital. The ICU was equipped with HVAC system by negative pressure pattern. Ten samples were provided from suppliers and extractor grilles of supply diffuser in ICU ward by sterile swab (22). Each sample was deposited to the sterile tube containing 2 mL of DMEM media.

COVID-19 Detection

To detect the COVID-19 virus, E and RDRP (RNA-dependent RNA polymerase) region of each sample was performed according to the real time reverse transcription-polymerase chain reaction (PCR). Viral RNA was isolated from 500 µl of media by a QIAamp DSP Virus kit (QIAGEN GmbH, Hilden, Germany) according to the manufacturer's instructions. Quantity and quality of the isolated RNA was evaluated using a NanoDrop (Thermo Scientific, Wilmington, USA) spectro-photometer. SARS-CoV-2 genomic RNA was detected with specific primers and probes suggested previously (23) by Rotor-Gene Q system (QIAGEN, Germany).

Air Quality Query

Indoor air quality of ICU ward was evaluated by MM040EA questionnaire. All the ICU staff from two shifts (n=19) filled the MM040EA questionnaire. While SBS was performed in the health workers, the studied ICU was specified for COVID-19 infected cases in the past two months. The English questionnaire had been translated to Persian and validated in another study (24). MM040EA contained 53 items with four parts. While two parts dealt with questions about public information and historical disease, two other parts examined the clinical symptoms and working environments in recent months. Clinical symptoms section was applied for SBS and working environment section was used for indoor air quality assessment.

RESULTS

The sampling stations from air turnover location have been presented in Figure 1. Negative pressure design in ventilation system of HVAC had been provided by ten air supply diffuser and 11 extractor grills. Nine extractor grills had been located on the wall behind the bed and two others behind the nurses' station. There was 0.3 m interval between extract grills and floor.

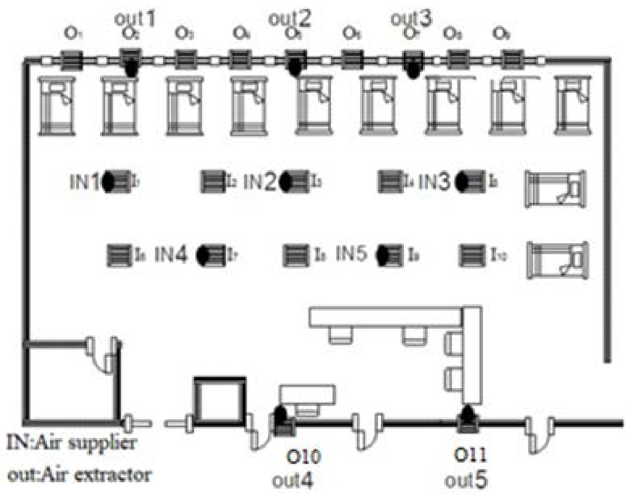

Figure 1. Sampling station from air supplier (IN1to IN5) and air extractor (out1 to out5).

Patients in the ICU ward were confirmed cases of SARS-CoV-2 infection. Table 1 revealed characterization of bedridden patients in the time of study. All swab samples from supplier and extractor grill surfaces presented negative results for SARS-CoV-2 detection.

Table 1. Specification of bedridden patient in studied ward

Patient	ICU (30*10)
Oxygen treatment	11
Intubation treatment	2
Patient symptoms	Fever, cough

Questions about ICU air quality and ventilation parameters such as air movement, temperature change, stuffy air, dust, and dry conditions were answered by health workers. For each environmental parameters answers were categorized into "often", "sometimes", and "never". The responses of most workers were suitable for air movement (5.3% chose "never"). Moreover, the percent of "often" answer for unsuitable conditions such as temperature change, stuffy air, and dust was lower than other answers (Figure 2).

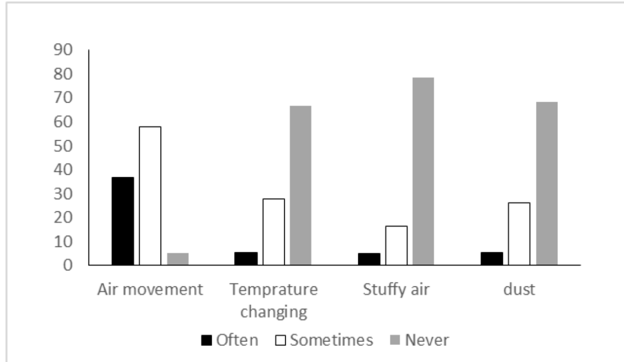

Figure 2. Responses to air condition query for the ICU workers

SBS was detected by general effects, eyes, respiratory effects, and skin signs. Table 2 shows characteristic symptoms extracting from questionnaire. However, the answer of each symptom was evaluated by "often", "sometimes", and "never" options.

Table 2. Specification of symptoms

Effect	Symptom
General effect	Fatigue, Heavy headed, Headache, Nausea, Centralization
eye	Burning eyes
Respiratory	Runny nose, cough, Dry throat
Skin	Skin redness, Itching scalp and ears, Dry skin

The mean age of health care workers was 33.16±9.28 years and their mean work experience was 9.98±7.5 years. Health effect for each subject was provided by detecting at least one symptom by answering "often". The results showed that the percent of respiratory effects in health care workers was higher than other signs (Table 3).

Table 3. Sick building syndrome sign in ICU workers

Effect	Percent of positive answer
General effect	57.9
Eye	26.3
Respiratory	68.4
Skin	47.3

DISCUSSION

Ventilation besides other prevention protocols could be an effective strategy for reducing the spread of virus (25, 26). Due to the unknown properties of SARS-CoV-2, identifying more innovative strategies for air conditioning may help to fight the spread of virus. This study was performed in the ICU ward of a hospital admitting COVID-19 patients. A negative pressure HVAC system was studied by viral contamination in the air turnover locations and health care workers answered the questions.

In this study, ICU ward was the contaminated area due to the admission of 11 patients with COVID-19. The extractor grills behind the bed were 0.5 meter away from the patients by 0.3 m interval. Since contaminated droplets travel to less than 1 m from the patient (27), arrival of SARS-CoV-2 after sneezing and coughing of affected patient is predictable. In this study, all samples from extractor grill surfaces were presented as negative. This result can be due to the fact that the air bends when entering the ventilation system and does not rub against the surrounding surfaces (vena contracta phenomenon) (28). As a result, the virus particles in the air also normalize the airflow and do not rub against surfaces. These results highlighted the potential of ventilation system for transporting the virus into environmental area. Also, this was related to the exhaust fan located on the rooftop and designing air change based on the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE-170) suggestion (13). Moreover, all samples from air supplier were negative. The studied HVAC systems had high-efficiency particulate absorbing (HEPA) filters and the entering of clear air was proved in our results.

The answers of health care workers to questions related to environmental conditions in the MM040EA questionnaire were in the line of experimental results. Air movement in the ICU was confirmed by 95% of workers due to responses of "often" and "sometimes". According to the viewpoints of 30% of workers, there was dust in the surfaces of ward. The load of SARS-COV-2 in the dust increases the risk of infection transmission (29). However, particles by diameter higher than 5 µm could be deposited on the surface, and then contaminated surface area could contribute in viral spread (30).

Regarding to heath effect answers from MM040EA questionnaire, respiratory effects including runny nose, cough, and dry throat in health care workers were increased. Among the sick building symptoms signs, prevalence of respiratory effect is considerable. Although, health workers were not infected to COVID-19 but they showed symptoms related to SARS-COV-2. It can confirm the possibility of health care workers being exposed to the SARS-COV-2 and the carrier potency of them. The results revealed that all cases had at least one "often" response to SBS questions.

The role of HVAC system by negative pressure for SARS-COV-2 decreasing has been specified in this study. But air circulation within the ICU room from supplier diffusers to extractor grills could be make respiratory exposure to SARS-COV-2 in health care workers. This might be due to the fact that droplets containing the virus adhered to the surfaces around the patient evaporate by the passage of air, then the virus enters the air with these vapors and is inhaled by health care workers. Vaporized droplets, of course, include droplets adhering to surfaces and droplets in the air. This means that parts of the airborne viruses enter the respiratory tract of health care workers before being collected by the ventilation system (13). This exposure is low due to suitable ventilation system, but could cause SBS. However, association between SBS symptoms and high bio-aerosol contamination was reported in an epidemiological study (31). Although medical care in ICU ward is near to AIIR, but ICU ventilation is not safe enough for health care workers.

CONCLUSION

In this study, we evaluated the spread of COVID-19 virus in the air supply diffusers of an ICU ward. We investigated air conditions and SBS prevalence by

MM040EA questionnaire in health care workers. The results addressed negative presentation for SARS-CoV-2 in the supplier diffuser and extractor grills of HVAC system. Most health care staff believed that there was an appropriate air conditioning in the ICU ward. According to the questionnaire, respiratory effects in the health workers have been increased recently. Although the HVAC system of ICU ward can provide appropriate air movement, it is not safe enough for health care workers.

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