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Research Article

Infection Control Unit Suppresses Airborne Aerosols during Cardiac Stress Testing in an Outpatient Cardiology Clinic

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ABSTRACT

Introduction: Patients with cardiovascular disease are at increased risk of complications of COVID19. Microdroplet aerosols play an important role in viral (SARS-CoV-2) transmission especially during (cardiac) diagnostic- and therapeutic procedures as medical personnel operates close to the patient. To better protect these vulnerable patients and ensure a safe continuity of these procedures during the COVID19 pandemic, we studied an Infection Control Unit (ICU) which actively clears out potentially dangerous aerosols during cardiac stress testing.

Results: We measured the aerosol generation and persistence and CO_2 levels during cardiac bicycle stress testing, in an outpatient cardiology clinic. The measurements were performed in a ventilated room, with and without a Novaerus NV800 ICU. Without the infection control unit, levels of aerosol and CO_2 concentration increased significantly during the stress test. With the ICU, CO_2 concentration increases but the aerosols are no longer detected.

Conclusion: The Novaerus NV800 ICU suppresses airborne aerosols efficiently, to levels that are no longer detectable resulting in a reduced transmission risk of SARS CoV-2 during cardiac stress testing. This enables not only a safe continuity of care for cardiovascular patients but also for patients who are subjected to other diagnostic and therapeutic procedures, during the COVID19 pandemic.

Keywords: COVID19; Ventilation; Cardiovascular disease

INTRODUCTION

The socio-economic impact of the global Coronavirus disease 2019 (COVID19) pandemic is enormous. Complications of SARS-CoV-2 infection have been related to age, obesity, and cardiovascular disease [1,2]. Patients with cardiovascular disease infected by SARS-CoV-2, have a significant higher mortality risk compared to patients without cardiovascular disease [3]. It is demonstrated that small aerosol microdroplets (<5 μm) produced by coughing and speaking can transmit the SARS-CoV-2 when inhaled by others [4]. These microdroplets remain airborne for a longer time and can travel distances significantly larger than 2 meters compared to larger droplets (>5 μm). Facemasks and social distancing protect against the larger droplets but their effectiveness against microdroplet aerosol transmission is limited [5,6]. Surgical masks filter out only 30% of the aerosol particles in laboratory experiments whereas N95 or FFP2 masks provide better protection from aerosols and reduce viral transmission when used by an infected person [7]. To limit the infection risk by aerosols preventive measures, such as distancing, space ventilation, in order to dilute and clear out the aerosols, and minimizing residence time of individuals, need to be implemented.

Often, distancing is not possible during (cardiac) diagnostic and therapeutic procedures as medical personnel needs to operate close to the patient. The proximity to the patient and diagnostic procedures such as cardiac stress testing also entails a larger risk of SARS-CoV-2 transmission through aerosols. To be able to better protect cardiovascular patients and ensure a safe continuity of these procedures during the COVID19 pandemic, we studied a mobile Infection Control Unit (ICU) ventilation system that actively clears out potentially dangerous aerosols during cardiac stress testing. There are various mechanisms for microorganism inactivation by this type of ventilation systems using non-thermal atmospheric plasma discharges. These mechanisms include damage by short wavelength UV radiation, oxidation by oxygen-containing radicals, microorganism wall bombardment by charged molecules or particles, damage by localized short-term heating, and

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the synergistic effect of combinations of various active components in the plasma [8]. Two studies were carried out using the dielectric barrier discharge found inside the NOVAERUS NV800 device used here [9,10]. The studies researched the effect of the plasma discharge ventilation system on E. coli (gram negative bacteria), S. epidermidis (gram positive bacteria) and A. Niger (fungal spores). In these studies, it was found, severe oxidation of the cell membrane and that cell structure was damaged for all microorganisms studied, to varying extents. In all cases, this resulted in loss of vital cellular material, and this method therefore seems well suited to reduce the aerosol transmission risk. We therefore evaluate the effect of the Novaerus Infection Control Unit (ICU) on the aerosol concentration and persistence time during cardiac stress testing in one of the outpatient clinics of Cardiology Centers of The Netherlands (CCN).

METHODS

Aerosol concentration is often measured using a laser sheet diffraction technique [11]. Using this technique as the standard, we validated a novel method using a handheld particle counter (Fluke 985, Fluke B.V. Europe, Eindhoven, The Netherlands) which is frequently used for air quality assessment, overcomes most of the above-mentioned drawbacks of the laser sheet diffraction technique [11-13] (Figure1).

Figure 1: The particle counter, measuring the number of particles per liter of air of a given size indicated in the display. When aerosols are produced, these are visible as an increase in the different channels over the background (dust) particles. The average size of aerosols produced by human activity is around 5 um, after evaporation of the water contained in saliva this gives rise to aerosols of about 1-2 um. We thus use this size range also for the production of the artificial aerosols; the measurements presented below show the data for the 1 um channel, however other channels give similar results and especially the same persistence time to within the experimental accuracy.

The Fluke device has six size channels of 0.3 µm, 0.5 µm, 1.0 µm, 2.0 µm, 5.0 µm, and 10.0 µm. Air is pumped into the device at a flow rate of 2.83 L/min and flows through the detection where a 90 mW laser beam of 775 nm to 795 nm wavelengths illuminates the dust or aerosol particles. The scattered and diffracted light from the particles is detected with a counting efficiency of 50% for the 0.3 µm channel and 100% for particles in all other channels. The accuracy and reproducibility of these measurements is 1%. We evaluated differences in aerosol production between patients, as we hypothesized that one individual may produce more aerosols ("superspreader") as compared with a typical infected other.

The experimental facility in the outpatient clinic of CCN is a 4.4.3 m3 exercise room where the particle counter is placed 2.5 m from the patient at a height of 1 meter from the floor. The clinic's air supply produces ~4400 m3/h while ~3700 m3/h is extracted. The total surface area of the outpatient clinic is 350 m2, and the height of the ceiling 3 m so the total volume is 103 m3, leading to a number of Air Changes per Hour (ACH) of 4-5. After each stress test, the room was ventilated for an hour to avoid an effect on the following test.

During aerosol concentration and persistence measurement, CO_2 was simultaneously determined under different ventilation conditions. A handheld Testo 440 dP (Testo BV, Almere, The Netherlands) was used for both the air renewal rate using the differential pressure sensor and the CO_2 measurement using a CO_2/temperature/relative humidity sensor. Temperature and humidity were constant during the experiments.

Cardiac stress testing

Patients were subjected to a bicycle cardiac stress test for the diagnostic workup of exercise related chest pain, palpitations or dyspnea was included in the study. All patients were referred by a general practitioner to an outpatient clinic of Cardiology Centers of the Netherlands. The study protocol was approved by the Medical Ethics Committee of the Amsterdam University Medical Centre. The stress test protocol is as follows: after a rest ECG was registered and blood pressure was measured, a warming up phase was started with a 60 Watt workload. Each 2 minutes the workload was increased with 20 Watts, and ECG and blood pressure was measured. Each person was instructed to keep the cycle speed at 50-60 rounds per minute. The test was terminated when the target heart rate was reached ((220-age)*0.85) or the patient experienced discomfort. Duration of the test was registered in minutes. Individual performance was characterized in terms of maximal workload (Watt), maximal heart rate, percentage of predicted target workload, and Rate Pressure Product (RPP) (maximal heart rate * systolic blood pressure).

RESULTS

Twelve patients were included in the study. Patient characteristics are shown in Table 1. Figures 2 shows a typical time trace of 1.0 micrometer particle concentrations as a function of time with normal ventilation and adding the mobile ventilation system. In both situations, artificial aerosols were generated in a 5-meter radius around the particle counter. The ventilation system significantly reduces both the absolute concentration and the persistence of the aerosols.

Table 1: Patient characteristics.

Patient characteristic	Average ± standard deviation
Age	56 ± 12
Sex (M/F)	9/3
Reason for referral	Chest pain (8)/dyspnea (2)/ palpitations (2)
Duration of test (min)	7.2 ± 4.1
Workload (Watt)	192 ± 85
Maximal heart rate (bpm)	151 ± 33
% of predicted workload (%)	115 ± 34
Rate-pressure product	28310 ± 7496

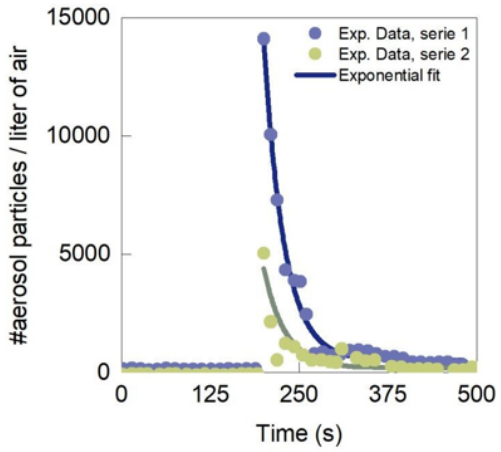
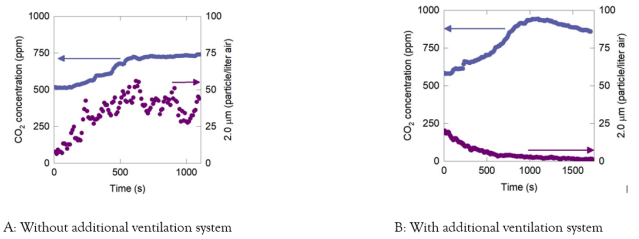


Figure 2: Measured number of aerosol particles as a function of time. Aerosols are produced artificially at t=200s, and their persistence is measured to evaluate the ventilation quality. The characteristic time for the persistence of the aerosols (from the exponential fit) in the waiting room of the outpatient clinic is >2 minutes for 'normal' ventilation (blue), and less than half that time with the mobile ventilation unit added (green).

In a parallel study on these 12 patients, there were very large differences in aerosol production between different patients [14]. It was therefore decided to perform the measurements twice on the same patient on different days. The results (Figure 3) show that without the mobile ventilation device, the cardiac stress testing produces a significant amount of aerosols, and their increase follows the same trend as the CO_2, clearly indicating that it is the stress testing that generates both. In addition, with the normal ventilation of the Cardiology clinic, a large concentration of aerosols remains minutes after an infectious person has left the stress testing room, implying a larger risk of transmission. On the other hand, with the Novaerus ICU, CO_2 is still generated, but the amount of small particles actually decreases; the Novaerus ICU airborne infection control device captures and destroys all the aerosols generated by the stress testing. In addition, the device further purifies the air from background dust particles.



A: Without additional ventilation system

B: With additional ventilation system

Figure 3: Measured number of aerosol particles (red symbols, right axis) and CO2 concentration (blue symbols, left axis) as a function of time. The cardiac stress test starts at 200 seconds and stops at 1000 seconds. For the experiment with the additional ventilation system, the latter is turned on at t=0.

DISCUSSION

In this study, we show that a significant amount of aerosols are produced by patients who are subjected to cardiac bicycle stress testing. These are consequently produced just by breathing, as there was no speaking, coughing or sneezing during the stress test. It has now been well established that aerosols are an important factor in SARS-CoV-2 transmission, especially in small and ill ventilated settings [15]. Since a direct measurement of aerosols is not always feasible, we also performed a simple measurement of CO_2 concentration in the air. During the cardiac stress test, both the aerosol and CO_2 concentration increased in a similar fashion, suggesting that a simple CO_2 measurement could suffice to evaluate the air and ventilation quality in a given environment.

The normal ventilation system reduces both, aerosol and CO2 concentration by exchanging the air with fresh air from outside. However even with the good ventilation system of the outpatient cardiology clinic, the cardiac stress test still produces a. significant amount of aerosols, and even though the air in the exercise room is exchanged with outside air, we still observe a significant increase of the aerosol concentration. Adding the mobile ventilation unit on top of the existing ventilation significantly reduces the aerosol concentration and persistence during the cardiac stress testing. This has important implications: In addition to preventive measures as wearing facemasks, and space ventilation, active air-clearing of aerosols by a dedicated system such as the plasma ventilation system tested here, further reduces the SARS-CoV-2 transmission risk. Such active air-clearing systems can be used in diagnostic- and therapeutic procedures where healthcare providers are working in the close vicinity of patients to achieve the lowest transmission risk possible. This will enable continuity of healthcare during the COVID19 pandemic, especially for patients with cardiovascular disease for whom delay of these procedures often cannot be accepted from a prognostic perspective. Therefore, adding an active aerosol air-clearing system to all other preventive SARS-CoV-2 transmission measures ensures a safe continuity of cardiovascular care [16,17].

CONCLUSION

The mobile ventilation system substantially reduces the amount of aerosol droplets during a cardiac bicycle stress testing to levels where they can no longer be detected. The use of such a system therefore mitigates the transmission risk of SARS-CoV-2 by aerosols during cardiac stress testing and possibly other diagnostic- and therapeutic procedures enabling a safe continuation of crucial healthcare services during the COVID19 pandemic. It is interesting to note that a so-called high transmission risk procedure, i.e., controlled intubation and extubation and high flow oxygen suppletion, generates a smaller number of aerosols compared to coughing and conventional oxygen suppletion, respectively. Future studies are needed to quantify the risk of aerosol transmission in different diagnostic- and therapeutic procedures.

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