Infection control airborne infection control unit suppresses airborne aerosols during cardiac stress testing in an outpatient cardiology clinic

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Summary

Introduction: Cardiovascular patients are at increased risk of complications due to COVID19. One of the current worries is that microdroplet aerosols can be responsible for viral (SARS-CoV-2) transmission. These droplets are especially important for (cardiac) diagnostic- and therapeutic procedures as medical teams operate close to the patient.

Results: We measured the aerosol generation and persistence and CO_2 levels during cardiac stress testing on an exercise bike, in an outpatient cardiology clinic. This was done with the room ventilation on, and with and without a Novaerus NV800 Infection Control Unit. Without the infection control unit, levels of aerosol and CO_2 concentration increase significantly during the stress test. With the Infection Control Unit, CO_2 concentration increases but the aerosols are no longer detected.

Conclusion: The Novaerus NV800 Infection Control Unit suppresses airborne aerosols very efficiently, to levels that are no longer detectable.

Introduction

The ongoing global CoronaVirus Disease 2019 (COVID19) pandemic has enormous social and economic impact. Susceptibility to SARS-CoV-2 infection and subsequent complications have been related to age, obesity, and cardiovascular disease[1,2]. Cardiovascular patients, if infected by SARS-CoV-2, have a significant higher mortality risk compared to patients without cardiovascular disease [3].

There is growing evidence that small aerosol microdroplets (<5 μm) produced by coughing and speaking can also transmit the virus [4]. Such small droplets remain airborne and inhalable for a longer time and can travel distances significantly larger than 2 meters when airborne. Facemasks and social distancing protect against larger droplets but their effectiveness against microdroplet aerosol transmission is limited [5,6]. The much-used surgical masks, for instance, filter out only 30% of the aerosol particles in laboratory experiments and only much better masks (N95 or FFP2) provide good protection from aerosols [7]. Additionally if an infected person wears such a high-protection mask this significantly reduces the generation of aerosols [7]. To limit the infection risk by aerosol particles other preventive measures, such as space ventilation in order to dilute and clear out the aerosols and minimizing residence time, need to be implemented.

The aim of this study is see whether a Novaerus Infection Control Unit can be used as a risk-mitigating device for the risk of aerosol transmission of SARS-CoV-2 during cardiac stress testing. We study cardiac stress testing at Cardiology Centers of The Netherlands (CCN), a chain of outpatient cardiology clinics.

Methods

Aerosol concentration is often measured using a laser sheet diffraction technique [8]. 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 and overcomes most of the above-mentioned drawbacks of the laser sheet diffraction technique [8], and is shown in Fig.1.

The experimental facility in the outpatient clinic is a $4{\cdot}4{\cdot}3$ m^3 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 m^3/h while ~3700 m^3/h is extracted. The total surface area of the outpatient clinic is 350 m^2, and the height of the ceiling 3 m so the total volume is 10^3 m^3, 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 440dP (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.

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 5um [9], after evaporation of the water contained in saliva this gives rise to aerosols of about 1-2um. We thus use this size range also for the production of the artificial aerosols; the measurements presented below show the data for the 1um channel, however other channels give similar results and especially the same persistence time to within the experimental accuracy.

Results

Aerosol persistence

We previously studied the temporal and spatial behavior of aerosol droplets, generated by healthy individuals through speaking and coughing [9]. We also showed how to artificially generate aerosol droplets, allowing us to measure their persistence and hence evaluate the ventilation quality of different spaces [8]. Here, we use the particle counting method to determine the aerosol droplet persistence over time in an outpatient cardiology clinic with different ways of ventilation. We do this in the cardiac stress testing room that has dimensions 4x4x3 m^3. Fig.2 shows a typical time trace of 1.0 micrometer particle concentrations as a function of time with normal ventilation (red points) and adding the Novaerus ventilation (blue points). In both situations, artificial aerosols were generated in a 5-meter radius around the particle counter that was standing on a table. It is clear from these data that the Novaerus ventilation system greatly reduces both the absolute concentration and the persistence time of the aerosols.

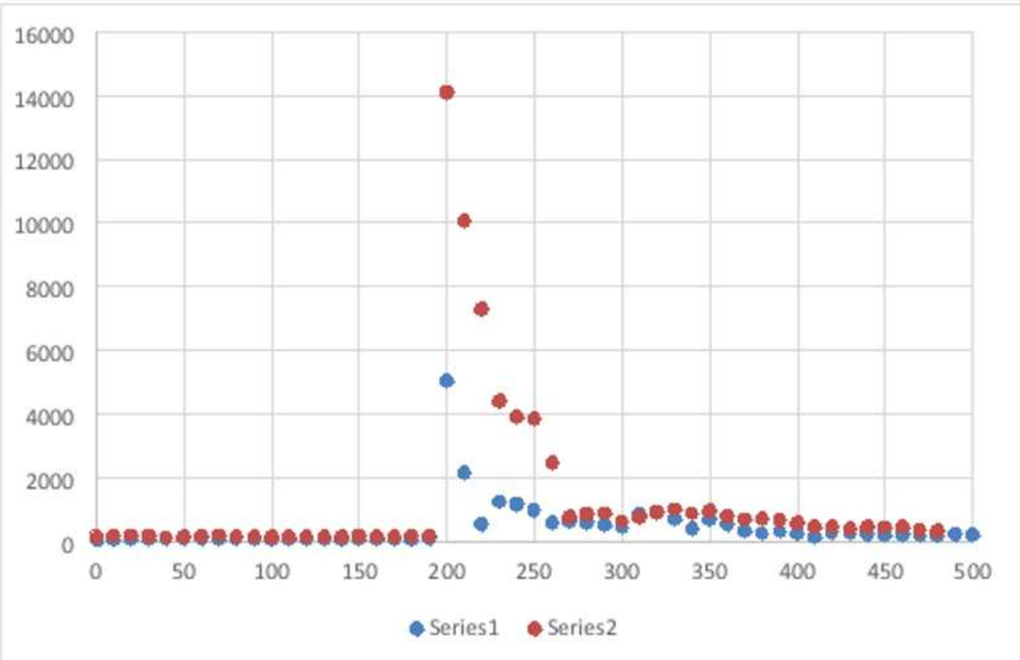


Figure 2. Measured number of aerosol particles as a function of time. Aerosols are produced artificially at t=20s, and their persistence is measured to evaluate the ventilation quality. The characteristic time for the persistence, here >2 minutes for 'normal' ventilation in the waiting room of the outpatient clinic, and less than that time with the Novaerus .

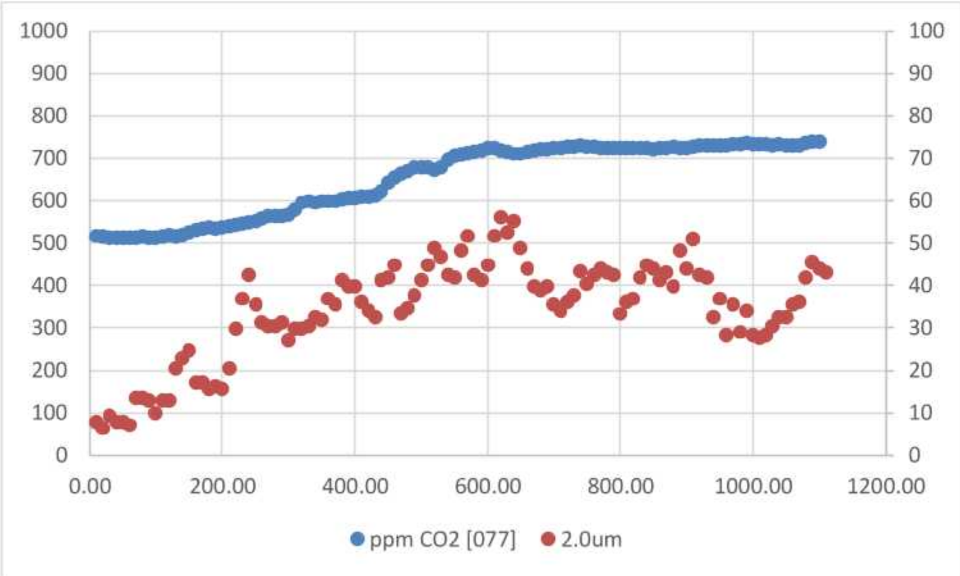
Cardiac stress testing

Patients were subjected to a bicycle cardiac stress test. The experimental configuration is shown in Fig.3. The stress test protocol is the following. 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 rated * systolic blood pressure).

Figure 3. Cardiac stress testing with measurement of aerosol concentration and CO2 levels. The Novaerus machine is positioned 2 meters from the patient, on the ground.

We found large differences in aerosol production between patients [10]. It was therefore decided to perform the measurements twice on the same patient on different days. The results (Fig.4) show that without the Novaerusairborne infection control 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 ECG exercise room,implying a larger risk of transmission. On the other hand, with the Novaerus, CO_2 is still generated, but the amount of small particles actually decreases: the Novaerus 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.

Without Novaerus



With Novaerus

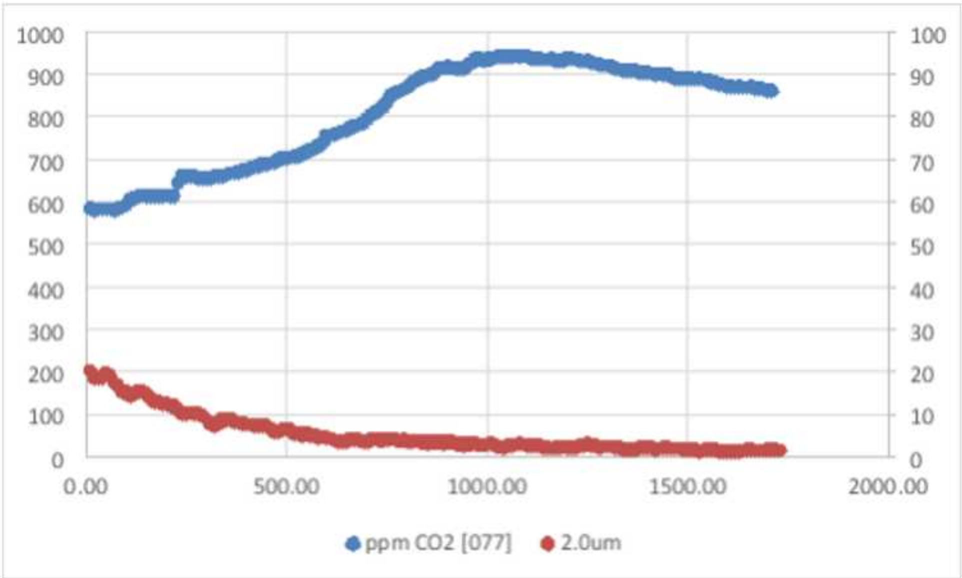


Figure 2. Measured number of aerosol particles (red symbols, right axis) and CO2 concentration (blue symbols, left axis) as a function of time. The cardiac stress test starts at 200 seconds, and stops at 1000 seconds. For experiment with the Novaerus (bottom graph), the machine is tuned on at t=0.

Conclusion

We conclude that the Novaerus airborne infection control device system substantially reduces the amount of aerosol droplets generated by cardiac stress testing to levels where they can no longer be detected.

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