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Brief Report

Feasibility and Consistency of Results with Deployment of an In-Line Filter for Exercise-Based Evaluations of Patients With Heart Failure During the Novel Coronavirus Disease-2019 Pandemic

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ABSTRACT

Background: Exercise testing plays an important role in evaluating heart failure prognosis and selecting patients for advanced therapeutic interventions. However, concern for severe acute respiratory syndrome novel coronavirus-2 transmission during exercise testing has markedly curtailed performance of exercise testing during the novel coronavirus disease-2019 pandemic.

Methods and Results: To examine the feasibility to conducting exercise testing with an in-line filter, 2 healthy volunteer subjects each completed 2 incremental exercise tests, one with discrete stages of increasing resistance and one with a continuous ramp. Each subject performed 1 test with an electrostatic filter in-line with the system measuring gas exchange and air flow, and 1 test without the filter in place. Oxygen uptake and minute ventilation were highly consistent when evaluated with and without use of an electrostatic filter with a >99.9% viral efficiency.

Conclusions: Deployment of a commercially available in-line electrostatic viral filter during cardiopulmonary exercise testing is feasible and provides consistent data compared with testing without a filter. (J Cardiac Fail 2021;27:105–108)

Key Words: Exercise, Peak VO2, COVID-19.

Introduction

Exercise is a critically important physiologic probe used to evaluate the presence and severity of cardiopulmonary diseases, including heart failure (HF). Measurement of peak oxygen uptake (VO2) with exercise testing is mandated by regulatory bodies in selecting appropriate candidates for advanced HF interventions, including left ventricular assist devices and heart transplantation. However, during maximum incremental exercise expiratory flow rates and minute ventilation increase by approximately 10-fold,1 raising concern for dissemination of infections including severe acute respiratory syndrome novel coronavirus-2 (SARS-CoV-2). Moreover, use of surgical or N95 masks limits airflow, and N95 masks have been shown to increase inhaled CO2, decrease inspired O2, and increase work of breathing,2 thereby potentially influencing the ability to perform maximum exercise while also precluding measurement of gas exchange during cardiopulmonary exercise testing (CPET). In addition to the established role of CPET in evaluating patients with HF, the use of CPET is anticipated to increase for characterization of patients with suspected persistent cardiopulmonary dysfunction after SARS-CoV-2 infection.3

Case

We conducted a proof-of-principle study in which a commercially available electrostatic filter MGC Diagnostics, Saint Paul, MN used for pulmonary function testing (Fig. 1), which has been shown to have >99.9% viral filter efficiency for viral particles embedded in 2.7 μm aerosol
particles at a challenge flow rate of 30 L/min, was used during CPET. This filter was placed in-line, upstream of the gas analyzer sample line but away from the exercising subject’s mouth for use during CPET. Two healthy subjects completed 2 incremental CPETs beginning with unloaded exercise and followed by either discrete incremental 50-W stages of exercise or a continuous incremental ramp protocol (Fig. 1). Each subject performed one CPET with the filter and one without, each to 200 W. Mechanical dead space was programmed at 53 mL with the filter and 45 mL without.

**Results**

In comparison with no internal filter, use of an in-line filter in subject 1 resulted in VO₂ measurements of 99%, 97%, 98%, and 97% during 50 W, 100 W, 150 W, and 200 W, respectively (Fig. 2). In subject 2, with a continuous ramp protocol, VO₂ measurements were highly consistent throughout incremental exercise (Fig. 2). With a filter, the 30-second median VO₂ values surrounding 50 W, 100 W, 150 W, and 200 W were 94%, 94%, 103%, and 103%, respectively, of the values without a filter. In both subjects, the highest achieved VO₂ was within 5% with and without a filter in place. VO₂/ work slope measurements and measurements of minute ventilation were also highly consistent throughout exercise in both subjects with and without use of a filter (Fig. 3).

**Discussion**

Exercise is associated with an approximately 10-fold increase in resting expiratory flow rates and minute ventilation raising concern that large volumes of contaminated air entering laboratory spaces could lead to transmission of SARS-CoV-2 by patients undergoing exercise testing. This case highlights the feasibility of introducing an in-line filter in an effort to decrease expulsion of droplets and viral particles during CPET without compromising measurement of VO₂ and other CPET measures. We observed almost identical measurements of VO₂ and minute ventilation, reflecting gas exchange and air flow detection, with an in-line filter in place as compared with the same measurements made without a filter.

Particulate or droplet filtration relies on various mechanisms ranging from physical particle capture with sieving of particles too large to pass through a pore to electrostatic attraction in which differences in electrical charge create an attraction of particles to the media of the filter. Electrostatic filters offer advantages of limiting airflow resistance due to their relatively open structure compared with overlapping fibers in high-efficiency particulate air filters. Additional

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**Fig. 1.** (Left) In-line electrostatic filter as indicated by arrow. (Right) Diagram of exercise ramp protocols completed by each subject.

**Fig. 2.** (Left) Oxygen uptake (VO₂)–time relationship for subject 1 tests with and without filter. (Right) VO₂/time relationship for subject 2 tests with and without filter. Subject 1’s peak VO₂ with filter is -4.9% different from peak VO₂ without filter. Subject 2’s peak VO₂ with filter is +4.1% different from peak VO₂ without filter.
advantages of electrostatic filters are low weight and cost and moisture resistance, which has led to use of electrostatic filters in pulmonary function testing.

Filters are typically rated by efficiency (output/input) for 0.3 μm particulate size because that is the most penetrable particle size. N95 masks derive their name based on their ability to filter ≥95% of 0.3 μm particles. SARS-CoV-2 is 0.12 μm in diameter, but is typically bound to droplets that exceed 1 μm with fine-particle aerosolized droplets defined as those <5 μm. Several commercially available electrostatic filters, including the one used in this report, have viral efficiency ratings of >99.9%. A distinct advantage of electrostatic filters is that they do not impose the resistance associated with N95 masks. This was corroborated by our findings with nearly identical measures of minute ventilation as well as VO₂ with and without the filter in place. However, it is important to note that efficiency ratings have not been specifically tested across the entire range of expiratory flow rates achieved during exercise or specifically with SARS-CoV-2.

Conclusions

Exercise testing is an integral part of cardiovascular care delivery. Currently, there is variation in CPET laboratory responses to the novel coronavirus disease-2019 pandemic and use of filters should be considered in the context of multifaceted safety measures. Some laboratories remain closed, whereas others have changed operational protocols to require prolonged room turnover times to permit droplet settling, enhanced disinfection procedures, minimization of patient contact during testing, pre-exercise SARS-CoV-2 testing, and universal use of patient protective equipment in the form of gowns, face shields, and N95 masks. These careful measures incur expenses, use resources that may be in short supply, and challenge testing efficiency, framing the need for durable strategies to optimize exercise testing safety. Our findings suggest that use of electrostatic viral filtration devices do not compromise collection of critically important data that informs the care of patients with HF.

Disclosures

There are no relevant disclosures from any author.

Dr. Lewis is supported by the American Heart Association Award 15GPGSC24800006 and by the National Heart, Lung and Blood Institute Awards R01-HL 131029 and R01-HL151841. Dr. Malhotra is supported by a Transformational Project Award 18TPA34230025 from the
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