Modifying a Full-Face Snorkel Mask to Meet N95 Respirator Standards for Use With Coronavirus Disease 2019 Patients

Mohamad Karim Kechli, MD,* Jerrold Lerman, MD, FRCPC, FANZCA,* and Mary M. Ross, RN†

We evaluated a full-face snorkel mask with an airway circuit filter to protect health care providers against airborne pathogens. First, a quantified N95 fit test was performed using aerosolized saline. Second, cardiorespiratory variables (heart rate, peripheral oxygen saturation, end-tidal carbon dioxide tension, and inspired fraction of carbon dioxide) were measured at rest and during moderate exercise. The modified mask passed the United States Occupational Safety and Health Administration (OSHA) N95 respirator (N95) fit test requirements with a fit factor of 142. Neither hypercapnia nor hypoxemia occurred. This modified mask has the potential to protect providers who care for patients with coronavirus disease 2019 (COVID-19). (A&A Practice. 2020;14:e01237.)

GLOSSARY

COVID-19 = coronavirus disease 2019; **Etco₂** = end-tidal carbon dioxide; **Fico₂** = fraction of inspired carbon dioxide; **HR** = heart rate; **N95** = N95 respirator; **OSHA** = Occupational Safety and Health Administration in the US Department of Labor; **SARS-CoV-2** = severe acute respiratory syndrome coronavirus 2; **Spo₂** = peripheral oxygen saturation

With the increasing number of coronavirus disease 2019 (COVID-19) patients, personal protective equipment is rapidly becoming depleted. Without N95 respirator (N95) mask protection, health care providers are at risk for contracting COVID-19. Full-face snorkel masks seal tightly against the skin and could serve as surrogates for medical N95 masks. Several studies have documented the effectiveness of airway filters to prevent contamination of anesthesia equipment with bacteria and viruses.¹⁻³ Although snorkel masks and airway filters have been used for this purpose, no evidence regarding their effectiveness has been forthcoming. Accordingly, we investigated whether a full-face snorkel mask with an airway filter satisfied the US Department of Labor Occupational Safety and Health Administration (OSHA) N95 standards for protection against airborne pathogens and whether the combination was tolerated.

DESCRIPTION

We modified a full-face snorkel mask with an airway breathing filter affixed to the snorkel fitting (after removing the snorkel; Figure 1).⁴ A large-size, full-face snorkel mask was selected because the orifice of the snorkel fitting is circular

and compatible with the airway filter connector. The full-face snorkel mask has 2 separate compartments: an upper for viewing and a lower sealed breathing compartment to

Figure 1. Lateral view of the airway filter inserted into the snorkel fitting. The plastic baffles within the snorkel fitting were cut and removed to accommodate the filter.

From the *Department of Anesthesiology, Oishei Children's Hospital, Jacobs School of Medicine and Biomedical Sciences, Buffalo, New York; and †Department of Human Resources, Bradford Regional Hospital, Bradford, Pennsylvania.

Accepted for publication April 30, 2020.

Funding: None.

The authors declare no conflicts of interest.

Address correspondence to Jerrold Lerman, MD, FRCPC, FANZCA, Department of Anesthesiology, Great Lakes Anesthesiology, 1001 Main St, Suite K-3502, Buffalo, NY 14203. Address e-mail to jerrold.lerman@gmail.com.

Copyright © 2020 International Anesthesia Research Society
DOI: 10.1213/XAA.0000000000001237

ensure that the visor remains clear during expiration. The airway breathing filter (Ultipor 25; PALL Life Sciences, Port Washington, NY) was selected because it is known to prevent contamination of the components of the anesthesia machine (Figure 2 [lower]).^{2,3} After removing the snorkel from the snorkel fitting, the airway filter was affixed over the fitting using an occlusive dressing to circumferentially seal the interface airtight (Figure 3). The airway filter (outer diameter 25 mm) could fit within the snorkel fitting (inner diameter 25.5 mm) except for the presence of 2 thin plastic baffles within the fitting. These baffles divide the lumen of the snorkel fitting into 3 channels: a central channel for inspiration and 2 outer channels for expiration (Figure 2 [upper]). The baffles can be cut to accommodate the filter, but we chose not to do so.

To determine whether the modified mask met OSHA N95 standards, a quantitative N95 fit test was performed. A PortaCount Plus Model 8020 (TSI Inc, Shoreview, MN) particle detector was used with a particle generator to aerosolize saline (Model 8026, TSI Inc, Shoreview, MN).⁵ The particle generator and detector were stabilized for 15 minutes before commencing the study.

Seven exercises (60 seconds each) were performed while wearing the modified mask (Figure 4). The fit factor for each exercise is the ratio between the concentration of particles in the ambient air and the concentration within the mask. The

Figure 2. The Pall airway filter (lower) and the snorkel fitting with 2 baffles within the lumen (upper).

Figure 3. A full-face snorkel mask with PALL Ultipor 25 breathing circuit filter. A full-face snorkel mask with PALL Ultipor filter affixed with an airtight seal to the snorkel fitting during testing with the Portacount Plus detector. The ambient sample tube (blue) is visibly positioned above the snorkel mask in the photo. The sample tube from the breathing compartment of the modified mask (white) is visible between the eyes of the investigator.

desired fit factor for each exercise should exceed 100 (the maximum score is 200). To satisfy OSHA N95 mask testing requirements, the overall fit test score, a composite of the 7 individual fit factors, should exceed 100. The overall fit test score is calculated as shown:

$$\text{Fit test score} = \frac{\text{Number of exercises}}{\frac{1}{\text{FF1}} + \frac{1}{\text{FF2}} + \dots + \frac{1}{\text{FF7}}},$$

where the number of exercises is 7 and FF_k is the fit factor for the “k”th exercise.

After applying the modified mask, the silicone skirt was inspected to ensure that it lay flat on the face. The ambient sample line (blue tube) was secured, and the breathing compartment sample line (white tube between the investigator’s eyes, Figure 3) was threaded into the breathing chamber.

The cardiorespiratory responses were then evaluated using a Datex/Ohmeda Aisys workstation (GE Healthcare, Madison, WI). A sidestream carbon dioxide sampling line was passed into the breathing compartment to measure the end-tidal carbon dioxide (EtCO_2) and fraction of inspired

FIT TEST REPORT

3/31/2020

ID NUMBER 6147
LAST NAME LERMAN
FIRST NAME JERNOLD
COMPANY BRADFORD BRMC
LOCATION ANESTHESIA

PASS/FAIL
OVERALL/F

TEST DATE 3/31/2020
DUE DATE 3/31/2021

PORTACOUNT S/N 8038125124
N95 COMPANION Y

RESPIRATOR 3M - 1804 N95-1804 3M [100]
MANUFACTURER 3M - 1804
MODEL N95-1804
MASK STYLE 3M
MASK SIZE REGULAR

PROTOCOL 29CFR1910.134-NEW 8038
PASS LEVEL 100
APPROVAL CDC
EFFICIENCY <99% True

EXERCISE	DURATION(sec)	FIT FACTOR	PASS
NORMAL BREATHING_8038_N95	60	164	Y
DEEP BREATHING	60	174	Y
HEAD SIDE TO SIDE	60	200+	Y
HEAD UP AND DOWN	60	161	Y
TALKING	60	94	N
GRIMACE	35	Excl.	
BENDING OVER	60	104	Y
NORMAL BREATHING	60	169	Y

OVERALL FF

142

Y

FITTEST OPERATOR

Mary Ross
MROSS

DATE

03-31-2020

NAME

JERNOLD LERMAN

DATE

NOTE:

Figure 4. The N95 fit test report. The fit factors exceeded 100 for all exercises performed, with the exception of talking (fit factor was 94). The overall fit factor for the modified mask, 142, indicates a passing grade on the Respiratory fit Test Card using the OSHA N95 criteria. N95 indicates N95 respirator; OSHA, United States Occupational Safety and Health Administration.

Respirator Fit Test Card

Name: JERNOLD LERMAN Test Date: 3/31/2020
ID: 6147 Next Test Date: 3/31/2021

Respirator

Mfg: 3M - 1804
Model: N95-1804
Style: 3M
Size: REGULAR

Results

Overall FF: 142
FF Pass Level: 100
Pass: Y
Operator: MROSS

Protocol: 29CFR1910.134-NEW 8038

Fit Test Method: QNFT using TSI PortaCount

*** Your company contact information here ***

carbon dioxide (Fico₂) tensions. A pulse oximeter probe was applied to measure the peripheral oxygen saturation (Spo₂) and heart rate. The variables were recorded every minute for the first 5 minutes, and at 10 and 20 minutes. The investigator then exercised using step-ups on a single stool (Sandel Ergo-Step stool, Ansell, Iselin, NJ) at 28 steps/min. During the exercise test, the same variables were recorded every minute for the first 5 minutes and then again at 10 minutes. Hypercapnia was defined as an Etco₂ > 50 mm Hg and hypoxemia as a Spo₂ < 95%. An audible alarm was set for Spo₂ < 95%.

RESULTS

The modified mask passed the OSHA N95 fit test, with an overall fit factor of 142 (Figure 4). The only exercise with a failing fit factor of 94 occurred while the subject was talking during the fit test. We attribute this sole borderline

measurement during talking to a minor breach either in the seal of the snorkel skirt or where the sample tube enters the breathing compartment.

The 4 measured cardiorespiratory variables remained unchanged except for an increase in heart rate during moderate exercise (Figure 5). Heart rate increased <20% with exercise. The Etco₂ increased slowly, reaching a maximum value of 48 mm Hg by the end of the study (~20% greater than at rest), with an average of 47 mm Hg.

Breathing difficulties, dyspnea, tachypnea, presyncope, or sweating did not occur either at rest or during exercise. Neither hypercapnia nor hypoxemia occurred.

DISCUSSION

These data confirm that this modified full-face snorkel mask with an airway filter meets OSHA N95 standards to protect health care providers from aerosolized small particles such

Figure 5. Cardiorespiratory variables EtCO₂, FiCO₂, SpO₂, and HR. The x-axis is time in minutes and the y-axis reflects the values and units for the 4 variables: HR (beats per minute), SpO₂ (%), EtCO₂ (mm Hg), and FiCO₂ (mm Hg). The modified snorkel mask, EtCO₂ sampling line, and SpO₂ probe were applied as described in the text. While the investigator was seated, measurements were recorded each minute for the first 5 min and then at 10 and 20 min. After a 10 min interval, the investigator began to exercise performing step-ups as described in the text. Measurements were again recorded each minute for the first 5 min and again at 10 min. EtCO₂ indicates end-tidal carbon dioxide; FiCO₂, fraction of inspired carbon dioxide; SpO₂, peripheral oxygen saturation; HR, heart rate.

as the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). In addition, the modified mask is well tolerated for brief periods even during moderate exercise.

The modified snorkel mask is easy to wipe clean and can be reused, although the Pall filter should be replaced after 24 hours according to the manufacturer.

OSHA outlines several fit test procedures that may be used to validate that an N95 mask meets their standards for medical use.⁶ Many institutions use a qualitative test that requires intact olfaction or taste, which may be subject to false negatives. For this study, we used a quantitative fit test that depends on measuring the presence of aerosolized saline within the breathing chamber.

Anecdotal evidence suggests that full-face snorkel masks have been associated with adverse events in healthy adults when used for activities beyond recreational snorkeling. Full-face snorkel masks channel inspiration and expiration through separate passageways within the facemask, with the exhaled breath directed from the breathing compartment into 2 lateral channels. With minimal or no exertion as in surface snorkeling, there is no perceived resistance to expiration while wearing these masks. However, during moderate exertion, some swimmers reported dyspnea, tingling in their legs, or an inability to exhale easily. Rarely, unexplained cardiac arrest has occurred. Our results confirmed that even with an airway filter tightly applied to the fitting in a full-face snorkel mask, there was no perceptible increase in inspiratory or expiratory effort at rest. This is unsurprising because these conditions are analogous to a patient breathing through a filter and anesthesia breathing

circuit. However, patients are not exercising while breathing through an anesthesia breathing circuit. Despite modifying the snorkel mask, we encountered no signs or symptoms of dyspnea or increased resistance to breathing while performing moderate exercise for 10 minutes. We did not identify substantive changes in cardiorespiratory indices that would point to a limitation in using the modified mask for periods of up to 20 minutes at rest or 10 minutes of moderate exertion (Figure 5).

Anesthesiologists, respiratory therapists, and intensive care physicians who manage the airways of COVID-19 patients should wear effective personal protective equipment. The full-face snorkel mask and Pall filter as described here satisfy the OSHA N95 criteria for caring for patients with COVID-19.

CONCLUSIONS

We modified a commercially available, full-face snorkel mask to use with an airway breathing circuit filter that satisfies OSHA N95 standards to protect frontline health care providers from pathogen aerosol exposure such as the novel SARS-CoV-2 virus. Wearing this mask and airway filter for 20 minutes while at rest and for 10 minutes during moderate exercise did not increase the resistance to breathing nor did it result in hypercapnia or hypoxemia. ■■

DISCLOSURES

Name: Mohamad Karim Kechli, MD.

Contribution: This author contributed the idea inception, writing and editing the manuscript.

Name: Jerrold Lerman, MD, FRCPC, FANZCA.

Contribution: This author helped with the idea, test the device, write and edit the manuscript.

Name: Mary M. Ross, RN

Contribution: This author contributed by conducting the N95 testing and analysis of the Portacount results.

This manuscript was handled by: BobbieJean Sweitzer, MD, FACP.

REFERENCES

- Wilkes AR. Measuring the filtration performance of breathing system filters using sodium chloride particles. *Anaesthesia*. 2002;57:162–168.
- Vezina DP, Trépanier CA, Lessard MR, Gourdeau M, Tremblay C, Guidoin R. An in vivo evaluation of the mycobacterial filtration efficacy of three breathing filters used in anesthesia. *Anesthesiology*. 2004;101:104–109.
- Heuer JF, Crozier TA, Howard G, Quintel M. Can breathing circuit filters help prevent the spread of influenza A (H1N1) virus from intubated patients? *GMS Hyg Infect Control*. 2013;8:Doc09.
- Livingston E, Desai A, Berkswits M. Sourcing personal protective equipment during the COVID-19 pandemic [epub ahead of print]. *JAMA*. 2020. doi: 10.1001/jama.2020.5317.
- Model 8095 N95-Companion™ Mask Fit Tester to the PORTACOUNT® Plus Respirator Fit Tester. Available at: <https://www.tsi.com/getmedia/23133329-810a-45d0-8bdf-145592b592c8/1980308J-8095-N95Companion?ext=.pdf>. Accessed April 4, 2020.
- United States Department of Labor, Occupational Health and Safety Administration. <https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.134AppA>. Accessed April 20, 2020.