PROTECTION EFFICIENCY OF N95 RESPIRATOR AGAINST COVID-19: AN EPIGRAMMATIC REVIEW

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ABSTRACT

Coronavirus Disease 2019 (COVID-19) has badly impacted the entire world. Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is causing this infectious disease. Healthcare professionals are using N95 respirator to prevent SARS-CoV-2 from entering the respiratory tract. This paper mainly discusses the protection efficiency of N95 respirator against COVID-19. The published guidelines, reports, and research articles were sought to collect information on the protection efficiency of N95 respirator. It has been found that they are highly efficient against the pathogens ≥ 300 nm in diametric size. They may not offer the desired protection with a 95% threshold value for the nano-size virus particles. Past research revealed that the penetration of small virus particles in the 10-80 nm size range can be more than 5% depending on the inhalation flow rate. In addition, the wearers may have more virus particles into their respiratory tract if the respirator is not well-fitted without any leakage. The viral load due to more than 5% penetration and respirator leakage can be quite enough over time to cause infection. The risk will be more for healthcare professionals working in aerosolized areas. To reduce the risk of infection, a face shield should be used over an N95 respirator. Moreover, a surgical mask can be used over an N95 respirator. This may reduce the viral load on N95 respirator. Furthermore, full-facepiece air-purifying respirator and powered air-purifying respirator including highly efficient filters should be used by the healthcare personnel in aerosolized areas for protection against COVID-19. Such practices will reinforce the defence level against COVID-19.

Keywords: COVID-19, N95 respirator, protection efficiency, SARS-CoV-2, virus particle.

INTRODUCTION

Coronavirus Disease 2019 (COVID-19), a highly infectious disease growing from China in December 2019, has caused a pandemic for the world. Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is the main reason for this disease (Pal et al. 2020) and it is spreading through respiratory secretions generated by expiratory activities (e.g., breathing, speaking, laughing, coughing, and sneezing). The transmission of COVID-19 can occur when the virus-bearing respiratory secretions expelled from an infected person reach the eyes, nose, or mouth of a susceptible individual through person-to-person or direct contact, such as handshaking and hugging (Mount Sinai Hospital 2020, World Health Organization 2020). Furthermore, COVID-19 can transmit indirectly through contact with fomites (objects or

materials contaminated with virus-bearing respiratory droplets or droplet residues; e.g., doorknobs and handrails) when hands touch those and then the face, and also via airborne route without any physical contact (Asadi et al. 2020, Meselson 2020). In airborne transmission, COVID-19 can spread in two distinct modes. A susceptible person may get COVID-19 being in the proximity of virus-laden respiratory droplet sprays emitted by an infected person through expiratory activities, such as sneezing or coughing (Asadi et al. 2020). A susceptible person may also inhale the airborne aerosols containing SARS-CoV-2 that causes COVID-19 (Asadi et al. 2020, Zhang et al. 2020).

Aerosol transmission of SARS-CoV-2 can occur in healthcare units. The hospitalized COVID-19 patients are generally expected to emit aerosolized coronaviruses in the air. Very recently, van Doremalen et al. (2020) have stated that aerosolized coronaviruses remain alive and infectious in the air for several hours. They concluded that both aerosol and fomite transmission of SARS-CoV-2 are possible. Asymptomatic or pre-symptomatic individuals can also spread COVID-19 via aerosol transmission; they can create an invisible cloud of aerosol particles of about 1 μm diameter during normal speaking and breathing (Asadi et al. 2019). These particles are large enough to carry coronaviruses (Asadi et al. 2020) and can diffuse more in the direction of airflow (Wei & Li 2016); also, they could be easily inhaled by a susceptible person because of their small size (Heyder et al. 1986). Such transmission of SARS-CoV-2 can be inhibited using high-efficiency face masks. N95 respirator is being used by healthcare professionals as a defensive measure against this novel virus. However, is this respirator providing adequate protection against COVID-19? This study was conducted to get the answer to this burning question based on secondary research. The authors carried out an epigrammatic survey of literature available on the protection efficiency of N95 respirator. The major findings are presented and discussed in this paper.

EFFICIENCY OF N95 RESPIRATOR FOR PROTECTION AGAINST COVID-19

According to the practical guide of World Health Organization (WHO), healthcare professionals must wear high-efficiency masks when attending and caring for patients having airborne infections, or when conducting bronchoscopies or comparable tests for self-protection (World Health Organization 2002). Healthcare personnel are using N95 respirator as a defensive measure against COVID-19. However, N95 respirator may not definitely provide adequate protection against SARS-CoV-2 bioparticles, which are much smaller than 300 nm inert particles used in the acceptance test of this type of respirator (Bałazy et al. 2006). The diametric size of SARS-CoV-2 varies in the range of 65-125 nm (Shereen et al. 2020). Hence, the penetration of SARS-CoV-2 bioparticles through N95 respirator could be more than 5% due to their very small size. Bałazy et al. (2006) showed that N95 respirator will be highly competent to impede the penetration of the particles with a diametric size $\geq$ 300 nm, but this type of respirator could not offer the appropriate protection level with a 95% threshold value for the nano-size virus particles; the maximum penetration of virus particles in 10-80 nm size range was about 3.5% at a lower inhalation flow rate of 30 L/min whereas it was around 5.75% at a higher inhalation flow rate of 85 L/min used in their study. Also, Patel et al. (2016) found that the capture (filtration) efficiency of better-fit N95 respirator without reduced leakage for aerosols exiting the source is 80-90% in the case of tidal breathing. It implies that 10-20% aerosols containing SARS-CoV-2 may escape N95 respirator. Moreover, the wearers might not get the required level of protection unless the respirator is well-fitted with the face without any leakage (Patel et al. 2016, Coffey et al. 2004). Such findings and observations imply that the 95% protection efficiency of N95 respirator is not warranted for the healthcare personnel providing treatment to COVID-19 patients.

ALTERNATIVE RESPIRATORS AND OTHER DEVICES FOR PROTECTION AGAINST COVID-19

As per the above discussion, the nano-size SARS-CoV-2 bioparticles could penetrate N95 respirator by more than 5%. A 5-10% penetration might be acceptable for some harmless inert particles. On the contrary, a slight penetration of highly virulent SARS-CoV-2 bioparticles could be enough to cause infection. A past study inferred that sometimes a single virus particle may cause infection (Morawska 2006) depending on its virulence. Hence, relying exclusively on N95 respirator could not be strategically wise to prevent SARS-CoV-2 from entering the respiratory tract. Healthcare professionals should use this type of respirator in together with other defensive measures to get multi-level protection. A face shield on top of an N95 respirator, as shown in Figure 1, can be worn by healthcare staff. Also, a surgical face mask may be used as a cover of N95 respirator used with or without a face shield, as illustrated in Figure 2 and Figure 3. They should also maintain a 2-m physical distance wherever possible. Such protective practices will provide better defence against COVID-19 by reducing the viral load on N95 respirator. However, in critical aerosolized places, healthcare professionals should use highly efficient protective measures, such as full-facepiece air-purifying respirator (APR) and powered air-purifying respirator (PAPR) for protection against COVID-19 (Centre for Disease Control and Prevention 2020). The eyes, nose, and mouth are simultaneously covered by APR or PAPR. Disposable N95 and P100 filters are commonly used in APR and PAPR. But N95 filters are not capable of providing more than 95% protection. Sometimes the protection level can be significantly less than 95%, as discussed in the preceding section. To resolve this issue, P100 filters can be used to achieve high-level respiratory protection. P100 filters are effective against all particulate aerosols and they are 99.97% efficient against 0.3µm particles (Clever et al. 2019). It implies that the penetration level of 0.3 µm diameter particles through P100 filters will not be more than 0.03%. Consequently, APR and PAPR including P100 filters would likely offer much better protection against COVID-19 compared to N95 respirator. Full-facepiece APR and PAPR can offer 5- and 100-times higher protection level than N95 respirator (Clever et al. 2019, Rengasamy et al. 2015, Vo et al. 2015).

Figure 1. Use of face shield on top of N95 respirator

Figure 2. Use of surgical face mask as a cover of N95 respirator

Figure 3. Use of surgical face mask and face shield over N95 respirator

CONCLUDING REMARKS AND RECOMMENDATIONS

- SARS-CoV-2 can transmit from an infected person to a susceptible person through the airborne route and therefore high-efficiency respirators should be used to impede infection.
- N95 respirator may not guarantee the protection level with a 95% threshold value against SARS-CoV-2. The nano-size coronavirus could penetrate this type of respirator by significantly more than 5%.

- Additional SARS-CoV-2 bioparticles may enter the respiratory tract if the respirator is not fitted well with the face without any leakage. Hence, the 95% protection efficiency of N95 respirator is not warranted.
- The multi-level defence against COVID-19 can be achieved if N95 respirator is used with face shield and/or surgical mask. The use of a face shield on top of a surgical mask covering an N95 respirator would intercept virus particles in three different layers of protection.
- In critical aerosolized conditions, healthcare professionals should use APR and PAPR including P100 filters for high-level protection against COVID-19.

AUTHOR CONTRIBUTIONS

The authors confirm being the contributors to this work without having any commercial or financial relationships.

CONFLICT OF INTEREST

The authors declare no conflict of interest relating to the materials presented in this article. The conclusions in this article are made by the authors and do not necessarily represent the views of George Brown College, Ryerson University, University of Windsor, and Dhaka University Engineering & Technology.

REFERENCES

Asadi et al. (2019) Aerosol emission and superemission during human speech increase with voice loudness. *Scientific Reports*, *9*, 2348.

Asadi et al. (2020) The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles? *Aerosol Science and Technology*, *54*, 635-638.

Bałazy et al. (2006) Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks? *American Journal of Infection Control*, *34*, 51-57.

Centre for Disease Control and Prevention (2020). *Interim Infection Prevention and Control Recommendations for Patients with Suspected or Confirmed Coronavirus Disease 2019 (COVID-19) in Healthcare Settings* [Accessed 13th May, 2020]. Centre for Disease Control and Prevention (CDC), Atlanta, Georgia, USA. Available online: https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Finfection-control%2Fcontrol-recommendations.html.

Coffey et al. (2004) Fitting characteristics of eighteen N95 filtering-facepiece respirators. *Journal of Occupational and Environmental Hygiene*, *1*, 262-271.

Heyder et al. (1986) Deposition of particles in the human respiratory-tract in the size range 0.005-15 µm. *Journal of Aerosol Science*, *17*, 811-825.

Meselson, M. (2020) Droplets and aerosols in the transmission of SARS-CoV-2. *The New England Journal of Medicine*, 382, 2061-2063.

Morawska, L. (2006) Droplet fate in indoor environments, or can we prevent the spread of infection. *Indoor Air*, *16*, 335-347.

Mount Sinai Hospital (2020) *FAQ: Methods of Disease Transmission*. [Accessed 31st March, 2020]. Department of Microbiology, Mount Sinai Hospital: Toronto, Ontario, Canada. Available online: https://eportal.mountsinai.ca/Microbiology/faq/transmission.shtml.

Pal et al. (2020) Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2): An update. *Cureus, 12*, e7423.

Patel et al. (2016) Respiratory source control using a surgical mask: An in vitro study. *Journal of Occupational and Environmental Hygiene, 13*, 569-576.

Rengasamy et al. (2015) Protection factor for N95 filtering facepiece respirators exposed to laboratory aerosols containing different concentrations of nanoparticles. *The Annals of Occupational Hygiene, 59*, 373-381.

World Health Organization (2002). *Prevention of Hospital-Acquired Infections: A Practical Guide*, Second Edition, WHO/CDS/CSR/EPH/2002.12 [Accessed 26th March, 2020]. World Health Organization (WHO), Geneva, Switzerland. Available online: https://www.who.int/csr/resources/publications/whocdscsreph200212.pdf.

Shereen et al. (2020) COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses. *Journal of Advanced Research, 24*, 91-98.

Clever et al. (2019) *Reusable Elastomeric Respirators in Health Care: Considerations for Routine and Surge Use*. Washington D.C., USA: The National Academies Press.

van Doremalen et al. (2020) Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *The New England Journal of Medicine, 382*, 1564-1567.

Vo et al. (2015) Respirator performance against nanoparticles under simulated workplace activities. *The Annals of Occupational Hygiene, 59*, 1012-1021.

Wei, J.J. & Li, Y.G. (2016) Airborne spread of infectious agents in the indoor environment. *American Journal of Infection Control, 44*, S102-S108.

World Health Organization (2020). *Pass the Message: Five Steps to Kicking out Coronavirus* [Accessed 24th March, 2020]. World Health Organization (WHO), Geneva, Switzerland. Available online: https://www.who.int/news-room/detail/23-03-2020-pass-the-message-five-steps-to-kicking-out-coronavirus.

Zhang et al. (2020) Identifying airborne transmission as the dominant route for the spread of COVID-19. *Proceedings of the National Academy of Sciences of the United States of America, 117*, 14857-14863.