International Research Journal of Public and Environmental Health Vol. 7(5), pp. 179-189, October 2020
Available online at https://www.journalissues.org/IRJPEH/
https://doi.org/10.15739/irjpeh.20.025

ISSN 2360-8803

Original Research Article

Efficiency of surgical masks as a means of source control of SARS-CoV-2 and protection against COVID-19

Received 18 June, 2020 Revised 28 July, 2020 Accepted 4 August, 2020 Published 23 October, 2020

Md. Safiuddin*[1] and M.A. Salam[2]

[1]Angelo DelZotto School of Construction Management, George Brown College, 146 Kendal Avenue, Toronto, Ontario M5T 2T9, Canada; Department of Civil Engineering, Faculty of Engineering and Architectural Science, Ryerson University, 350 Victoria Street, Toronto, Ontario M5B 2K3, Canada; Department of Civil and Environmental Engineering, Faculty of Engineering, University of Windsor, 401 Sunset Avenue, Windsor, Ontario N9B 3P4, Canada.
[2]Department of Civil Engineering, Dhaka University of Engineering & Technology, Gazipur-1707, Bangladesh.

*Corresponding Author's E-mail: msafiuddin@georgebrown.ca, safiq@yahoo.com

Tel.: 1-416-415-5000, ext. 6692

Coronavirus Disease 2019 (COVID-19) caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) has badly impacted the public health, economy, and social life in the entire world. Healthcare professionals and community people are using surgical masks as a protective measure to prevent SARS-CoV-2 from entering the respiratory tract. This paper briefly reviews and discusses the source control mechanisms and protection efficiency of surgical masks against COVID-19. Scholarly articles, reports, and guidelines were searched to gather information regarding the performance of surgical masks. It has been found that they are not very effective to prevent the penetration of virus particles into the respiratory tract. More than 10% of the virus particles in the 10–80 nm size range can penetrate high-barrier surgical masks at a low inhalation flowrate of 30 L/min whereas it can be above 20% at a high inhalation flowrate of 85 L/min. The penetration level of virus particles could be extremely high (≥ 80%) for low-barrier surgical masks at both low and high inhalation flowrates. However, many studies implied that surgical masks can be used effectively as a means of source control to minimize the onward transmission of SARS-CoV-2 from symptomatic and pre-symptomatic or asymptomatic COVID-19 patients. They are useful to lessen the load of virus-bearing respiratory droplets (≥ 5 µm) and aerosols (< 5 µm) in the air if worn by infected people. Moreover, surgical masks can reduce the inward transmission of SARS-CoV-2 into susceptible persons although they are not as effective as respirators. Surgical masks can also be used along with other protective means such as physical distancing, face shields, and surgical N95 respirators to provide enhanced protection for the healthcare personnel looking after COVID-19 patients. Such uses of surgical masks would play a vital role to reduce the community transmission of COVID-19.

Keywords: Aerosols, COVID-19, inward transmission, onward transmission, protection efficiency, respiratory droplets, SARS-CoV-2, source control, surgical masks.

INTRODUCTION

Coronavirus Disease 2019 (COVID-19), a highly contagious disease, has caused a pandemic for the world. Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is the perpetrator of this disease (Pal et al., 2020; Lai et al., 2020) and it is transmittable from human to human through respiratory secretions generated by expiratory activities (e.g., breathing, speaking, laughing, coughing, and sneezing) in the forms of droplets and aerosols (Meselson, 2020; Prather et al., 2020; Zhang et al., 2020). The transmission of COVID-19 occurs when the virus-bearing respiratory secretions expelled from an infected individual reach the eyes, nose, or mouth of susceptible individuals who receive viruses being near to the source (Mount Sinai Hospital, 2020; WHO, 2020). It has been reported that SARS-CoV-2 can transmit directly through person-to-person contact such as handshaking and hugging, indirectly through contact with fomites (objects or materials contaminated with pathogens, e.g., viruses) such as handrail and doorknob, and also via airborne route without any physical contact (Asadi et al., 2020; Meselson, 2020; van Doremalen et al., 2020; Morawska and Cao, 2020).

In many countries, both healthcare professionals and community people are using surgical masks as a protective means among various defensive measures in the current pandemic to lessen the transmission of COVID-19 (Kähler and Hain, 2020; Supehia et al., 2020; Chiang et al., 2020). Surgical masks are much cheaper than surgical respirators (Mukerji et al., 2017) and they are allowed for use in healthcare settings (Australian Government, 2020; CDC, 2020; Lepelletier et al., 2020; Desai and Aronoff, 2020). However, do they provide adequate protection against COVID-19? Are these masks efficient in controlling sources of respiratory secretions to minimize the spread of SARS-CoV-2? Can they be useful to reduce the community transmission of COVID-19? This study was conducted to get the answers of these burning questions mainly based on the secondary data obtained from the published literature.

The findings regarding the source control and protection efficiency of surgical masks have been presented and discussed in this paper. The classification with barrier properties, material aspects, and manufacturing process of surgical masks have also been discussed. For better clarification, the discussion has been made using several images and illustrations created by the authors. It is hoped that the content of the paper will be beneficial for healthcare professionals and general people in fighting the current pandemic caused by COVID-19.

METHODOLOGY

This study is based on the analysis of secondary data available on surgical masks for source control and prevention of COVID-19. It has also been enriched by the authors' inputs. Scholarly articles were searched through Google Scholar, ResearchGate, Scopus, ScienceDirect, Web of Science, and PubMed databases. In addition, the reports and guidelines published in the websites of different medical institutes and public health organizations were sought. During the search, the following keywords were used: "Aerosols", "Airborne Viruses", "Coronaviruses", "COVID-19", "Face Masks", "Infection Prevention", "Medical Masks", "Nonwoven Fabric", "Personal Protective Equipment", "Protection Efficiency", "Respiratory Droplets", "Respiratory Infections", "Respiratory Viruses", "SARS-CoV-2", "Source Control", "Surgical Masks", "Respirators", "Transmission", and their different combinations thereof.

From the search outcomes, the publications related to the source control mechanisms and protection efficiency of surgical masks were emphasized more, keeping consistency with the theme of the present study. In this regard, the main articles used are listed in Table 1 with their focus of study and key findings.

Definition and classification of surgical masks

Surgical masks, commonly known as face masks (shown in Figure 1), are loose-fitting, single-use, and disposable medical masks that form a physical barrier between the wearer's lower face (nose and mouth) and the potential contaminants (e.g., chemicals) or infectants (e.g., pathogens) in the surrounding environments (Food and Drug Administration, 2020). They are designed to obstruct large droplets, splashes, sprays, or aerosols that may have pathogens (e.g., bacteria and viruses). Surgical masks are also helpful to decrease the discharge of saliva and respiratory secretions from humans. However, they never should be reversed during usage to avoid spreading or receiving of infectants.

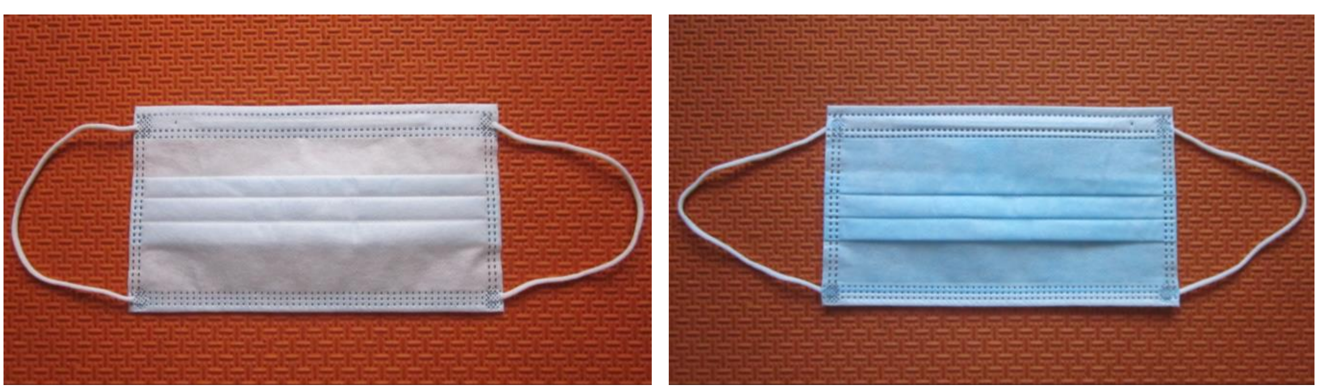
There are three classes of surgical masks based on the barrier properties – Level 1, Level 2, and Level 3 as per ASTM specifications (ASTM F2100-19e1, 2019; Chellamani et al., 2013). ASTM Level 1 surgical masks provide low barrier protection and they are used in the circumstances with no exposure to fluids, sprays, or aerosols. ASTM Level 2 surgical masks offer medium or moderate barrier protection and they are used in the cases involving low to moderate levels of fluids, sprays, or aerosols. ASTM Level 3 surgical masks give high barrier protection and they are used against heavy levels of fluids, sprays, or aerosols. Each class of surgical masks can be made in various fabric colors. The packaging color may also be different for each class. However, ASTM F2100-19e1 (2019) requires that mask packaging to be clearly marked with the level of protection in one of three levels: 1, 2, or 3. The barrier properties of the three classes of surgical masks are given in Table 2.

Materials and manufacturing of surgical masks

Surgical masks are generally made with nonwoven fabrics (shown in Figure 2) obtained from plastics; the typical plastic material used for surgical masks is polypropylene (Henneberry, 2020); the other plastic materials such as polystyrene, polycarbonate, polyethylene, and polyester are also used to manufacture this type of masks (Kiron, 2020). The density of polypropylene, the commonly selected material for manufacturing surgical masks, should be 20-25 gsm (gram per square metre) (Chellamani et al., 2013; Raju, 2020). Surgical masks are usually designed with three or four layers of nonwoven fabric, which acts as a filter to prevent microbes (e.g., pathogens) from exiting or entering the mask but provides adequate air permeability. Nonwoven fabrics are engineered fabrics with a planar structure consisting of one or more fibre layers; thin, spun-bond, high-filtration nonwoven fabrics made of micro-denier fibres are normally used to produce surgical masks (Raju, 2020). They are highly flexible, provide excellent resistance to liquid and bacterial penetration, and generate

Table 1. Some of the major articles used in the present study

References	Focus of study		Key findings
	Prevention via source control	**Protection via exposure control**	
Lee et al., 2005	No	Yes	The filtering efficiency of surgical masks was the lowest as compared to different types of respirators.
Bałazy et al., 2006	No	Yes	The penetration of nano-size virus particles through high-barrier surgical masks was 20.5% whereas it was 84.5% in the case of low-barrier surgical masks.
Leung et al., 2020	Yes	No	Surgical masks could prevent the transmission of coronaviruses from symptomatic persons.
Esposito et al., 2020	Yes	Yes	Surgical masks can control respiratory secretions at the source; they can also prevent large droplets and sprays from entering the respiratory tract but they have limited ability to filter out sub-micron sized airborne particles; the universal use of face masks as a means of source control in public places is strongly advocated to reduce the community transmission of COVID-19.
MacIntyre and Chughtai, 2020	Yes	Yes	Surgical masks are effective in controlling the sources of coronaviruses and reducing the transmission of COVID-19; however, they are less protective than respirators in healthcare settings.
Patel et al., 2016	Yes	Yes	Source control combined with environmental controls is more effective than personal protection alone to prevent the spread of respiratory infections; source control by surgical masks could work as a defensive measure against the spread of respiratory infections; but the use of surgical masks as a means of respiratory protection was not suggested.



(a) Interior view **(b) Exterior view**

Figure 1: Surgical masks

Table 1. Continue

Chu et al., 2020	No	Yes	The use of face masks protects people in both healthcare and non-healthcare settings; however, surgical masks provide less protection than surgical N95 or similar respirators against the inhalation of coronaviruses that cause COVID-19.
Smith et al., 2016	No	Yes	Surgical masks appeared to be less protective than surgical N95 respirators against transmissible acute respiratory infections.
Kähler and Hain, 2020	Yes	Yes	Surgical masks greatly limit the spread of viruses in the surrounding environments and thus reduce the risk of infections for the nearby people; they inhibit contact infection, serving as a barrier between face and hands; but they provide less protection against droplet infection than close-fitting, particle-filtering respirators.
Chiang et al., 2020	Yes	No	Surgical masks could prevent the transmission of coronaviruses from infected persons; the practice of wearing surgical masks may also prevent the potential asymptomatic or pre-asymptomatic transmission of COVID-19, as evidenced by the epidemiological data obtained from Taiwan and Singapore.
Liu and Zhang, 2020	Yes	No	The use of surgical masks can prevent the transmission of COVID-19 from infected individuals, as revealed from the epidemiological survey conducted in China.

Table 2. Classification of surgical masks and their barrier properties (sourced and adapted from ASTM F2100-19e1, 2019)

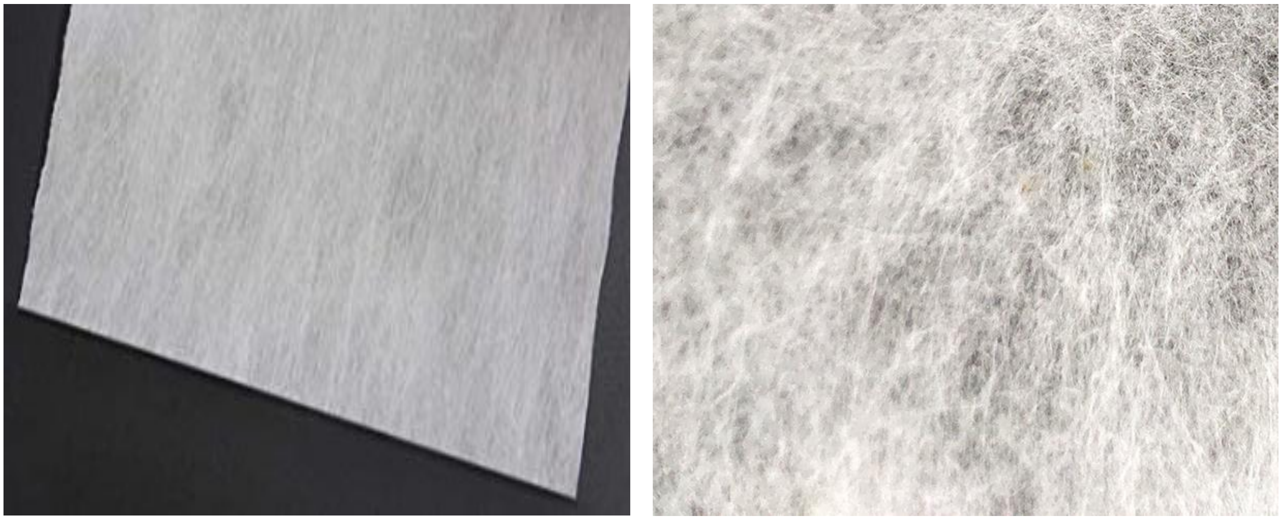
Classes of surgical mask	**Barrier properties**			
	Bacterial filtration efficiency* (%)	**Resistance to penetration by synthetic blood in terms of pressure† (mmHg)**	**Differential pressure as a measure of breathing resistance‡ (mm H_2O/cm^2)**	**Sub-micron particulates filtration efficiency at 0.1 µm§ (%)**
Level 1 (Low-barrier)	≥ 95	≥ 80	< 4.0	≥ 95
Level 2 (Medium-barrier)	≥ 98	≥ 120	< 5.0	≥ 98
Level 3 (High-barrier)	≥ 98	≥ 160	< 5.0	≥ 98

*Measures how well a surgical mask filters out bacteria when encountered with bacteria-containing aerosols. †Reflects the ability of a surgical mask to minimize the amount of fluid that can pass through it from outside as the result of a splash or spray. ‡Measures the air flow resistance of a surgical mask to ensure its breathability. §Measures how well a surgical mask filters out sub-micron particles with the anticipation that viruses will be filtered out in a similar manner.

less lint or particle emissions (Chellamani et al., 2013). Nonwoven fabrics are preferred to manufacture surgical masks mainly because of their high barrier properties.

Protection efficiency of surgical masks against COVID-19

According to the World Health Organization (WHO), for patient protection, surgical masks are sufficient for healthcare staff to wear when they work in the operating room, perforate body cavities, and give care for immuno-compromised patients; WHO also states that patients with airborne infections must wear surgical masks when they are outside the isolation room (WHO, 2020b). However, it should be kept in mind that they are not designed to block ultrafine airborne particles (Food and Drug Administration, 2020) of nano-scale size less than 100 nm in diameter. SARS-CoV-2 varies in the size range of 65-125 nm (Shereen



(a) Normal view **(b) Magnified view**

Figure 2: Nonwoven fabric

Table 3. Penetration of virus particles (10-80 nm size range) through surgical masks (the penetration data are sourced from Bałazy et al., 2006)

Surgical mask (SM)	Bacterial filtration efficiency* (%)	Maximum fractional penetration† (%)	
		Inhalation flowrate, 30 L/min	Inhalation flowrate, 85 L/min
Low-barrier SM	> 96	80	84.5
High-barrier SM	> 99	13.5	20.5

*Measures how well a surgical mask filters out bacteria when encountered with bacteria-containing aerosols. †Reflects the protection efficiency of a surgical mask – the lower the percentage, the better the mask filtration.

et al., 2020). Therefore, surgical masks may not be very effective to stop the penetration of airborne coronaviruses.

An experimental study showed that, for high-barrier (Level 3) surgical masks, the penetration of small virus particles in the 10-80 nm size range can be more than 10% at a low inhalation flowrate of 30 L/min whereas it can be above 20% at a high inhalation flowrate of 85 L/min (Bałazy et al., 2006). In the former case, the maximum penetration of virus particles was 13% whereas it was 20.5% in the latter case. Another study (Lee et al., 2005) revealed that the penetration of airborne particles in the size range of 40-1300 nm can be 12.5% to 20.5% for high-barrier surgical masks at 30 L/min flowrate.

The penetration level of virus particles could be extremely high (≥ 80%) for low-barrier surgical masks (refer to Table 3). In the study of Bałazy et al. (2006), for the small virus particles in the 10-80 nm size range, the penetration at a low inhalation flowrate of 30 L/min increased to 80% whereas it was 84.5% at a high inhalation flowrate of 85 L/min. According to ASTM F2100-19e1 (2019), the sub-micron particulates filtration efficiency at a particle size of 0.1 μm (100 nm) in diameter should be ≥ 95% for low-barrier surgical masks and ≥ 98% for medium-barrier and high-barrier surgical masks when measured for a flowrate of 28.3 L/min. It implies that the penetration of 0.1 μm diameter particles at 28.3 L/min flowrate should not be more than 2% to 5%, depending on the type of surgical masks. Thus, the above discussion suggests that the performance of surgical masks could be below the threshold for the virus particles in the nano-size range.

Surgical masks could also allow the virus particles to enter the respiratory system because of their loose fitting with the face (Food and Drug Administration, 2020) leading to inward leakage (Kähler and Hain, 2020), as evident from Figure 3. Hence, surgical masks may not give adequate protection for healthcare professionals when they are looking after COVID-19 patients. In fact, they are not intended to protect the wearer from the environments rather they are designed to protect the environments from the wearer (Bałazy et al., 2006; Lepelletier et al., 2020). A recent study reported that surgical masks are not effective for protection against coronaviruses and other respiratory transmissible viruses in healthcare settings although they appeared to be useful in community settings (MacIntyre and Chughtai, 2020). An earlier study also stated that surgical masks provide less protection than surgical N95 respirators for healthcare workers against transmissible respiratory diseases caused by viruses (Smith et al., 2016).

Figure 3. Loose-fitting of surgical mask

Efficiency of surgical masks in controlling sources and community transmission of COVID-19

Surgical masks can be more effective in reducing the onward transmission of SARS-CoV-2 by respiratory secretions from COVID-19 patients although outward leakage can occur to some extent because of loose-fitting (Kähler and Hain, 2020). The results obtained from a very recent research revealed that this type of face masks reduced the detection of coronavirus RNA (Ribonucleic Acid) in respiratory droplets and aerosols emitted in the immediate environment (Leung et al., 2020). It implies that surgical masks can control the spread of SARS-CoV-2 from an infected person as they create a physical barrier between the lower face (mouth and nose) and the surrounding environments. The virus-bearing respiratory droplets of relatively large size (≥ 5 μm) encounter with the surgical mask before they interact with the ambient environment. An earlier study reported that the source control by wearing surgical masks may resist the spread of respiratory infections (Patel et al., 2016). Because of larger size, most respiratory droplets cannot pass through surgical masks and spread in the environment. This indicates that surgical masks are conducive to reduce the community transmission of COVID-19 if they are used as a means of source control, as illustrated in Figure 4. Indeed, recent epidemiological data from Taiwan, Singapore, and China support such benefits of surgical masks (Chiang et al., 2020; Liu and Zhang, 2020).

High-barrier (Level 3) surgical masks will also be able to reduce the inward transmission of virus particles by obstructing small respiratory droplets and aerosols present in the air although they may not be as effective as respirators (Bałazy et al., 2006; Chu et al, 2020; Lee et al., 2005; Smith et al., 2020). They will also help to decrease the inward transmission of the viruses through direct and indirect contacts by avoiding touching of the face with contaminated hands (Kähler and Hain, 2020). Hence, the community transmission of COVID-19 shall be minimized through wearing surgical masks by both infected (symptomatic and pre-symptomatic or asymptomatic) and susceptible persons.

The use of surgical masks combined with physical distancing is expected to provide better performance in infection control. Surgical masks might provide some source control even where physical distancing is not possible to maintain, like in crowded places (Public Health Ontario, 2020; Esposito et al., 2020; Desai and Aronoff, 2020). Recent research results indicated that surgical masks provide better source control and higher protection than cloth masks or cotton masks against infectious diseases due to their greater barrier function although they are not superior to surgical N95 respirators (MacIntyre and Chughtai, 2020; Smith et al., 2016).

The use of surgical masks simultaneously with a goggle in addition to physical distancing results in much better performance to prevent the transmission of COVID-19 (Chu et al., 2020). Furthermore, the concurrent usage of a surgical mask as an outer protective barrier over a surgical N95 respirator, as demonstrated in Figure 5, was suggested

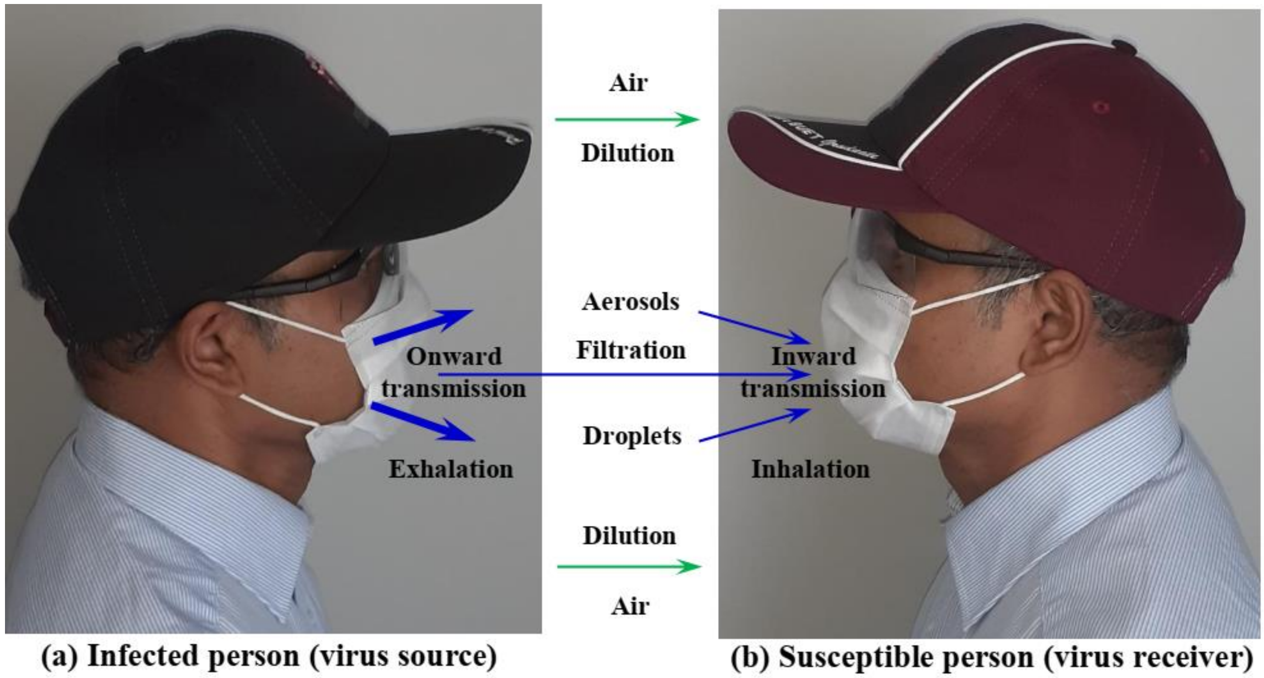


Figure 4: Source control of virus particles by surgical masks

Figure 5: Enhanced protection using surgical mask over surgical N95 respirator

Figure 6: Enhanced protection using surgical mask combined with face shield

to extend the useful life of respirator (Roberge, 2008). This mode of usage is also expected to increase the defence level against COVID-19 providing two layers of protection.

A face shield can also be used as an additional device over a surgical mask (Roberge, 2016), as presented in Figure 6, to enhance the protection level against COVID-19. This mode of use may provide better protection against COVID-19 as compared with surgical masks alone; the defence level shall be further increased if a surgical N95 respirator is used under a surgical mask (Johns Hopkins Medicine, 2020), as illustrated in Figure 7. This is because the virus particles shall be intercepted in three layers of barricade in such mode of usage.

Conclusions and Recommendations

The findings from the present study suggest that surgical masks are not very effective in preventing the virus particles during inhalation. The nano-size coronavirus could easily penetrate surgical masks. Particularly, the penetration of virus particles through low-barrier surgical masks can be very high, as compared to high-barrier surgical masks.

Surgical masks do not tightly fit with the face; the respiratory secretions from COVID-19 patients might leak because of loose-fitting. On the other hand, the virus-bearing small respiratory droplets and aerosols present in the air may enter the respiratory tract through the loose-fit boundary locations of the mask.

Surgical masks can be used for symptomatic and pre-symptomatic or asymptomatic people infected with COVID-19 to lessen the spread of viruses with respiratory secretions, that is, the onward transmission of SARS-CoV-2 from the sources. Where physical distancing is not possible to maintain strictly in crowded places, wearing surgical masks by both infected (symptomatic and pre-symptomatic or asymptomatic) and susceptible persons can be useful in reducing the community transmission of COVID-19.

Surgical masks may play a vital role in source control to minimize the community transmission of COVID-19. However, relying on just this type of masks strategically will not be enough to prevent SARS-CoV-2 from entering the respiratory tract. Enhanced protection should be sought

Figure 7: Enhanced protection using surgical mask combined with face shield and surgical N95 respirator

to effectively control the inward transmission of viruses. Surgical masks may be used in together with other protective devices to enhance the protection level for healthcare professionals; for example, the use of a face shield on top of a goggle, a surgical mask, and a surgical N95 respirator (covered by the surgical mask) would intercept the viruses in different layers of protection.

Further studies on the protection efficiency of surgical masks in the environments with nano-size particles (< 100 nm) are required to evaluate the respiratory protection against coronaviruses. More comprehensive research is also needed to evaluate the overall protective performance when surgical masks are used in together with other means of protection. As well, the mechanisms of transmission of coronaviruses in indoor environments should be well-understood to prevent human infections.

Key Messages

- Low-barrier surgical masks should not be used by healthcare professionals.
- Adequate protection by surgical masks is not guaranteed for healthcare professionals.
- Surgical masks can play a vital role in controlling the sources of SARS-CoV-2.
- Protection against COVID-19 can be enhanced when surgical masks are used combined with other defensive measures.
- Surgical masks should be worn by general people to reduce the community transmission of COVID-19.

Conflicts of Interest

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

REFERENCES

Asadi S, Bouvier N, Wexler AS, Ristenpart WD (2020) 'The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles?', Aerosol Sci. Tech., 54(6):

635-638.
ASTM F2100-19e1 (2019) ‘Standard specification for performance of materials used in medical face masks’, ASTM International: West Conshohocken, Pennsylvania, USA. pp.390-392.
Australian Government (2020) ‘Guidance on the use of personal protective equipment (PPE) in hospitals during the COVID-19 outbreak’, Version 6, June 19, 2020; Department of Health, Commonwealth of Australia: Canberra, Australia. Retrieved on July 28, 2020. Available online: https://www.health.gov.au/sites/default/files/documents/2020/07/guidance-on-the-use-of-personal-protective-equipment-ppe-in-hospitals-during-the-covid-19-outbreak.pdf.
Bałazy N, Toivola M, Adhikari A, Sivasubramani SK, Reponen T, Grinshpun SA (2006) ‘Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks?’, Am. J. Infect. Control, 34(2): 51-57.
CDC (2020) ‘Interim infection prevention and control recommendations for patients with suspected or confirmed Coronavirus Disease 2019 (COVID-19) in healthcare settings’, Centre for Disease Control and Prevention (CDC): Atlanta, Georgia, USA. Retrieved on May 13, 2020. 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.
Chellamani KP, Veerasubramanian D, Balaji RSV (2013) ‘Surgical face masks: manufacturing methods and classification’, J. of Acad. and Ind. Res., 2(6): 320-324.
Chiang C-H, Chiang C-H, Chiang C-H, Chen Y-C (2020) ‘The practice of wearing surgical masks during the COVID-19 pandemic’, Emerg. Infect. Dis., 26(8): 1962.
Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ (2020) ‘Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis’, The Lancet, 395: 1973-1987.
Desai AN, Aronoff DM (2020) ‘Masks and coronavirus disease 2019 (COVID-19)’, JAMA Patient Page, 323(20): 2103.
Esposito S, Principi N, Leung CC, Migliori GB (2020) ‘Universal use of face masks for success against COVID-19: evidence and implications for prevention policies’, Eur. Respir. J., 55(6), 9 pp.
Food and Drug Administration (2020) ‘N95 respirators and surgical masks (face masks)’, U.S. Food and Drug Administration (FDA): Silver Spring, Maryland, USA. Retrieved on March 28, 2020. Available online: https://www.fda.gov/medical-devices/personal-protective-equipment-infection-control/n95-respirators-and-surgical-masks-face-masks#s2.
Henneberry B (2020) ‘How surgical masks are made’, Thomas Publishing Company. Retrieved on July 29, 2020. Available online: https://www.thomasnet.com/articles/other/how-surgical-masks-are-made/#_How_are_Surgical.
Johns Hopkins Medicine (2020) ‘Masks and other protective equipment for health care worker’, The Johns Hopkins Hospital and Johns Hopkins Health System, The Johns Hopkins University: Baltimore, Maryland, USA. Retrieved on July 03, 2020. Available online: https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/coronavirus-face-masks-what-you-need-to-know.
Kähler CJ, Hain R (2020) ‘Fundamental protective mechanisms of face masks against droplet infections’, J. Aerosol Sci., 148(105617): 13 pp.
Kiron MI (2020) ‘Surgical mask: types, manufacturing process and uses in coronavirus’ Textile Learner (web-based textile blog). Retrieved on July 02, 2020. Available online: https://textilelearner.blogspot.com/2020/03/surgical-mask-types-manufacturing.html.
Lai C-C, Shih T-P, Ko W-P, Tang H-J, Hsueh P-R (2020) ‘Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-19 (COVID-19): The epidemic and the challenges’, Int. J. Antimicrob. Agents, 55(3): 9 pp.
Lee BU, Yermakov M, Grinshpun SA (2005) “Filtering efficiency of N95- and R95-type facepiece respirators, dust-mist facepiece respirators, and surgical masks operating in unipolarly ionized indoor air environments’, Aerosol Air Qual. Res., 5(1): 25-38.
Lepelletier D, Grandbastien B, Romano-Bertrand, S, Aho S, Chidiac C, Géhanno J-F, Chauvi F (2020), ‘What face mask for what use in the context of COVID-19 pandemic? The French guidelines’, J. Hosp. Infect., 105(3): 414-418.
Leung NHL, Chu DKW, Shiu EYC, Chan K-H, McDevitt JJ, Hau BJP, Yen H-L, Li Y, Ip DKM, Peiris JSM, Seto W-H, Leung GM, Milton DK, Cowling BJ (2020) ‘Respiratory virus shedding in exhaled breath and efficacy of face masks’, Nat. Med., 26: 676-680.
Liu X, Zhang S (2020) ‘COVID-19: Face masks and human-to-human transmission’, Influenza Other Respi. Viruses, 14: 472-473.
MacIntyre CR, Chughtai AA (2020) ‘A rapid systematic review of the efficacy of face masks and respirators against coronaviruses and other respiratory transmissible viruses for the community, healthcare workers and sick patients’, Int. J. Nurs. Stud., 108: 1-6.
Meselson M (2020) ‘Droplets and aerosols in the transmission of SARS-CoV-2’, N. Engl. J. Med., 382(210): 2061-2063.
Morawska L, Cao J (2020) ‘Airborne transmission of SARS-CoV-2: The world should face the reality’, Environ. Int., 139(105730): 3 pp.
Mount Sinai Hospital (2020) ‘FAQ: Methods of disease transmission’, Department of Microbiology, Mount Sinai Hospital: Toronto, Ontario, Canada. Retrieved on March 31, 2020. Available online:

https://eportal.mountsinai.ca/Microbiology/faq/transmission.shtml.

Mukerji S, MacIntyre CR, Seale H, Wang Q, Yang P, Wang X, Newall AT (2017) 'Cost-effectiveness analysis of N95 respirators and medical masks to protect healthcare workers in China from respiratory infections', BMC Infect. Dis., 17(464): 11 pp.

Pal M, Berhanu G, Desalegn C, Kandi V (2020) 'Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2): An update', Cureus, 12(3), e7423.

Patel RB, Skaria SD, Mansour MM, Smaldone GC (2016) 'Respiratory source control using a surgical mask: An in vitro study', J. Occup. and Environ. Hyg., 13(7): 569-576.

Prather KA, Wang CC, Schooley RT (2020) 'Reducing transmission of SARS-CoV-2', Science, 368(6498): 1422-1424.

Public Health Ontario (2020) 'Masking for source control of COVID-19: Considerations for workers in non-healthcare settings', Public Health Ontario (PHO): Toronto, Ontario, Canada; April 27, 2020. Retrieved on July 01, 2020. Available online: https://www.publichealthontario.ca/-/media/documents/ncov/ipac/report-covid-19-masking-source-control-workers-non-healthcare-settings.pdf?la=en.

Raju R (2020) 'Characteristics of nonwoven fabric – uses and specialty of nonwoven products' Textile Learner (web-based textile blog). Retrieved on July 02, 2020. Available online: https://textilelearner.blogspot.com/2015/12/characteristics-of-nonwoven-fabric-uses.html.

Roberge RJ (2008) 'Effect of surgical masks worn concurrently over N95 filtering facepiece respirators: Extended service life versus increased user burden', J. Public Health Manag. Pract., 14(2): E19-E26.

Roberge RJ (2016) 'Face shields for infection control: A review', J. Occup. Environ. Hyg., 13(4): 235-242.

Shereen MA, Khan S, Kazmi A, Bashir N, Siddique R (2020) 'COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses', J. Adv. Res., 24: 91-98.

Smith JD, MacDougall CC, Johnstone J, Copes RA, Schwartz B, Garber GE (2016) 'Effectiveness of N95 respirators versus surgical masks in protecting health care workers from acute respiratory infection: a systematic review and meta-analysis', Can. Med. Assoc. J., 188(8): 567-574.

Supehia S, Singh V, Sharma T, Khapre M, Gupta PK (2020) 'Rational use of face mask in a tertiary care hospital setting during COVID-19 pandemic: An observational study', Indian J. Public Health, 64(2): S225-S227.

van Doremalen N, Morris DH, Holbrook MG, Gamble A, Williamson BN, Tamim A, Harcourt JL, Thronburg NJ, Gerber SI, Lloyd-Smith JO, de Wit E, Munster VJ (2020) 'Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1', N. Engl. J. Med., 382(16): 1564-1567.

World Health Organization (2020a) 'Pass the message: Five steps to kicking out coronavirus', World Health Organization (WHO): Geneva, Switzerland; March 23, 2020. Retrieved on March 24, 2020. Available online: https://www.who.int/news-room/detail/23-03-2020-pass-the-message-five-steps-to-kicking-out-coronavirus.

World Health Organization (2020b) 'Prevention of hospital-acquired infections: A practical guide', Second Edition; Ducel G, Fabry J, Nicolle L, Eds.; World Health Organization (WHO): Geneva, Switzerland, 2002. Retrieved on March 26, 2020. Available online: https://www.who.int/csr/resources/publications/whocdscsreph200212.pdf.

Zhang R, Li Y, Zhang AL, Wang Y, Molina MJ (2020) 'Identifying airborne transmission as the dominant route for the spread of COVID-19', Proc. Natl. Acad. Sci. U. S. A.,117(26): 14857-14863.