

# COMMENTARY: Masks-for-all for COVID-19 not based on sound data

[cidrap.umn.edu/news-perspective/2020/04/commentary-masks-all-covid-19-not-based-sound-data](https://cidrap.umn.edu/news-perspective/2020/04/commentary-masks-all-covid-19-not-based-sound-data)

Lisa M Brosseau, ScD, and Margaret Sietsema, PhD | Apr 01, 2020



*Dr. Brosseau is a national expert on respiratory protection and infectious diseases and professor (retired), University of Illinois at Chicago.*

*Dr. Sietsema is also an expert on respiratory protection and an assistant professor at the University of Illinois at Chicago.*

---

**Editor's Note:** *The authors added the following statement on Jul 16.*

The authors and CIDRAP have received requests in recent weeks to remove this article from the CIDRAP website. Reasons have included: (1) we don't truly know that cloth masks (face coverings) are not effective, since the data are so limited, (2) wearing a cloth mask or face covering is better than doing nothing, (3) the article is being used by individuals and groups

to support non-mask wearing where mandated and (4) there are now many modeling studies suggesting that cloth masks or face coverings could be effective at flattening the curve and preventing many cases of infection.

### **If the data are limited, how can we say face coverings are likely not effective?**

---

We agree that the data supporting the effectiveness of a cloth mask or face covering are very limited. We do, however, have data from laboratory studies that indicate cloth masks or face coverings offer very low filter collection efficiency for the smaller inhalable particles we believe are largely responsible for transmission, particularly from pre- or asymptomatic individuals who are not coughing or sneezing. At the time we wrote this article, we were unable to locate any well-performed studies of cloth mask leakage when worn on the face—either inward or outward leakage. As far as we know, these data are still lacking.

The guidelines from the Centers for Disease Control and Prevention (CDC) for face coverings initially did not have any citations for studies of cloth material efficiency or fit, but some references have been added since the guidelines were first posted. We reviewed these and found that many employ very crude, non-standardized methods (Anfinrud 2020, Davies 2013, Konda 2020, Aydin 2020, Ma 2020) or are not relevant to cloth face coverings because they evaluate respirators or surgical masks (Leung 2020, Johnson 2009, Green 2012).

The CDC failed to reference the National Academies of Sciences Rapid Expert Consultation on the Effectiveness of Fabric Masks for the COVID-19 Pandemic (NAS 2020), which concludes, “The evidence from...laboratory filtration studies suggests that such fabric masks may reduce the transmission of larger respiratory droplets. There is little evidence regarding the transmission of small aerosolized particulates of the size potentially exhaled by asymptomatic or presymptomatic individuals with COVID-19.” As well, the CDC neglected to mention a well-done study of cloth material filter performance by Rengasamy et al (2014), which we reviewed in our article.

### **Is wearing a face covering better than nothing?**

---

Wearing a cloth mask or face covering could be better than doing nothing, but we simply don't know at this point. We have observed an evolution in the messaging around cloth masks, from an initial understanding that they should not be seen as a replacement for physical distancing to more recent messaging that suggests cloth masks are equivalent to physical distancing. And while everyone appears to understand that this messaging suggests that a cloth mask is appropriate only for source control (ie, to protect others from infection), recent CDC and other guidance recommending their use by workers seems to imply that they offer some type of personal protection.

We know of workplaces in which employees are told they cannot wear respirators for the hazardous environments they work in, but instead need to wear a cloth mask or face covering. These are dangerous and inappropriate applications that greatly exceed the initial purpose of a cloth mask. We are concerned that many people do not understand the very limited degree of protection a cloth mask or face covering likely offers as source control for people located nearby.

## **Do we support cloth mask wearing where mandated?**

---

Despite the current limited scientific data detailing their effectiveness, we support the wearing of face coverings by the public when mandated and when in close contact with people whose infection status they don't know. However, we also encourage everyone to continue to limit their time spent indoors near potentially infectious people and to not count on or expect a cloth mask or face covering to protect them or the people around them. The pandemic is not over and will not likely be over for some time. As states and local jurisdictions reopen, we encourage people to continue to assess and limit their risks. Cloth masks and face coverings likely do *not* offer the same degree of protection as physical distancing, isolation, or limiting personal contact time.

## **Will face coverings 'flatten the curve' and stop the pandemic?**

---

We have reviewed the many modeling studies that purport to demonstrate that cloth masks or face coverings have the potential for flattening the curve or significantly decrease the number of cases. These studies fail to recognize several important facts:

- The filter performance of a cloth material does not directly translate or represent its performance on an individual, because it neglects the understanding of fit.
- Cloth masks or coverings come in a variety of shapes, sizes, and materials and are not made according to any standards.
- Transmission is not simply a function of short random interactions between individuals, but rather a function of particle concentration in the air and the time exposed to that concentration.
- A cloth mask or face covering does very little to prevent the emission or inhalation of small particles. As discussed in an earlier CIDRAP [commentary](#) and more recently by Morawska and Milton (2020) in an open letter to WHO signed by 239 scientists, inhalation of small infectious particles is not only biologically plausible, but the epidemiology supports it as an important mode of transmission for SARS-CoV-2, the virus that causes COVID-19.

In summary, though we support mask wearing by the general public, we continue to conclude that cloth masks and face coverings are likely to have limited impact on lowering COVID-19 transmission, because they have minimal ability to prevent the emission of small particles, offer limited personal protection with respect to small particle inhalation, and should not be recommended as a replacement for physical distancing or reducing time in enclosed spaces

with many potentially infectious people. We are very concerned about messaging that suggests cloth masks or face coverings can replace physical distancing. We also worry that the public doesn't understand the limitations of cloth masks and face coverings when we observe how many people wear their mask under their nose or even under their mouth, remove their masks when talking to someone nearby, or fail to practice physical distancing when wearing a mask.

## References

---

**Anfinrud P, Stadnytskyi V, Bax CE, et al.** Visualizing speech-generated oral fluid droplets with laser light scattering. *N Engl J Med* 2020 (published online Apr 15)

**Davies A, Thompson KA, Giri K, et al.** Testing the efficacy of homemade masks: would they protect in an influenza pandemic? *Disaster Med Public Health Prep* 2013 Aug;7(4):413-8

**Green CF, Davidson CS, Panlilio AL, et al.** Effectiveness of selected surgical masks in arresting vegetative cells and endospores when worn by simulated contagious patients. *Infect Control Hosp Epidemiol* 2012 May;33(5):487-94

**Johnson DF, Druce JD, Birch C, et al.** A quantitative assessment of the efficacy of surgical and N95 masks to filter influenza virus in patients with acute influenza infection. *Clin Infect Dis* 2009 Jul 15;49(2):275-7

**Konda A, Prakash A, Moss GA, et al.** Aerosol filtration efficiency of common fabrics used in respiratory cloth masks. *ACS Nano.* 2020 (published online Apr 24)

**Leung NHL, Chu DKW, Shiu EYC, et al.** Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nat Med* 2020 (published online Apr 3)

**Ma QX, Shan H, Zhang HL, et al.** Potential utilities of mask-wearing and instant hand hygiene for fighting SARS-CoV-2. *J Med Virol* 2020 (published online Mar 31)

**Morawska L, Milton DK.** It is time to address airborne transmission of COVID-19. *Clin Infect Dis* 2020 (published online Jul 6)

**National Academies of Sciences, Engineering, and Medicine.** 2020. Rapid expert consultation on the effectiveness of fabric masks for the COVID-19 pandemic. Washington, DC, National Academies Press. Apr 8, 2020

**Rengasamy S, Eimer B, Szalajda J.** A quantitative assessment of the total inward leakage of NaCl aerosol representing submicron-size bioaerosol through N95 filtering facepiece respirators and surgical masks. *J Occup Environ Hyg* 2014 May 9;11(6):388-96

---

**Editor's Note:** Also on Jul 16, The following text was changed directly after the "Surgical masks as source control" subhead in the original commentary:

Original: Household studies find very limited effectiveness of surgical masks at reducing respiratory illness in other household members.<sup>22-25</sup>

Updated: We were able to identify only two household studies in which surgical masks were worn by the index patient only, as source control.<sup>24,25</sup> Neither of these found a significant impact on secondary disease transmission, although both studies had important limitations.

The original reference 24 (bin-Reza 2011) was changed to Canini 2010. In an unrelated correction on Jul 16, reference 45 was incorrect and now correctly cites bin-Reza 2012.

---

In response to the stream of misinformation and misunderstanding about the nature and role of masks and respirators as source control or personal protective equipment (PPE), we critically review the topic to inform ongoing COVID-19 decision-making that relies on science-based data and professional expertise.

As noted in a previous [commentary](#), the limited data we have for COVID-19 strongly support the possibility that SARS-CoV-2—the virus that causes COVID-19—is transmitted by inhalation of both droplets and aerosols near the source. It is also likely that people who are pre-symptomatic or asymptomatic throughout the duration of their infection are spreading the disease in this way.

## **Data lacking to recommend broad mask use**

---

We do not recommend requiring the general public who do not have symptoms of COVID-19-like illness to routinely wear cloth or surgical masks because:

- There is no scientific evidence they are effective in reducing the risk of SARS-CoV-2 transmission
- Their use may result in those wearing the masks to relax other distancing efforts because they have a sense of protection
- We need to preserve the supply of surgical masks for at-risk healthcare workers.

Sweeping mask recommendations—as many have proposed—will not reduce SARS-CoV-2 transmission, as evidenced by the widespread practice of wearing such masks in Hubei province, China, before and during its mass COVID-19 transmission experience earlier this year. Our review of relevant studies indicates that cloth masks will be ineffective at preventing SARS-CoV-2 transmission, whether worn as source control or as PPE.

Surgical masks likely have some utility as source control (meaning the wearer limits virus dispersal to another person) from a symptomatic patient in a healthcare setting to stop the spread of large cough particles and limit the lateral dispersion of cough particles. They may also have very limited utility as source control or PPE in households.

Respirators, though, are the only option that can ensure protection for frontline workers dealing with COVID-19 cases, once all of the strategies for optimizing respirator supply have been implemented.

We do not know whether respirators are an effective intervention as source control for the public. A non-fit-tested respirator may not offer any better protection than a surgical mask. Respirators work as PPE only when they are the right size and have been fit-tested to demonstrate they achieve an adequate protection factor. In a time when respirator supplies are limited, we should be saving them for frontline workers to prevent infection and remain in their jobs.

These recommendations are based on a review of available literature and informed by professional expertise and consultation. We outline our review criteria, summarize the literature that best addresses these criteria, and describe some activities the public can do to help "flatten the curve" and to protect frontline workers and the general public.

We realize that the public yearns to help protect medical professionals by contributing homemade masks, but there are better ways to help.

## **Filter efficiency and fit are key for masks, respirators**

---

The best evidence of mask and respirator performance starts with testing filter efficiency and then evaluating fit (facepiece leakage). Filter efficiency must be measured first. If the filter is inefficient, then fit will be a measure of filter efficiency only and not what is being leaked around the facepiece.

### **Filter efficiency**

---

Masks and respirators work by collecting particles through several physical mechanisms, including diffusion (small particles) and interception and impaction (large particles).<sup>1</sup> N95 filtering facepiece respirators (FFRs) are constructed from electret filter material, with electrostatic attraction for additional collection of all particle sizes.<sup>2</sup>

Every filter has a particle size range that it collects inefficiently. *Above and below this range, particles will be collected with greater efficiency.* For fibrous non-electret filters, this size is about 0.3 micrometers ( $\mu\text{m}$ ); for electret filters, it ranges from 0.06 to 0.1  $\mu\text{m}$ . When testing, we care most about the point of inefficiency. As flow increases, particles in this range will be collected less efficiently.

The best filter tests use worst-case conditions: high flow rates (80 to 90 liters per minute [L/min]) with particle sizes in the least efficiency range. This guarantees that filter efficiency will be high at typical, lower flow rates for all particle sizes. Respirator filter certification tests use 84 L/min, well above the typical 10 to 30 L/min breathing rates. The N95 designation means the filter exhibits at least 95% efficiency in the least efficient particle size range.

Studies should also use well-characterized inert particles (not biological, anthropogenic, or naturogenic ones) and instruments that quantify concentrations in narrow size categories, and they should include an N95 FFR or similar respirator as a positive control.

## **Fit**

---

Fit should be a measure of how well the mask or respirator prevents leakage around the facepiece, as noted earlier. Panels of representative human subjects reveal more about fit than tests on a few individuals or mannequins.

Quantitative fit tests that measure concentrations inside and outside of the facepiece are more discriminating than qualitative ones that rely on taste or odor.

## **Mask, N95 respirator filtering performance**

---

Following a recommendation that cloth masks be explored for use in healthcare settings during the next influenza pandemic,<sup>3</sup> The National Institute for Occupational Safety and Health (NIOSH) conducted a study of the filter performance on clothing materials and articles, including commercial cloth masks marketed for air pollution and allergens, sweatshirts, t-shirts, and scarfs.<sup>4</sup>

Filter efficiency was measured across a wide range of small particle sizes (0.02 to 1  $\mu\text{m}$ ) at 33 and 99 L/min. N95 respirators had efficiencies greater than 95% (as expected). For the entire range of particles tested, t-shirts had 10% efficiency, scarves 10% to 20%, cloth masks 10% to 30%, sweatshirts 20% to 40%, and towels 40%. All of the cloth masks and materials had near zero efficiency at 0.3  $\mu\text{m}$ , a particle size that easily penetrates into the lungs.<sup>4</sup>

Another study evaluated 44 masks, respirators, and other materials with similar methods and small aerosols (0.08 and 0.22  $\mu\text{m}$ ).<sup>5</sup> N95 FFR filter efficiency was greater than 95%. Medical masks exhibited 55% efficiency, general masks 38% and handkerchiefs 2% (one layer) to 13% (four layers).

These studies demonstrate that cloth or homemade masks will have very low filter efficiency (2% to 38%). Medical masks are made from a wide range of materials, and studies have found a wide range of filter efficiency (2% to 98%), with most exhibiting 30% to 50% efficiency.<sup>6-12</sup>

We reviewed other filter efficiency studies of makeshift cloth masks made with various materials. Limitations included challenge aerosols that were poorly characterized<sup>13</sup> or too large<sup>14-16</sup> or flow rates that were too low.<sup>17</sup>

## **Mask and respirator fit**

---

Regulators have not developed guidelines for cloth or surgical mask fit. N95 FFRs must achieve a fit factor (outside divided by inside concentration) of at least 100, which means that the facepiece must lower the outside concentration by 99%, according to the [OSHA respiratory protection standard](#). When fit is measured on a mask with inefficient filters, it is really a measure of the collection of particles by the filter plus how well the mask prevents particles from leaking around the facepiece.

Several studies have measured the fit of masks made of cloth and other homemade materials.<sup>13,18,19</sup> We have not used their results to evaluate mask performance, because none measured filter efficiency or included respirators as positive controls.

One study of surgical masks showing relatively high efficiencies of 70% to 95% using NIOSH test methods measured total mask efficiencies (filter plus facepiece) of 67% to 90%.<sup>7</sup> These results illustrate that surgical masks, even with relatively efficient filters, do not fit well against the face.

In sum, cloth masks exhibit very low filter efficiency. Thus, even masks that fit well against the face will not prevent inhalation of small particles by the wearer or emission of small particles from the wearer.

One study of surgical mask fit described above suggests that poor fit can be somewhat offset by good filter collection, but will not approach the level of protection offered by a respirator. The problem is, however, that many surgical masks have very poor filter performance. Surgical masks are not evaluated using worst-case filter tests, so there is no way to know which ones offer better filter efficiency.

## **Studies of performance in real-world settings**

---

Before recommending them, it's important to understand how masks and respirators perform in households, healthcare, and other settings.

### **Cloth masks as source control**

---

A historical overview of cloth masks notes their use in US healthcare settings starting in the late 1800s, first as source control on patients and nurses and later as PPE by nurses.<sup>20</sup>

Kellogg,<sup>21</sup> seeking a reason for the failure of cloth masks required for the public in stopping the 1918 influenza pandemic, found that the number of cloth layers needed to achieve acceptable efficiency made them difficult to breathe through and caused leakage around the



mask. We found no well-designed studies of cloth masks as source control in household or healthcare settings.

In sum, given the paucity of information about their performance as source control in real-world settings, along with the extremely low efficiency of cloth masks as filters and their poor fit, there is no evidence to support their use by the public or healthcare workers to control the emission of particles from the wearer.

### **Surgical masks as source control**

---

We were able to identify only two household studies in which surgical masks were worn by the index patient only, as source control.<sup>24,25</sup> Neither of these found a significant impact on secondary disease transmission, although both studies had important limitations.

Clinical trials in the surgery theater have found no difference in wound infection rates with and without surgical masks.<sup>26-29</sup> Despite these findings, it has been difficult for surgeons to give up a long-standing practice.<sup>30</sup>

There is evidence from laboratory studies with coughing infectious subjects that surgical masks are effective at preventing emission of large particles<sup>31-34</sup> and minimizing lateral dispersion of cough particles, but with simultaneous displacement of aerosol emission upward and downward from the mask.<sup>35</sup>

There is some evidence that surgical masks can be effective at reducing overall particle emission from patients who have multidrug-resistant tuberculosis,<sup>36</sup> cystic fibrosis,<sup>34</sup> and influenza.<sup>33</sup> The latter found surgical masks decreased emission of large particles (larger than 5  $\mu\text{m}$ ) by 25-fold and small particles by threefold from flu-infected patients.<sup>33</sup> Sung<sup>37</sup> found a 43% reduction in respiratory viral infections in stem-cell patients when everyone, including patients, visitors, and healthcare workers, wore surgical masks.

In sum, wearing surgical masks in households appears to have very little impact on transmission of respiratory disease. One possible reason may be that masks are not likely worn continuously in households. These data suggest that surgical masks worn by the public will have no or very low impact on disease transmission during a pandemic.

There is no evidence that surgical masks worn by healthcare workers are effective at limiting the emission of small particles or in preventing contamination of wounds during surgery.

There is moderate evidence that surgical masks worn by patients in healthcare settings can lower the emission of large particles generated during coughing and limited evidence that small particle emission may also be reduced.

### **N95 FFRs as source control**

---

Respirator use by the public was reviewed by NIOSH: (1) untrained users will not wear respirators correctly, (2) non-fit tested respirators are not likely to fit, and (3) improvised cloth masks do not provide the level of protection of a fit-tested respirator.

There are few studies examining the effectiveness of respirators on patients. An N95 FFR on coughing human subjects showed greater effectiveness at limiting lateral particle dispersion than surgical masks (15 cm and 30 cm dispersion, respectively) in comparison to no mask (68 cm).<sup>35</sup> Cystic fibrosis patients reported that surgical masks were tolerable for short periods, but N95 FFRs were not.<sup>34</sup>

In summary, N95 FFRs on patients will not be effective and may not be appropriate, particularly if they have respiratory illness or other underlying health conditions. Given the current extreme shortages of respirators needed in healthcare, we do not recommend the use of N95 FFRs in public or household settings.

### **Cloth masks as PPE**

---

A randomized trial comparing the effect of medical and cloth masks on healthcare worker illness found that those wearing cloth masks were 13 times more likely to experience influenza-like illness than those wearing medical masks.<sup>38</sup>

In sum, very poor filter and fit performance of cloth masks described earlier and very low effectiveness for cloth masks in healthcare settings lead us to conclude that cloth masks offer no protection for healthcare workers inhaling infectious particles near an infected or confirmed patient.

### **Surgical masks as PPE**

---

Several randomized trials have not found any statistical difference in the efficacy of surgical masks versus N95 FFRs at lowering infectious respiratory disease outcomes for healthcare workers.<sup>39-43</sup>

Most reviews have failed to find any advantage of one intervention over the other.<sup>23,44-48</sup> Recent meta-analyses found that N95 FFRs offered higher protection against clinical respiratory illness<sup>49,50</sup> and lab-confirmed bacterial infections,<sup>49</sup> but not viral infections or influenza-like illness.<sup>49</sup>

A recent pooled analysis of two earlier trials comparing medical masks and N95 filtering facepiece respirators **with controls** (no protection) found that healthcare workers continuously wearing N95 FFRs were 54% less likely to experience respiratory viral infections than controls ( $P = 0.03$ ), while those wearing medical masks were only 12% less likely than controls ( $P = 0.48$ ; result is not significantly different from zero).<sup>51</sup>

While the data supporting the use of surgical masks as PPE in real-world settings are limited, the two meta-analyses and the most recent randomized controlled study<sup>51</sup> combined with evidence of moderate filter efficiency and complete lack of facepiece fit lead us to conclude that surgical masks offer very low levels of protection for the wearer from aerosol inhalation. There may be some protection from droplets and liquids propelled directly onto the mask, but a faceshield would be a better choice if this is a concern.

## **N95 FFRs as PPE**

---

A retrospective cohort study found that nurses' risk of SARS (severe acute respiratory syndrome, also caused by a coronavirus) was lower with consistent use of N95 FFRs than with consistent use of a surgical mask.<sup>52</sup>

In sum, this study, the meta-analyses, randomized controlled trial described above,<sup>49,51</sup> and laboratory data showing high filter efficiency and high achievable fit factors lead us to conclude that N95 FFRs offer superior protection from inhalable infectious aerosols likely to be encountered when caring for suspected or confirmed COVID-19 patients.

The precautionary principle supports higher levels of respiratory protection, such as powered air-purifying respirators, for aerosol-generating procedures such as intubation, bronchoscopy, and acquiring respiratory specimens.

## **Conclusions**

---

While this is not an exhaustive review of masks and respirators as source control and PPE, we made our best effort to locate and review the most relevant studies of laboratory and real-world performance to inform our recommendations. Results from laboratory studies of filter and fit performance inform and support the findings in real-world settings.

Cloth masks are ineffective as source control and PPE, surgical masks have some role to play in preventing emissions from infected patients, and respirators are the best choice for protecting healthcare and other frontline workers, but not recommended for source control. These recommendations apply to pandemic and non-pandemic situations.

Leaving aside the fact that they are ineffective, telling the public to wear cloth or surgical masks could be interpreted by some to mean that people are safe to stop isolating at home. It's too late now for anything but stopping as much person-to-person interaction as possible.

Masks may confuse that message and give people a false sense of security. If masks had been the solution in Asia, shouldn't they have stopped the pandemic before it spread elsewhere?

## **Ways to best protect health workers**

---

We recommend that healthcare organizations follow US Centers for Disease Control and Prevention (CDC) guidance by moving first through conventional, then contingency, and finally crisis scenarios to optimize the supply of respirators. We recommend using the CDC's burn rate calculator to help identify areas to reduce N95 consumption and working down the CDC checklist for a strategic approach to extend N95 supply.

For readers who are disappointed in our recommendations to stop making cloth masks for themselves or healthcare workers, we recommend instead pitching in to locate N95 FFRs and other types of respirators for healthcare organizations. Encourage your local or state government to organize and reach out to industries to locate respirators not currently being used in the non-healthcare sector and coordinate donation efforts to frontline health workers.

## References

---

1. **Lee KW, Liu BYH.** On the minimum efficiency and the most penetrating particle size for fibrous filters. J Air Pollut Control Assoc 1980 Mar 13;30(4):377-81
2. **Martin SB Jr, Moyer ES.** Electrostatic respirator filter media: filter efficiency and most penetrating particle size effects. Appl Occup Environ Hyg 2000 Nov 30;15(8):609-17
3. Reusability of facemasks during an influenza pandemic. News conference, Apr 27, 2006
4. **Rengasamy S, Eimer B, Shaffer RE.** Simple respiratory protection—evaluation of the filtration performance of cloth masks and common fabric materials against 20-1000 nm size particles. Ann Occup Hyg 2010 Jun 28;54(7):789-98
5. **Jung H, Kim J, Lee S, et al.** Comparison of filtration efficiency and pressure drop in anti-yellow sand masks, quarantine masks, medical masks, general masks, and handkerchiefs. Aerosol Air Qual Res 2014;14(14):991-1002.
6. **Grinshpun SA, Haruta H, Eninger RM, et al.** Performance of an N95 filtering facepiece particulate respirator and a surgical mask during human breathing: two pathways for particle penetration. J Occup Environ Hyg 2009 Jul 22;6(10):593-603
7. **Oberg T, Brosseau LM.** Surgical mask filter and fit performance. Am J Infect Control 2008 May;36(4):276-82
8. **Willeke K, Qian Y, Donnelly J, et al.** Penetration of airborne microorganisms through a surgical mask and a dust/mist respirator. Am Ind Hyg Assoc J 1996;57(4):348-55
9. **Brosseau LM, McCullough NV, Vesley D.** Mycobacterial aerosol collection efficiency of respirator and surgical mask filters under varying conditions of flow and humidity. Appl Occup Environ Hyg 1997;12(6):435-45
10. **Chen CC, Willeke K.** Aerosol penetration through surgical masks. Am J Infect Control 1992 Aug;20(4):177-84
11. **McCullough NV, Brosseau LM, Vesley D.** Collection of three bacterial aerosols by respirator and surgical mask filters under varying conditions of flow and relative humidity. Ann Occup Hyg 1997 Dec;41(6):677-90

12. **Rengasamy S, Eimer B, Szalajda J.** A quantitative assessment of the total inward leakage of NaCl aerosol representing submicron-size bioaerosol through N95 filtering facepiece respirators and surgical masks. J Occup Environ Hyg 2014 11(6):388-96
13. **Davies A, Thompson KA, Giri K, et al.** Testing the efficacy of homemade masks: would they protect in an influenza pandemic? Disaster Med Public Health Prep 2013 Aug;7(4):413-8
14. **Cherrie JW, Apsley A, Cowie H, et al.** Effectiveness of face masks used to protect Beijing residents against particulate air pollution. Occup Environ Med 2018 Jun;75(6):446-52
15. **Mueller W, Horwell CJ, Apsley A, et al.** The effectiveness of respiratory protection worn by communities to protect from volcanic ash inhalation. Part I: filtration efficiency tests. Int J Hyg Environ Health 2018 July;221(6):967-76
16. **Bowen LE.** Does that face mask really protect you? Appl Biosaf 2010 Jun 1;15(2):67-71
17. **Shakya KM, Noyes A, Kallin R, et al.** Evaluating the efficacy of cloth facemasks in reducing particulate matter exposure. J Expo Sci Environ Epidemiol 2017 May;27(3):352-7
18. **van der Sande M., Teunis P, Sabel R.** Professional and home-made face masks reduce exposure to respiratory infections among the general population. PLOS One 2008 Jul 9;3(7):0002618
19. **Derrick JL, Gomersall CD.** Protecting healthcare staff from severe acute respiratory syndrome: filtration capacity of multiple surgical masks. J Hosp Infect 2005 Apr;59(4):365-8
20. **Chughtai AA, Seale H, MacIntyre CR.** Use of cloth masks in the practice of infection control—evidence and policy gaps. Int J Infect Control 2013 Jun;9(3)
21. **Kellogg WH, MacMillan G.** An experimental study of the efficacy of gauze face masks. Am J Public Health 1920;10(1):34-42
22. **Saunders-Hastings P, Crispo JA, Sikora L, et al.** Effectiveness of personal protective measures in reducing pandemic influenza transmission: A systematic review and meta-analysis. Epidemics 2017 Sep;20:1-20
23. **Cowling B J, Zhou Y, Ip DKM, et al.** Face masks to prevent transmission of influenza virus: a systematic review. Epidemiol Infect 2010 Jan 22;138(4):449-56
24. **Canini L, Andreoletti L, Ferrari P, et al.** Surgical mask to prevent influenza transmission in households: a cluster randomized trial. PLOS One 2010 Nov 17;5(11):e13998
25. **MacIntyre CR, Zhang Y, Chughtai AA, et al.** Cluster randomised controlled trial to examine medical mask use as source control for people with respiratory illness. BMJ Open 2016 Dec 30;6(12):e012330
26. **Meleny FL.** Infection in clean operative wounds: a nine year study. Surg Gynecol Obstet 1935;60:264-75
27. **Orr NWM.** Is a mask necessary in the operating theater? Ann R Coll Surg Engl 1981;63:390-2

28. **Mitchell NJ, Hunt S.** Surgical face masks in modern operating rooms—a costly and unnecessary ritual? *J Hosp Infect* 1991;18(3):239-42
29. **Tunevall TG.** Postoperative wound infections and surgical face masks: a controlled study. *World J Surg* 1991 May-Jun;15(3):383-7
30. **Belkin NL.** Masks, barriers, laundering, and gloving: Where is the evidence? *AORN J* 2006 Oct 25;84(4):655-63
31. **Johnson DF, Druce JD, Birch C, et al.** A quantitative assessment of the efficacy of surgical and N95 masks to filter influenza virus in patients with acute influenza infection. *Clin Infect Dis* 2009 Jul 15;49(2):275-7
32. **Driessche KV, Hens N, Tilley P, et al.** Surgical masks reduce airborne spread of *Pseudomonas aeruginosa* in colonized patients with cystic fibrosis. *Am J Respir Crit Care Med* 2015 Oct 1;192(7):897-9
33. **Milton DK, Fabian MP, Cowling BJ, et al.** Influenza virus aerosols in human exhaled breath: particle size, culturability, and effect of surgical masks. *PLoS Pathog* 2013 Mar;9(3):e1003205
34. **Stockwell RE, Wood ME, He C, et al.** Face masks reduce the release of *Pseudomonas aeruginosa* cough aerosols when worn for clinically relevant periods. *Am J Respir Crit Care Med* 2018 Nov 15;198(10):1339-42
35. **Hui DS, Chow BK, Chu L, et al.** Exhaled air dispersion during coughing with and without wearing a surgical or N95 mask. *PLoS One* 2012;7(12):e50845
36. **Dharmadhikari AS, Mphahlele M, Stoltz A, et al.** Surgical face masks worn by patients with multidrug-resistant tuberculosis: impact on infectivity of air on a hospital ward. *Am J Respir Crit Care Med* 2012 May 15;185(10):1104-9
37. **Sung AD, Sung JA, Thomas S, et al.** Universal mask usage for reduction of respiratory viral infections after stem cell transplant: a prospective trial. *Clin Infect Dis* 2016 Oct 15;63(8):999-1006
38. **MacIntyre CR, Seale H, Dung TC, et al.** A cluster randomised trial of cloth masks compared with medical masks in healthcare workers. *BMJ Open* 2015 Apr 22;5(4):e006577
39. **Loeb M, Dafoe N, Mahony J, et al.** Surgical mask vs N95 respirator for preventing influenza among healthcare workers: a randomized trial. *JAMA* 2009 Nov 4;302(17):1865-71
40. **MacIntyre CR, Wang Q, Cauchemez S, et al.** A cluster randomized clinical trial comparing fit-tested and non-fit-tested N95 respirators to medical masks to prevent respiratory virus infection in health care workers. *Influenza Other Respir Viruses* 2011;5(3):170-9
41. **MacIntyre CR, Wang Q, Rahman B, et al.** Efficacy of face masks and respirators in preventing upper respiratory tract bacterial colonization and co-infection in hospital healthcare workers—authors' reply. *Prev Med* 2014 Aug;65:154
42. **MacIntyre CR, Wang Q, Seale H, et al.** A randomized clinical trial of three options for N95 respirators and medical masks in health workers. *Am J Resp Crit Care Med* 2013;187(9):960-6

43. **Radonovich LJ, Simberkoff MS, Bessesen MT, et al.** N95 respirators vs medical masks for preventing influenza among health care personnel: a randomized clinical trial. JAMA 2019 Sep 3;322(9):824-33
44. **Gralton J, and McLaws ML.** Protecting healthcare workers from pandemic influenza: N95 or surgical masks?. Crit Care Med 2010 Feb;38(2):657-67
45. **bin-Reza F, Chavarrias VL, Nicoll A, et al.** The use of masks and respirators to prevent transmission of influenza: a systematic review of the scientific evidence. Influenza Other Respir Virus 2012 Jul;6(4):257-67
46. **Bunyan D, Ritchie L, Jenkins D, et al.** Respiratory and facial protection: a critical review of recent literature. J Hosp Infect 2013 Nov;85(3):165-9
47. **Smith JD, MacDougall CC, Johnstone J, et al.** Effectiveness of N95 respirators versus surgical masks in protecting health care workers from acute respiratory infection: a systematic review and meta-analysis. CMAJ 2016 May 17;188(8):567-74
48. **Jefferson T, Jones M, Ansari LAA, et al.** Physical interventions to interrupt or reduce the spread of respiratory viruses. Part 1 - Face masks, eye protection and person distancing: systematic review and meta-analysis. medRxiv 2020 Mar 30
49. **Offeddu V, Yung CF, Low MSF, et al.** Effectiveness of masks and respirators against respiratory infections in healthcare workers: a systematic review and meta-analysis. Clin Infect Dis 2017 Aug 7;65(11):1934-42
50. **Long Y, Hu T, Liu L, et al.** Effectiveness of N95 respirators versus surgical masks against influenza: A systematic review and meta-analysis. J Evid Based Med 2020 (published online Mar 13)
51. **MacIntyre CR, Chughtai AA, Rahman B, et al.** The efficacy of medical masks and respirators against respiratory infection in healthcare workers. Influenza Other Respir Viruses 2017;11(6):511-7
52. **Loeb M, McGeer A, Henry B, et al.** SARS among critical care nurses, Toronto. Emerg Infect Dis 2004 Feb;10(2):251-5