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Effectiveness of Surgical and Cotton Masks in Blocking SARS–CoV-2: A Controlled Comparison in 4 Patients

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Author, Article and Disclosure Information

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This article has been retracted. See Notice of Retraction.

Background: During respiratory viral infection, face masks are thought to prevent transmission (1). Whether face masks worn by patients with coronavirus disease 2019 (COVID-19) prevent contamination of the environment is uncertain (2, 3). A previous study reported that surgical masks and N95 masks were equally effective in preventing the dissemination of influenza virus (4), so surgical masks might help prevent transmission of severe acute respiratory syndrome–coronavirus 2 (SARS–CoV-2). However, the SARS–CoV-2 pandemic has contributed to shortages of both N95 and surgical masks, and cotton masks have gained interest as a substitute.

Objective: To evaluate the effectiveness of surgical and cotton masks in filtering SARS–CoV-2.

Methods and Findings: The institutional review boards of 2 hospitals in Seoul, South Korea, approved the protocol, and we invited patients with COVID-19 to participate. After providing informed consent, patients were admitted to negative pressure isolation rooms. We compared disposable surgical masks (180 mm × 90 mm, 3 layers [inner surface mixed with polypropylene and polyethylene, polypropylene filter, and polypropylene outer surface], pleated, bulk packaged in cardboard; KM Dental Mask, KM Healthcare Corp) with reusable 100% cotton masks (160 mm × 135 mm, 2 layers, individually packaged in plastic; Seoulsa).

A petri dish (90 mm × 15 mm) containing 1 mL of viral transport media (sterile phosphate-buffered saline with bovine serum albumin, 0.1%; penicillin, 10 000 U/mL; streptomycin, 10 mg; and amphotericin B, 25 μg) was placed approximately 20 cm from the patients' mouths. Patients were instructed to cough 5 times each onto a petri dish while wearing the following sequence of masks: no mask, surgical mask, cotton mask, and again with no mask. A separate petri dish was used for each of the 5 coughing episodes. Mask surfaces were swabbed with aseptic Dacron swabs in the following sequence: outer surface of surgical mask, inner surface of surgical mask, outer surface of cotton mask, and inner surface of cotton mask.

The median viral loads of nasopharyngeal and saliva samples from the 4 participants were 5.66 log copies/mL and 4.00 log copies/mL, respectively. The median viral loads after coughs without a mask, with a surgical mask, and with a cotton mask were 2.56 log copies/mL, 2.42 log copies/mL, and 1.85 log copies/mL, respectively. All swabs from the outer mask surfaces of the masks were positive for SARS–CoV-2, whereas most swabs from the inner mask surfaces were negative (Table).

Table. SARS–CoV-2 Viral Load in Patient Samples, Petri Dishes, and Mask Surfaces

Table. SARS-CoV-2 Viral Load in Patient Samples, Petri Dishes, and Mask Surfaces

Characteristic	Patient 1 (Hospital A)	Patient 2 (Hospital A)	Patient 3 (Hospital B)	Patient 4 (Hospital B)
Age, *y*	61	62	35	82
Sex	Male	Female	Male	Female
Clinical diagnosis	Pneumonia	Upper respiratory infection	Upper respiratory infection	Pneumonia with ARDS
Symptom onset before admission, *d*	24*	4	5	10
Timing of the mask test, *hospital days*	8	4	2	14
Viral load, *log copies/mL*				
Nasopharyngeal swab	7.68	5.42	5.98	3.57
Saliva	4.29	2.59	5.91	3.51
Petri dish				
Coughing without a mask (before control)	3.53	2.14	2.52	ND
Coughing with a surgical mask	3.26	1.80	2.21	ND
Coughing with a cotton mask	2.27	ND	1.42	ND
Coughing without a mask (after control)	3.23	2.06	2.64	2.44
Mask surface				
Outer surface of surgical mask	2.21	2.11	2.63	2.59
Inner surface of surgical mask	ND	ND	2.00	ND
Outer surface of cotton mask	2.76	2.66	3.61	2.58
Inner surface of cotton mask	ND	ND	3.70	ND

ARDS = acute respiratory distress syndrome; ND = not detected; SARS-CoV-2 = severe acute respiratory syndrome–coronavirus 2.
* Transferred from the other hospital.

Discussion: Neither surgical nor cotton masks effectively filtered SARS–CoV-2 during coughs by infected patients. Prior evidence that surgical masks effectively filtered influenza virus (1) informed recommendations that patients with confirmed or suspected COVID-19 should wear face masks to prevent transmission (2). However, the size and concentrations of SARS–CoV-2 in aerosols generated during coughing are unknown. Oberg and Brousseau (3) demonstrated that surgical masks did not exhibit adequate filter performance against aerosols measuring 0.9, 2.0, and 3.1 μm in diameter. Lee and colleagues (4) showed that particles 0.04 to 0.2 μm can penetrate surgical masks. The size of the SARS–CoV particle from the 2002–2004 outbreak was estimated as 0.08 to 0.14 μm (5); assuming that SARS-CoV-2 has a similar size, surgical masks are unlikely to effectively filter this virus.

Of note, we found greater contamination on the outer than the inner mask surfaces. Although it is possible that virus particles may cross from the inner to the outer surface because of the physical pressure of swabbing, we swabbed the outer surface before the inner surface. The consistent finding of virus on the outer mask surface is unlikely to have been caused by experimental error or artifact. The mask's aerodynamic features may explain this finding. A turbulent jet due to air leakage around the mask edge could contaminate the outer surface. Alternatively, the small aerosols of SARS–CoV-2 generated during a high-velocity cough might penetrate the masks. However, this hypothesis may only be valid if the coughing patients did not exhale any large-sized particles, which would be expected to be deposited on the inner surface despite high velocity. These observations support the importance of hand hygiene after touching the outer surface of masks.

This experiment did not include N95 masks and does not reflect the actual transmission of infection from patients with COVID-19 wearing different types of masks. We do not know whether masks shorten the travel distance of droplets during coughing. Further study is needed to recommend whether face masks decrease transmission of virus from asymptomatic individuals or those with suspected COVID-19 who are not coughing.

In conclusion, both surgical and cotton masks seem to be ineffective in preventing the dissemination of SARS–CoV-2 from the coughs of patients with COVID-19 to the environment and external mask surface.

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Comments

20 Comments

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ken • palmar • 21 May 2020

inhalation of virus

I'm interested in if masks can prevent inhalation of viruses - not so much if one can sneeze or cough thru a mask.

JSmith • None • 19 May 2020

Methodology clarification

Within the portion of the study under methodology it states, “Patients were instructed to cough 5 times each onto a petri dish while wearing the following sequence of masks…”How were the masks brought into the room? Where were they stored during testing prior to each mask being used? How was each mask placed on each patient? In other words, what precautions were taken to ensure the masks were not contaminated prior to placement on the subjects, during placement on the subjects, or during use? Similarly, how did the experiment ensure no other possible sources for transferred viral load? Were the hands of those who placed the masks on the subjects cleaned and then tested for viral load to ensure no cross contamination? Were control masks included that accompanied the test masks and also tested for viral loads with the same procedures?

Paul W Leu • University of Pittsburgh • 19 May 2020

Irrelevent to Efficacy of Masks

The conclusions of this study by Bae et. al are not only erroneous but misleading. 1. The main result of this study is that higher concentrations of SARS-CoV-2 were found on the outside of masks that were coughed into as opposed to the inside. The fact that the virus was determined to be present on the outside of the mask is unsurprising. Surgical and cotton masks are fabrics which will simply absorb any droplets they come into contact with. The higher concentrations found on the outside of the masks may be due to their swabbing the outside of the masks first (which may remove some of the virus) as opposed to the inside. Results should be compared with swabbing the inside first and then the outside. 2. The presence of SARS-CoV-2 on the outside of masks of infected people is of very limited concern for transmission. Most people put on and remove their own masks and do not touch each other’s masks. 3. The results of this study do NOT show that masks are "ineffective in preventing the dissemination of SARS–CoV-2 from the coughs of patients with COVID-19 to the environment.” As the authors acknowledge, their study does NOT evaluate the ability of the masks to shorten the trajectory of droplets emitted during coughing. The function of the mask is to reduce how far aerosol droplets travel during breathing, speaking, singing, sneezing, or coughing. This is the same reason one should cover one’s mouth or nose with your forearm, inside of your elbow, or tissue when sneezing. CDC guidelines advise the wearing of face coverings to "slow the spread of the virus and help people who may have the virus and do not know it from transmitting it to others.”

Joe Breuer • none • 19 May 2020

Theory on negative result on inside of masks

This is a layman's idea for a possible explanation of the counterintuitive result that for the most part the outside of masks tested positive and the insides negative.I cannot speak on its validity and just wish to posit it for discussion by experts. If it possibly leads to valuable insights, great; if it's off base, I hope I did not waste anyone's time.How about the patients expel, along with the virus, other material/cells - related to their immune system or not - that inactivates the virus? And this material or cells *cannot* pass through the masks, so on the insides the inactivation continues / takes place, whereas towards the outside only the infectious material is transported.

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More detailed information about the experiment is needed.

We read with interest Bae and colleagues' study of the effectiveness of surgical and cotton masks against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (1). Although their study is important, some points should be clarified prior to drawing conclusions.The first issue is contamination of aerosolized or small particles. Coughing can cause environmental contamination. Nevertheless, all experiments appeared to have been performed within the same room. Coughing into Petri dishes without a mask could have produced airborne virus-containing droplets that contaminated the next steps of experiment. The sequences would be better following; surgical mask, cotton mask, and no mask. Additionally, fitted mask are critical for preventing room contamination, but mask fit was not discussed (2).

Second, swabbing the inner surfaces of masks may not have been sufficient for the "not detected" results in their Table (1). Removing mask layer and subsequent particle elution in media for nucleic acid amplification might have been a better alternative (3), especially for the evaluation of inner surfaces. Third, the results and conclusions appeared to differ. Cotton masks reduced virus titers by 1-2 log10 copies/mL in Patients 1, 2, and 3. For Patient 4, the virus was detected only in the coughing-without-a-mask Petri dish and only on the outer surfaces of her surgical and cotton masks.

The conclusion that cotton masks do not effectively filter SARS-CoV-2 does not correspond to these findings. In addition, the number of experiments was too small for the conclusion.Finally, a few PCR results in the report (1) were under the measurable level by most PCR protocols widely used. The authors did not describe the PCR protocol adopted or the analytical performance of it with the limit of detection (LoD). Most sensitive LoD theoretically possible is 3 copies/reaction. Assuming that the total reaction volume and RNA volume for the PCR reaction were 5 and 25 μL, respectively, and that the widely used QIAamp Viral RNA MINI kit (Qiagen, Hilden, Germany) was utilized for RNA extraction per the manufacturer's protocol, the LoD should be approximately 2.41 log copies/mL. Indeed, Corman reported 2.31 log copies/mL based on a 25 μL reaction volume (4), and Pfefferle reported 2.83 log copies/mL (5). Additionally, the limit of quantitation is usually higher than the LoD. The authors reported 1.42 log10 copies/mL, which appears too low. Results below LoD should be reported as "less than LoD." Before resolving these issues, the conclusion should be interpreted with caution.

References

1.Bae S, Kim M-C, Kim JY, et al. Effectiveness of surgical and cotton masks in blocking SARS-CoV-2: a controlled comparison in 4 Patients. Ann Int Med. 2020. [Epub ahead of print]. PubMed PMID: 32251511. doi:10.7326/M20-1342

2.Patel RB, Skaria SD, Mansour MM, et al. Respiratory source control using a surgical mask: an in vitro study. J Occup Environ Hyg. 2016;13:569–576. PubMed PMID: 26225807.

3.Chughtai AA, Stelzer-Braid S, Rawlinson W, et al. Contamination by respiratory viruses on outer surface of medical masks used by hospital healthcare workers. BMC Infect Dis. 2019;19(1):491. PubMed PMID: 31159777.

4.Corman VM, Landt O, Kaiser M, et al. Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. Euro Surveill. 2020;25. PubMed PMID: 31992387.5.Pfefferle S, Reucher S, Nörz D, et al. Evaluation of a quantitative RT-PCR assay for the detection of the emerging coronavirus SARS-CoV-2 using a high throughput system. Euro Surveill. 2020;25.PubMed PMID: 32156329.

AcknowledgmentsAuthor contributionsDrs. Ki Ho Hong and So Yeon Kim contributed equally as co-first authors. Drs. Jaehyeon Lee and Ki Ho Hong drafted the manuscript. All authors participated in the concept development and critical revision of the manuscript for important intellectual content.

Conflicts of interest All authors declare no conflict of interest.

Angela C • None • 16 May 2020

Need a larger sample size and more control tests

Hello,I am very interested in this study, as I have my own suspicions about the effectiveness of wearing face masks. I would like to see a larger, more random study conducted. I don't feel a study with 4 participants can give you reliable data. Also, I would like to see the inside and outside of these masks tested prior to the cough tests being completed. And finally, I didn't see the results of the viral load on each of the Petri dishes that the participants coughed onto. That would be interesting to have them cough into Petri dishes at various distances wearing different face masks, including the N95. Thank you for starting this study. I think it needs more work though. I have been a paid RN, BSN for the past 20 years, but my opinions do not reflect those of my employers.

Sung-Han Kim, MD. • Asan Medical Center • 28 April 2020

Author's response

We totally agree with Dr. Glele and colleagues' comment on the high variability of coughing intensity within subjects. Furthermore, it is worth to note that one of eight coughing experiments without mask in patients with COVID-19 revealed a negative SARS-CoV-2 PCR result (Table 1). The heterogeneity of transmission of coronavirus including SARS-CoV, MERS-CoV, and SARS-CoV-2 may explain this observation. The recent study reported that none 41 healthcare workers with most surgical masks and minor N95 masks who were exposed to the aerosol-generating procedures in eventually diagnosed

COVID-19 patients developed symptoms, and all PCR tests for SARS-CoV-2 were negative (COVID-19 and the risk to health care workers: a case report. Ann Intern Med 2020 March 16). Given that viral expectoration from coughing COVID-19 patients was not uniform based on our experiment, cautious interpretation for unusual transmission events is always needed. Dr. Glele and colleagues also commented that no detection of SARS-CoV-2 RNA from inner surface except one patient precludes any reliable conclusions. We assume that multiple factors may affect swab sampling from the outer and inner surfaces of the masks. Although environmental sampling from hard surfaces such as plastic or metal has been widely studied, there are limited studies on sampling from fabric materials. Elution of punched layers of face masks may provide more valuable information about the surface contamination of the masks. Further studies are needed on the viral contamination of mask surfaces. In this context, this variability of viral shedding from coughing within the subject and the nature of fabric swab sampling should be bear in mind for the interpretation of our small experimental data.

As Dr. Glele and colleagues' comment, Leung et al. reported the efficacy of surgical masks in reducing coronavirus detection and viral load from 17 patients (Nat Med 2020 Apr 3). The big difference between Leung's study and ours is the method of collecting human coronavirus particles from the patients. Leung's study collected virus particles by a closed system such as G-II bioaerosol collecting device which consists of a large cone connected with a closed duct. In contrast, we collected virus particle of SARS-CoV-2 directly from coughing COVID-19 patients with an open air system in a negative pressure room. Furthermore, the results of the efficacy of surgical masks on influenza virus from Leung's study (Nat Med 2020 Apr 3) are different from those by the previous study (Clin Infect Dis 2009; 49:275-7). The different methodology of sample collection may explain this discrepancy.

Dr. Purens and colleagues pointed the statistical issue. Our complete case analysis (CCA) may overestimate the true value. In contrast, if we included "not detectable" as "zero", the calculation may underestimate the true value. So, an alternative calculation such as single imputation or Dr. Purens' calculation may result in the value between these two. Thank you for suggesting one of good sensitivity analysis.

We appreciated Dr. Yeung's good balanced view of our study results. We agree with Dr. Yeung's opinion on that our small study (n=4) is a pilot study. We have recently completed additional mask tests in 7 COVID-19 patients to compare the use of surgical masks to the use of N95-equivalent respirators. We believe that these data will provide more information on this issue. Furthermore, other independent groups should evaluate the outward and inward protective effectiveness of various masks against SARS-CoV-2 with more well-designed protocols in which the issues raised in this pilot study by many experts can be settled. Therefore, we totally agree with Dr. Yeung's view on this pilot study like the glass half full or empty.

Christopher T. Leffler, MD, MPH.1 Edsel Ing MD, MPH, CPH, MIAD.2 Joseph D. Lykins V, MD.1 Craig A. McKeown, MD3. Andrzej Grzybowski, MD.4 • 1. Virginia Commonwealth University 2. University of Toronto 3. University of Miami 4. University of Warmia and Mazury • 30 April 2020

Prevention of the spread of coronavirus using masks.

We read the work which concluded “both surgical and cotton masks seem to be ineffective in preventing the dissemination of SARS–CoV-2...”1 In fact, compared with the control condition, the petri dish viral load was less with a cloth mask for all patients, and in half, was not detectable.1
Such reductions do help at the population level.2,3 We retrieved mortality and testing data for 169 countries from a publicly available source on April 22, 2020.4 On average, the time from infection to symptoms is 5.1 days, and that from infection to death is 23 days.2 Therefore, the date of each country’s initial infection was estimated as the earlier of: 5 days before the first reported infection, or 23 days before the first death.4,5 As deaths by April 22, 2020 would typically reflect infections beginning 23 days previously (by March 30), both the time from the first infection, and from the time the public began wearing masks, until March 30 were determined. Countries in which mask usage has been widespread include Hong Kong, South Korea, Malaysia, Taiwan, Japan, and Mongolia.2 Mandates for wearing of masks in public had been issued by March 30 in Thailand (March 12), Vietnam (March 16), Czechia (March 19), and Slovakia (March 25).2 The exponential growth associated with the spread of an epidemic appears linear on a logarithmic scale.2 By multivariable linear regression, significant predictors of the logarithm of each country’s per-capita coronavirus mortality included: duration of infection in the country, duration of wearing masks, population size, and per-capita testing (all p<0.001, Table 1). In a population not wearing masks, the per-capita mortality tended to increase each week by a factor of 10^0.156 = 1.43, or 43%. On the other hand, in a population wearing masks, the per-capita mortality tended to increase by a factor of 10^(0.156-0.144) = 1.028, or just 2.8%. The positive association with testing probably reflects the greater recognition of coronavirus-related mortality with more testing, as well as the increased incentive countries have to test when they suffer a more intense outbreak. These results support the universal wearing of masks by the public to suppress the spread of the coronavirus. Mask-wearing should be adopted immediately, based on the precautionary principle.2,3

References.

1. Bae S, Kim MC, Kim JY, Cha HH, Lim JS, Jung J, Kim MJ, Oh DK, Lee MK, Choi SH, Sung M. Effectiveness of surgical and cotton masks in blocking SARS–CoV-2: a controlled comparison in 4 patients. Annals of Internal Medicine. 2020 Apr 6.
2. Leffler CT, Ing E, McKeown CA, Pratt D, Grzybowski A. Final Country-wide Mortality from the Novel Coronavirus (COVID-19) Pandemic and Notes Regarding Mask Usage by the Public. April 4, 2020. Available from: https://www.researchgate.net/publication/340438732_Country-wide_Mortality_from_the_Novel_Coronavirus_COVID-19_Pandemic_and_Notes_Regarding_Mask_Usage_by_the_Public DOI: 10.13140/RG.2.2.36006.27200
3. Howard J, Huang A, Li Z, Tufekci Z, et al. Face masks against COVID-19: an evidence review. Preprints 2020; published online April 12. DOI:10.20944/preprints202004.0203.v1 (preprint).
4. Worldometers. COVID-19 Coronavirus Pandemic. Available from: https://www.worldometers.info/coronavirus/?utm_campaign=homeAdUOA?Si Accessed April 22, 2020.
5. European Centre for Disease Prevention and Control. COVID-19 Coronavirus data. Available from: https://data.europa.eu/euodp/en/data/dataset/covid-19-coronavirus-data

Accessed April 16, 2020.

None of the authors has any conflicts of interest to disclose.

Table 1. Predictors of (log) Country-wide Per-capita Coronavirus Mortality by Multivariable Linear Regression in 169 Countries.

Coefficient (SE) 95% CI P value.

Duration in country (weeks) 0.156 (SE 0.034) (95% CI 0.089 to 0.223) p<0.001.

Time wearing masks (weeks) -0.144 (SE 0.033) (95% CI -0.209 to -0.079) p<0.001.

Population (log) -0.297 (SE 0.079) (95% CI -0.453 to -0.141) p<0.001.

Tests per capita (log) 0.612 (SE 0.085) (95% CI 0.445 to 0.779) p <0.001.

Constant -2.571 (SE 0.368) (95% CI -3.299 to -1.844) p<0.001.

Eugene Y.H. Yeung • Faculty of Medicine, University of Ottawa; Eastern Ontario Regional Laboratory Association (EORLA) • 27 April 2020

Effectiveness of Masks in Blocking SARS-CoV-2: Depends on Whether You See the Glass Half Full or Empty

It is difficult to draw a solid conclusion from a study of 4 participants, which clearly lacked statistical power to detect difference between control and intervention groups. This is a pilot study at best, but our interpretation depends on whether we see the glass half full or empty. Optimistic researchers would notice a trend of decrease in SARS-CoV-2 viral load when each participant had face mask on. Although the study found contamination on the outer surface of face masks, there was no evidence that the viral particles bypassed the mask and entered the wearers' mucosa. Three of the 4 participants had undetectable viral load in inner surface of masks. These findings suggested potential role of masks as barriers against entrance of viral particles. Optimistic researchers would be satisfied with these preliminary findings, and thereby conduct a larger study with sufficient statistical power. On the contrary, pessimistic researchers would see this study as a failure and conclude masks are ineffective in preventing the dissemination of SARS–CoV-2. As Sir Winston Churchill stated, "A pessimist sees the difficulty in every opportunity; an optimist sees the opportunity in every difficulty."

Disclosures: I have been paid for working in primary and secondary care settings, but not for writing this letter. Opinions expressed are solely my own and do not express the views of my employer.

Ludwig Serge Aho Glele, Sara romano-Bertrand, Jean-Francois Gehanno, Didier Lepelletier • Epidemiology, infection control, evaluation. Dijon, Montpellier, Rouen, Nantes. France and public health • 27 April 2020

General response to Bae et al.

We read with interest the article by Seongman Bae et al. (1) estimating the blocking power of surgical mask and cotton mask against SARS-CoV-2.
Patients with known viral loads had to cough five times in a petri dish following the sequence: no mask, surgical mask, cotton mask then no mask again. Different petri dishes were used for each of the five cough episodes and we assume that each patient coughed 5 times on each petri dish for each step of the sequence, as there were only four steps by sequence.
Authors implicitly consider that the intensity of coughing does not vary between subjects and during the course of the experiment, which is not in line with the high variability within subjects (2).
Outcomes criteria were the contamination of petri dishes, and of external and internal surfaces of masks. No air samples were collected close to patients along with the experiment but it would be informative on SARS-CoV-2 shedding through ineffective masks.
Outer surfaces of masks were more contaminated than inner surfaces, but this was in fact assessed only for one patient (patient 3), since inner surface contamination was not detected for the three other patients. This precludes any statistical test and therefore any reliable conclusion.
Authors based the statement that neither surgical nor cotton masks effectively filtered SARS–CoV-2 during coughs on only two patients (1 and 3) without any statistical test. The median viral loads (log copies/mL) in nasopharynx and saliva from the four participants were respectively of 5.66 and 4.00, but varied from 3.51 to 7.68. Furthermore viral loads, when detected, were often very close to the RT-PCR detection limit. This can induce bias but is not discussed by authors. We therefore consider that their statement cannot be considered reliable. A study on 17 patients demonstrated the efficacy of surgical masks in reducing coronavirus detection and viral loads in both large respiratory droplets and aerosols (3). Non-parametric tests can be performed even with very small samples (4). Potential confounding factors, particularly viral loads, were collected but were not statistically analysed. Larger sample size would have allowed the development of an experimental design that could consider: initial viral load level and correlation of the data (difference in viral load between outer and inner surfaces, initial level in the oropharynx and mask contamination, contamination of petri dishes and surfaces...). Such a more complex experimental design (5) would allow more reliable conclusions.

References
1. Bae S, Kim M-C, Kim JY, Cha H-H, Lim JS, Jung J, et al. Effectiveness of Surgical and Cotton Masks in Blocking SARS-CoV-2: A Controlled Comparison in 4 Patients. Ann Intern Med. 2020 Apr 6;
2. Duguid JP. The size and the duration of air-carriage of respiratory droplets and droplet-nuclei. J Hyg (Lond). 1946 Sep;44(6):471–9.
3. Leung NHL, Chu DKW, Shiu EYC, Chan K-H, McDevitt JJ, Hau BJP, et al. Respiratory virus shedding in exhaled breath and efficacy of face masks. Nat Med [Internet]. 2020 Apr 3 [cited 2020 Apr 6]; Available from: http://www.nature.com/articles/s41591-020-0843-2

4. Dwivedi AK, Mallawaarachchi I, Alvarado LA. Analysis of small sample size studies using nonparametric bootstrap test with pooled resampling method. Statistics in Medicine. 2017;36(14):2187–205.
5. Baker TB, Smith SS, Bolt DM, Loh W-Y, Mermelstein R, Fiore MC, et al. Implementing Clinical Research Using Factorial Designs: A Primer. Behav Ther. 2017;48(4):567–80.

Ken Lim • CyberMedia Convergence consulting • 20 April 2020

Principal Investigator

Extremely flawed experiment got published with n=4!!! OFC the virus went thru! the masks aren't waterproof. OFC it went thru, force of cough pushed it thru. The test should be how many viral droplets appeared on another person or surface 2-3m away! The test should be hi-speed video showing # of particles expelled w & w/o mask! Unbelievably poor experiment!

Kristopher Purens, PhD, Abigail Purens, DVM/MPH candidate • Descartes Labs, Inc., University of Minnesota College of Veterinary Medicine • 17 April 2020

Statistical analysis shows decreased airborne SARS-CoV-2 transmission with the use of masks in line with previous studies

To test the efficacy of masks to reduce respiratory transmission of SARS-CoV-2, Bae et al.(1) replicated methods previously published by Johnson et al. (2009)(2) in an important early comparative study. A precautionary approach to new public health threats such as the COVID-19 pandemic is to use the best available models as analogues, make conservative recommendations, and update as new data become available. This necessitates careful null hypothesis selection and an information-gained approach to new data and ongoing analysis. A precautionary null hypothesis to COVID-19 is to test whether new evidence is strong enough to reject prior recommendations, such as widespread mask use. Johnson found that masks reduced respiratory transmission of influenza virus, a disease commonly used as a model for SARS-CoV-2.(3) In this context, Bae's null hypothesis that masks do not reduce viral load transmission was inappropriate. Combined with Bae's small sample size, this led to reporting of mask wearing causing no significant reduction in SARS-CoV-2 viral load transmission, in contrast to Johnson's findings for influenza.

Additionally, statistical analyses for non-normally distributed data and small sample size are appropriate in this context, to prevent being misled by violating the assumptions of common statistical methods. Two such appropriate analyses are probability based methods, and permutation tests. Analytical power can be increased by treating each pair of masked/non-masked attempts as a trial, and correcting for differences in base viral load for each individual.(4) We assumed no detection (ND) just below the lowest detected threshold reported, with differences calculated from that highest-reasonable viral load that would result in ND.

To this end we performed two tests: 1) non-parametric probabilistic approach testing whether Bae's results indicate masks caused no reduction in respiratory SARS-CoV-2 transmission and 2) permutation resampling testing of whether Bae's results were significantly different than Johnson's influenza virus transmission results.(4) Our analysis found that masks provide >0 reduction in viral load transmission (p=0.0078) and that Bae's results for SARS-CoV-2 were not significantly different from Johnson's results for influenza in reducing respiratory viral load transmission (p = 0.158). Our results support the continued use of influenza as a model for public health decisions regarding SARS-CoV-2. Importantly for public health, our analysis supports current recommendations for widespread mask wearing during the COVID-19 pandemic.(5)

The combined data set assembled, Bae et al. and Johnson et al., and analysis is available at https://github.com/purens/sars_cov2_masks to allow further study.

References

1. Bae S, Kim M-C, Kim JY, Cha H-H, Lim JS, Jung J, et al. Effectiveness of Surgical and Cotton Masks in Blocking SARS–CoV-2: A Controlled Comparison in 4 Patients. Annals of Internal Medicine [Internet]. 2020 Apr 6 [cited 2020 Apr 7]; Available from: https://doi.org/10.7326/M20-1342

2. Johnson DF, Druce JD, Birch C, Grayson ML. 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.

3. Cowling BJ, Ali ST, Ng TWY, Tsang TK, Li JCM, Fong MW, et al. Impact assessment of non-pharmaceutical interventions against COVID-19 and influenza in Hong Kong: an observational study. medRxiv. 2020 Mar 16;2020.03.12.20034660.

4. Sokal RR, Rohlf FJ. Biometry : the principles and practice of statistics in biological research. 4th ed. New York: WH Freeman and Company; 2013. 937 p.

5. CDC. Recommendation Regarding the Use of Cloth Face Coverings, Especially in Areas of Significant Community-Based Transmission [Internet]. Centers for Disease Control and Prevention. 2020 [cited 2020 Apr 5]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover.html

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Sung-Han Kim, MD. • Asan Medical Center • 15 April 2020

Author's response to the comments

Thank you for your thoughtful comments on the concept of the strong ability of airborne transmission of SARS-CoV-2 (Dr. Shu Yuan). So, they commented the possibility of the environmental air contamination before the patients wore the masks. I also agree with that environmental air contamination may result in outer surface contamination of masks and petri dish in front of the patients. Initially, we did not concern about air contamination by coughing without mask, like the previous study (Clin Infect Dis 2009; 49:275-7). So, we performed testing sequence as coughing without mask first. But, it is possible that initial coughing without masks might contaminate the surrounding air, given that NEJM paper demonstrated air stability of SARS-CoV-2. However, negative pressure room where the patients stayed had more than 12 air change per hour, so theoretically 99% of particles is cleared within 23 min. In addition, we used small petri dish, so it is unlikely that aerosol landed on this area of small petri dish during the testing with subsequent mask changes. Actually, we performed air sampling before this experiment to investigate the aerosol transmission in the patients' room. We had collected about 1,000 L air for 20 min by air sampler (Sartorius) like our previous study in MERS infected patients' room (Clin Infect Dis 2016; 63:363-9). We can found a few positive PCR results from air sampling, although we collected air sampling without active coughing (unpublished data). Instead, we assume that fine aerosols leaked from the masks may contaminated the outer surface of the masks. In addition, we hypothesized the spit without virus particle might be deposited in the inner surface of the mask like Dr. Hoehn's comment. However, further well-controlled study with air sampling and more cautious coughing sequence in different rooms may provide us valuable information for these hypotheses.

Dr. Lasica and Dr. Ing commented the statistical points. But, we think that the numerical data presented in this small study do not have any statistical meaning. So, the interpretation based on the median or mean values with the calculation of p value may be not useful. A more adequate powered studies are urgently needed.

Dr. Harada commented that the value for the mask surface is difficult to express at per mL. We used dacron swabs premoistened with viral transport media (3 mL) to swab the outer and inner surfaces of the mask aseptically. So, we expressed the values as per mL.

Dr. Rzymski's comment provide valuable information to us for the designing of further experiments. He suggested that prolonged speaking may be associated with the release of the higher number of droplets than coughing. So, we are now planning to evaluate the efficacies of various types of masks during talking.

We totally agree with Dr. Camioli's comments indicating that there are no evidence about that surgical masks are ineffective for healthcare workers. In addition, we agree with his opinion that masks may reduce the forward momentum of the virus-spit particles. Our small study did not show surgical or cottom masks have no role to spread SARS-CoV-2 to the environment. We assume that surgical mask may be not equivalent to N95-equivalent high efficient masks for outward spreading especially in coughing COVID-19 patients, while we just completed additional experiment using N95-equivalent masks. We did not show that any kind of masks such as cotton or surgical masks have no role to quantitatively reduce the spread of coughing SARS-CoV-2 to the environment. Based on empirical evidence, masks might shorten the distance of aerosol containing virus (Dr. Camioli's comments), redirect the turbulent jets in less harmful directions (outward proection), and reduce the amount of virus particles from the patients, although the targeted studies using SARS-CoV-2 are lacking. Furthermore, the inhaled air might have different aerodynamics in terms of low velocity particles with adherence of masks to face by depressurizing. So, the ineffectiveness of outward protection of surgical or cotton masks in coughing COVID-19 patients do not mean ineffectiveness inward protection of these masks. As Dr. Camioli's comment and the CDC guidelines, wearing any kind of masks in public settings with hand hygiene is highly recommended.

Cristina Corsini Campioli MD, Stacey Rizza MD, Abinash Virk MD, John C. O'Horo, MD, MPH • Mayo Clinic Rochester, Minnesota • 14 April 2020

Masking in COVID-19: Teach the Controversy

TO THE EDITOR:

The paper by Seongman Bae (1) and colleagues' study regarding the effectiveness of surgical and cotton masks in blocking SARS-CoV-2 presented several unexpected findings. Seongman Bae et al evaluated the amount of virus coughed through a surgical or cotton mask at a distance close to 8 inches in four patients. Virus was recovered at this distance, but more surprisingly, virus was identified on the outer surface of the masks, but not on the inner surface after coughing. The authors conclude that surgical and cotton masks are ineffective at preventing the dissemination of SARS-CoV-2. This is likely to aggravate ongoing controversy regarding personal protective equipment (PPE).

Public health authorities define a significant exposure to SARS-CoV-2 as face-to-face (unmasked) contact within 6 feet with a patient with symptomatic infection. The situation where both a healthcare worker and a patient is masked, as currently recommended by the Centers for Disease Control and Prevention's Universal Masking guideline, was not evaluated in this study. Masks may reduce the forward momentum of the virus-spit particles so that they are not launched as far forward as an unconstrained cough. Testing at a distance of only 8 inches in four patients provides inadequate evidence to stop using these masks for this purpose. The finding of lower viral load on the petri dish compared to the surgical mask goes against the known poor filterability of 2-ply cotton masks. A previous study showed that 2-ply cotton masks are ineffective in preventing respiratory viral infections (RVI) (2), while other studies have demonstrated efficacy of the medical masks in decreasing RVI (3, 4).

This also should not be construed as evidence that surgical masks are ineffective for healthcare workers. Testing how much virus escaped from five coughs is not representative of the effectiveness of these masks at filtering virus during normal respiration. Indeed, a case report in the Annals last month indicated that wearing a surgical mask was adequate PPE for exposure of 41 healthcare workers to a series of aerosol generating procedures in a COVID-19 positive patient (5).

The contribution of this paper is recognizing the significant contamination of the outer surface after coughing. Masking alone without the combination of meticulous hand hygiene, proper doffing and physical distancing, may risk spread of SARS-CoV-2. This article should not be interpreted as advice to the public to forgo masks or evidence against droplet precautions effectiveness for healthcare workers.

1. Bae S, Kim MC, Kim JY, Cha HH, Lim JS, Jung J, et al. Effectiveness of Surgical and Cotton Masks in Blocking SARS-CoV-2: A Controlled Comparison in 4 Patients. Ann Intern Med. 2020.

2. MacIntyre CR, Seale H, Dung TC, Hien NT, Nga PT, Chughtai AA, et al. A cluster randomised trial of cloth masks compared with medical masks in healthcare workers. BMJ Open. 2015;5(4):e006577.

3. Sung AD, Sung JAM, Thomas S, Hyslop T, Gasparetto C, Long G, et al. Universal Mask Usage for Reduction of Respiratory Viral Infections After Stem Cell Transplant: A Prospective Trial. Clin Infect Dis. 2016;63(8):999-1006.

4. Yeo KT, Yung CF, Chiew LC, Yunus HM, Thoon KC, Gomez M, et al. Universal Mask Policy in the Neonatal

Unit to Reduce Respiratory Viral Infections. Clin Infect Dis. 2017;64(6):817.
5. Ng K, Poon BH, Kiat Puar TH, Shan Quah JL, Loh WJ, Wong YJ, et al. COVID-19 and the Risk to Health Care Workers: A Case Report. Ann Intern Med. 2020.

Lukasz Szarpak, Krzysztof J. Filipiak, Milosz Jaguszewski, Jerzy R. Ladny, Jacek Smereka • Lazarski University, Medical University of: Warsaw, Gdansk, Bialystok and Wroclaw • 11 April 2020

Does the use of surgical or cotton masks reduce the risk of SARS-CoV-2 infection?

We have read with great interest the article Bae et al. regarding the effectiveness of the use of surgical and cotton masks in blocking SARS-CoV-2.
This is an important contribution to the discussion on the prevention of SARS-CoV-2 pandemic infections, especially at a time when there is a widespread lack of basic personal protective equipment for medical personnel and other persons exposed to potentially infected or confirmed COVID-19 individuals The rationale for using surgical and cotton masks by potentially healthy persons to reduce transmission of the infection from asymptomatic persons is currently being discussed. Many studies have shown that the effectiveness of medical masks and N95 respirators in reducing the risk of respiratory infections was comparable.
However, in the context of the studies carried out by Bae et al. it should be taken into account that a petri dish containing viral transport media was placed approximately 20 cm from the patients' mouths. Such a short distance was indeed necessary for methodological reasons, however, the results do not indicate the possibility of spreading the aerosol over longer distances and it is still possible that both surgical and cotton masks limit the range of the aerosol with SARS-CoV-2 virus.
The authors in the conclusion stated that surgical and cotton masks seem to be ineffective in preventing the dissemination of SARS-CoV-2 from the coughs of patients with COVID-19 to the environment and external mask surface, but this statement should be complemented by a clear declaration that the samples were taken at a distance of only 20 cm and that these test results do not refer to the possibility of reducing infections.

Lukasz Szarpak, Krzysztof J. Filipiak, Milosz Jaguszewski, Jerzy R. Ladny, Jacek Smereka • Lazarski University, Medical University if Warsaw, Medical University of Gdansk, Medical University of Bialystok, Wroclaw Medical University • 11 April 2020

The use of personal protective equipment in the COVID-19 pandemic era

The current pandemic is reducing medical resources and requires PPE adaptation to the circumstances and to the scale of the threat to medical personnel. One should remember that it is the most important to follow the general recommendations on hand disinfection and the sequence of procedures when putting on and taking off PPE. It is essential to use masks with a filter, but also goggles and visors to protect the face, as well as double or triple gloves (Figure). Sterile surgical gloves are particularly useful as they are longer.
The optimal solution is to fully protect the entire body surface, isolate it from the environment, and breathe in air from a portable source, but this is not necessary in the case of SARS-CoV-2. At present, it is

recommended to apply various types of equipment, including, in particular, partial protection of the environment through the use of surgical masks or ordinary face masks by persons with confirmed or potential SARS-CoV-2 infection; this may reduce the risk of infecting people in the environment, including medical personnel.

At present, performing a number of procedures in emergency medicine is associated with additional problems and risks for medical personnel. Emergency physicians, anesthesiologists and intensive care specialists, as well as the relevant scientific societies issue recommendations concerning endotracheal intubation or other procedures dangerous for the medical personnel. It should be remembered that endotracheal intubation by using direct laryngoscopy without adequate protection presents a high risk of SARS-CoV-2 infection. The proposed modifications of endotracheal intubation include special preparation of the equipment and medical personnel, using a special protective box, foils applied to the upper half of the patient's body, and the use of indirect laryngoscopy methods, including video laryngoscopy and rapid sequence intubation. In this context, it should be emphasized that attempts of prehospital endotracheal intubation by inexperienced personnel constitute a challenge, and supraglottic methods should be kept in mind. If intravenous access cannot be established or is technically difficult, it is still possible to establish intraosseous access. Performing several procedures in protective clothing is technically difficult and exhausting, which is especially true for CPR. Certain intra-hospital procedures must be modified, for example, cardiopulmonary resuscitation in a patient with ARDS in a prone position and electrical defibrillation.

The COVID-19 pandemic poses a huge challenge for emergency teams, as well as physicians in emergency departments. The need for additional protection of the patient and medical personnel may result in a significant delay in the arrival of the emergency team, patient transport, and provision of intended medical care. During any pandemic, people still suffer from various diseases and injuries that require treatment. The need to regroup medical forces and resources should not increase morbidity or mortality from diseases other than COVID-19.

Kouji H. Harada, Mariko Harada Sassa • Kyoto University • 11 April 2020

Concerns on the method and data presentation

We express concerns over the values presented in this report. The concerns come from the improper description of the method and findings. Viral loads are described as log copies/mL, but it is not clear to evaluate the results. Particularly, the value for the mask surface is difficult to be expressed at per mL. In addition, detectable level of viral loads in each media is not provided in the report. When comparing different media, it is inappropriate to simply describe the levels because the amount of the sample and the detection limit are different among media. We are worried about the probable confusion caused by the report.

Disclosures: None.

Piotr Rzymski • Department of Environmental Medicine, Poznan University of Medical Sciences, Poland • 10 April 2020

Effectiveness during speech and normal breathing

It would of high interest and value to conduct a similar study in which the effectiveness of surgical and cotton masks in blocking SARS-CoV-2 is assessed during normal speech. Speaking (as demonstrated by counting to 100) can be associated with the release of the higher number of droplets than a single cough [1, 2], and the rate of emission is related to loudness [3] although the released particles are smaller. Therefore, the force exerted on the mask and associated aerosol penetration should both be lower than in the case of coughing. On the other hand, prolonged speaking in the mask could damp it and eventually lead to the release of droplets containing an infectious agent. Moreover, it would be valuable to investigate whether droplets released during normal breathing by a positive patient can lead to aerosol penetration of a mask and the spread of the virus. Some works have shown that normal breathing, without coughing or sneezing, by influenza-positive patients can lead to the generation of small droplets containing significant number of influenza RNA [4]
Testing the above experimentally would provide some indirect information on whether surgical and cotton masks can be effective in decreased the transmission of the virus before the symptoms are onset. Obviously, it would be best to perform such a study on positive subjects not presenting COVID-19 symptoms although it would be logistically challenging.

[1] Loudon, R. G. & Roberts, R. M. (1968) Droplet expulsion from the respiratory tract. American Review of Respiratory Disease 95, 435–442.
[2] Papineni, R. S. & Rosenthal, F. S. (1997) The size distribution of droplets in the exhaled breath of healthy human subjects. Journal of Aerosol Medicine and Pulmonary Drug Delivery 10, 105–116.
[3] Asadi, S. et al. (2019) Aerosol emission and superemission during human speech increase with voice loudness. Scientific Reports 9, 2348.
[4] Yan, J. et al. (2018) Infectious virus in exhaled breath of symptomatic seasonal influenza cases from a college community. Proceedings of the National Academy of Sciences of the United States of America 115, 1081–1086.

Francisco Bracho • Ventura County Med Ctr, Childrens Hosp Los Angeles Med Group • 9 April 2020

Inside of mask negative?

It looks like a translation error but the inside of the mask could not be negative and the outside positive.

Michal Lasica, PhD • Institute of Mathematics of the Polish Academy of Sciences • 9 April 2020

Apparent serious error in analysis and interpretation of the data

I write as a professional mathematician and a concerned member of the public. Admittedly, I have no professional background in life sciences. However, I see an important flaw in the paper, which seems serious, and may even negate the final conclusion, as it is stated. My concerns were essentially stated by Dr Michael J DeWeert, but I would like to reiterate with more detail.

According to included table, when coughing onto a Petri dish without a barrier, the 4 patients release detectable viral load. When coughing through a cotton mask, in 2 cases the viral load is not detectable (ND), and in the other 2 it is reduced more than 10 times. Yet, according to the average (the authors use the word "median", while they actually compute averages) viral loads presented by the authors as main results, the viral load is reduced only 5 times. This is apparently because in the computations, the averages are taken over whole rows of the table with the ND instances ignored. This is a serious methodological error. If the virus was not detected in 3 patients instead of 2, the average could have been even higher.

As Dr DeWeert stated, this seems to undermine the conclusion that "cotton masks seem to be ineffective in preventing the dissemination of SARS–CoV-2 from the coughs of patients with COVID-19 to the environment". In fact, if a larger-scale study of this kind yielded similar results, this could be a strong argument for the use of cotton masks by general public in advanced stages of the pandemic.
I am particularly concerned that the paper might discourage the use of masks by the public. In fact I learned about the study from an article on a Polish news website, which cited the conclusion of the authors together with the erroneous averages.

PREVIOUS ARTICLE

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