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Efficacy of cloth face mask in prevention of novel coronavirus infection transmission: A systematic review and meta-analysis

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Abstract:

INTRODUCTION: Novel coronavirus is believed to be tiny enough (0.08–0.14 μm) to penetrate through face mask, thus protection offered by cloth mask may be too low. However, the use of cloth face mask in community has been recommended by the United States Centre for Disease Control and Prevention and regulatory bodies of other countries. There is paucity of literature on efficacy of cloth face mask in preventing SARS-CoV-2 infection transmission; thus, this review aims to update the available most recent evidences on efficacy of cloth face masks in prevention of viral infection transmission.

METHODS: We searched MEDLINE, EMBASE, and Clinical Trials Register for identifying studies related to this review using free-text terms and MeSH terms. Both experimental and observational studies on efficacy of cloth masks which were published in English language have been included in this review except expert opinions, commentaries, editorials, and review articles. Twelve studies were eligible to be included in review for data extraction and qualitative synthesis was carried out from extracted data but quantitative analysis (meta-analysis) could not be performed because of serious heterogeneity between the studies.

RESULTS: Cloth face masks show minimum efficacy in source control than the medical grade mask. The efficacy of cloth face masks filtration varies and depends on the type of material used, number of layers, and degree of moisture in mask and fitting of mask on face.

CONCLUSION: Cloth face masks have limited efficacy in combating viral infection transmission. However, it may be used in closed, crowded indoor, and outdoor public spaces involving physical proximity to prevent spread of SARS-CoV-2 infection.

Keywords:

COVID-19, face masks, homemade mask, viral infection

Introduction

The use of face mask is quite common among people of Asian Countries such as South Korea, Japan, China, and Thailand; pollution or earlier outbreaks of respiratory illnesses such as SARS and H1N1 could be the reason for this practice of mask usage. The current outbreak of COVID-19 is devastating and China dictated that everyone must wear face mask but also

recommended use of cloth face mask for people at very low risk of contracting and spreading infection.^[1]

The United States Centre for Disease Control and Prevention also recommended cloth face covering especially in areas of significant community-based transmission and discouraged people to use surgical face mask^[2] to prevent their irrational usage that could potentially cause a serious shortage for frontline health-care workers (HCWs)

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who actually need it.^[3] On similar lines, countries such as the United Kingdom, New Zealand, and Singapore specifically urged people not to use surgical face mask to procure enough supplies in stock for HCWs.^[4]

Countries such as the Czech Republic, Slovakia, Austria, Morocco, Turkey, Poland, Jamaica, Germany went a step further in their attempt to curb virus spread, mandating the use of face masks, with citizens facing penalties if caught barefaced. India acted in accordance to situation and followed a modest approach and advised people to wear homemade cloth mask along with meticulous hand hygiene to prevent transmission of the novel corona virus (SARS-CoV-2).^[5]

SARS-CoV-2 primarily spreads through droplet and contact transmission;^[6,7] however, the risk of airborne transmission remains questionable and requires additional empirical data for confirmation.^[8,9] Droplet and contact methods are considered as predominant modes for transmission of SARS-CoV-2 but reports still present conflicting data about universal use of face mask to curb such transmission.

COVID-19 is a pandemic, which people are struggling to combat worldwide and countries are facing scarcity of resources especially medical grade masks (surgical masks, N95, and other necessary respirators). In such situation, it is important that policymakers look for other options to maintain or balance the chain of demand and supply to minimize infection transmission.^[10] Therefore, it is crucial at this point to know the efficacy of cloth face masks as an alternative for medical masks for the prevention of SARS-CoV-2 infection.

Amidst current knowledge gaps, evidence-based answer is urgently required for a critically important question, i.e., does the cloth face mask help curb SARS-CoV-2 transmission? To meet this important need of the hour, we present this comprehensive, rapid evidence-based review to answer the aforesaid question.

Methods

Search strategy

Using PRISMA guidelines, we searched MEDLINE, EMBASE, Cochrane Library, and Clinical Trials Register for identifying studies related to this Review. Free-text terms and Mesh terms such as “masks” OR “respiratory protective devices” AND “COVID-19,” “masks” OR “mask” AND “(cloth OR fabric OR homemade OR home-made)” “virus diseases,” “respiratory AND “virus diseases” AND “mask” “masks,” and “respiratory protective devices” or “masks” AND “respiratory tract infections” were used for the purpose. Two reviewers carried out the search, examined the eligibility of the

studies independently. We also reviewed cross-references cited in retrieved articles to identify additional relevant studies. The discrepancy among the two reviewers was resolved through discussion with the primary reviewer.

Study selection

We selected studies, which were fulfilling the following criteria:

- Studies examining cloth face mask filtration effectiveness
- Studies examining cloth face mask efficacy in clinical and community settings
- Studies published in English language
- All experimental and observational studies till the date of search.

We excluded the following studies or papers:

- Case reports, letters, editorials, opinions
- Review papers.

Data extraction

Data regarding selected variables were extracted from each included study as per objective of this review, including the filtration efficacy of cloth face masks and clinical outcomes. Finally, 12 articles [Figure 1] were found suitable for consideration in writing this comprehensive evidence-based rapid review.

Assessment of risk of bias

Risk of bias for the included randomized controlled trials was assessed using the risk of bias Tool version 2 by the Cochrane Collaboration. Two independent authors carried out risk of bias assessment. The summary of risk of bias is presented in Figure 2. Quality of the observational

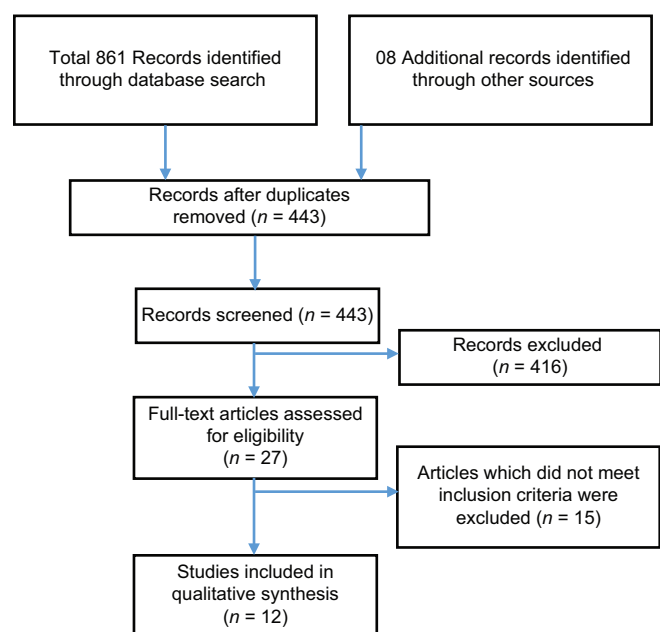


Figure 1: PRISMA flow diagram

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Bae 2020	+	-	-	-	+	+	+
MacIntyre 2015	+	-	-	+	+	+	+

Figure 2: Risk bias summary

studies was assessed on the basis of STROBE guidelines and mentioned in respective summary table.

Data synthesis and analysis

The data were categorized and tabulated based on review objectives. The meta-analysis could not be done because of clinical and methodological heterogeneity among included studies. Therefore, narrative summary approach was used for data synthesis.

Results

We performed literature search till May 10, 2020, as per PRISMA guideline [Figure 1]. A total of 861 studies were identified using different data bases (PubMed-323, EMBASE-378, Cochrane Library and Clinical Trial-127 and 25, respectively, while 8 studies were from other sources). We identified 12 studies,^[10-21] which fulfilled eligibility criteria of our review. Among them, nine studies were non-clinical trials, one study was nonrandomized controlled trial, and other two studies were randomized controlled trials [Tables 1 and 2].

There is no published randomized controlled trial to advocate mask usage as an effective strategy for control of SARS-CoV-2 transmission, although various studies have tried to indirectly assess the efficacy of masks against spread of various respiratory infections.

A review has also demonstrated the use of hand washing as an additional practice to mask users that may decrease the dissemination of respiratory viral infection.^[22]

An evidence-based review recommended that practice of wearing cloth mask is an effective strategy for SARS-CoV-2 infection control in conjunction with social distancing, hand hygiene, and contact tracing measures.^[23] The evidences from various studies and recommendations of different organizations suggested that cloth masks are not ideal, but in the present situation of COVID-19 pandemic, where some countries are facing shortage of N95 or surgical masks, the only option left is to use cloth masks and they may be effective in preventing infection transmission.^[11] The Institute of Medicine (IOM) acknowledged the probable reliance on cloth masks during an influenza pandemic and recommended the need for further research on the use of cloth masks.^[22] Tables 1 and 2 show the role of homemade masks in clinical efficacy,^[11,12] filtration efficacy in laboratory setup,^[10,11,13-15,17-21] effect of leakage on masks efficacy,^[14] and compliance.^[16]

The SARS-CoV-2 virus particle is very tiny (0.08–0.14 μm),^[11] therefore, tightly woven cotton fabric such as towel, scarves, cotton sheets, quilt or T-shirt fabric were also recommended for making cloth mask to improve its virus filtration efficacy, comfort, and enhanced moisture regain (7%–11%).^[2,18,19] Additional features to enhance the filtration efficiency of cloth masks may be a snug fit mask with minimal leak and use of three-layered mask with middle layer made of nonwoven breathable filter of anti-microbial finish, like coffee filter.^[2,18] Strict adherence to mask wearing, regular washing with detergent and disinfection in sunlight is essential for achieving enhanced efficacy of cloth face mask. A brief summary on efficacious use of cloth mask is presented in Table 3.

Discussion

Although there is lack of strong empirical evidence on efficacy of cloth face masks; however, available literature reports a lower level of efficacy of cloth facemask in reducing the risk of contracting viral infections.^[11,13,21] Furthermore, filtering efficiency of cloth face mask is seriously affected by risk of poor facial fitting of cloth masks,^[14] which is further lowered by repeated washing and drying cycle.^[15] Studies have reported that filtration efficacy of cloth masks is strongly affected by various factors such as type of cloth, layers of cloth in mask, combination of different types of cloths, leakage of air around mask, and degree of moisture in mask. Three or more layers of cotton cloth mask in combination with either silk, chiffon, or flannel which is well-fitted on face with minimal or no leak of air around mask and having no moisture provides the best possible protection against viral infection.^[14,24,26,27,29]

Table 1: Summary of interventional studies on efficacy of cloth face masks versus medical grade masks for prevention of viral infection transmission

First author, year, province	Study aim	Setting	Sample size and study duration	Study design	Intervention	Comparison	Outcome	Quality
MacIntyre 2015, Vietnam ^[11]	To compare the efficacy of cloth masks to medical masks in hospital HCWs	14 secondary-level/ tertiary-level hospitals, Hanoi, Vietnam	1607 hospital HCWs working full-time in selected high-risk wards	Cluster Randomized clinical trial	Medical Mask: Locally manufactured (three layer, made of nonwoven material) Cloth Masks: Two layer, made of cotton commonly used in Vietnamese hospitals	Standard practice, which may or may not include mask use	Invasion of particles with cloth masks was almost 97% and 44% with medical masks. Analysis revealed significant higher incidence of Influenza like illness (RR=6.64, 95% CI 1.45-28.65) and laboratory confirmed virus (RR=1.72, 95% CI 1.01-2.94) in the cloth masks group as compared to medical masks group	High
Bae, 2020, South Korea ^[12]	To evaluate the effectiveness of surgical and cotton masks in filtering SARS-CoV-2	02 hospitals in Seoul, South Korea	04 patients with COVID-19	Intervention based Observation Report	Surgical masks (180 mm×90 mm, 3 layers KM Dental Mask, KM Healthcare Corp)	Reusable 100% cotton masks (160 mm × 135 mm, 2 layers, individually Packaged in plastic)	Both surgical mask and cotton mask were ineffective in preventing the spread of SARS-CoV-2 with a reported median viral loads of 2.42 log copies/mL, and 1.85 log copies/mL after cough by infected patients with surgical mask, and cotton mask, respectively	Moderate
Davies United Kingdom ^[13]	To examine homemade masks as an alternative to surgical masks	London, United Kingdom	21 healthy volunteers prepared their face mask using several household materials for prevention of bacterial and viral aerosols	Nonrandomized Study	No mask: Volunteers wear no mask Homemade Mask: 100% cotton t-shirt fabric	Surgical mask (Mo"lnlycke Health Care Barrier face mask 4239, EN14683 class I)	Surgical masks were 3 times more effective in blocking droplet transmission than homemade because it has shown higher filtration efficiency with B atrophaeus	Low

HCWs=Healthcare workers, CI=Confidence interval, RR=Relative risks

Studies have stated that cloth face masks are ineffective to prevent influenza-like diseases when compared to the surgical masks (relative risk 13.25, 95% confidence interval [CI] 1.74–100.97). Moreover, filtration efficacy of cloth face mask was found as low as 3% on laboratory based filtration test of cloth masks, which could be because of poor quality of cloth used for making face mask.^[11]

Surprisingly, one of the studies reported no relationship between compliance rate of cloth face mask and rate of infection; which raises doubts on whether the use of mask has any role in prevention of risk for contracting the viral infection. However, these findings were contradictory to the findings of a systematic review and meta-analysis published in 2011.^[30] This review presented the results of seven case-control studies and reported that the odds ratio of group using cloth masks versus control group

was 0.32 (95% CI, 0.26–0.39) on rate of respiratory viral infection.

Filtering efficiency of cloth face masks is low as compared to surgical and 95 masks and it may be further affected by several other factors. First, small number of aerosols passing through the cloth mask may be enough in number to make a person infected. Another probability is that, the leakage around the cloth masks may significantly reduce its efficiency and studies also reported that leakage may decrease nearly 50% of masks efficacy.^[14,31] However, these problems may also be related to medical grade masks and affects their efficiency. Cloth masks are routinely washed and dried and used for a long time while surgical masks disposed after single use. However, one study^[15] reported that washing and drying repeatedly may deteriorate the quality and efficacy of the cloth masks, by nearly 20% after four times of this cycle.

Table 2: Summary of observational studies on efficacy of cloth face masks versus medical grade masks for prevention of viral infection transmission

First author, year, province	Study aim	Setting	Surveillance protocol	Methodology	Outcome	Quality
Ma, 2020, China ^[10]	To examine the effectiveness of three different types of masks (homemade, N95, and medical) for prevention of AIV	College of Veterinary Medicine, Qingdao Agricultural University, Qingdao, China	Standard Surveillance	No humans or animals were involved in study Real-time reverse transcription-polymerase chain reaction was used for virus quantification	Result explained no significant difference in removal of virus with hand wiping by towel soaked in 1% soap water, 0.05% chlorine water, and 0.025% chlorine water from sodium hypochlorite Approximately 99.36%, 97% and 95%, 97% and 99.3% of the virus were prevented by homemade masks, medical masks, and N95 masks, respectively	High
Konda, 2020 USA ^[14]	To assess the filtration efficacy of masks made of silk, cotton, flannel, chiffon, various synthetics, and their combinations	Argonne National Laboratory, United States	Standard Surveillance	Particle analyzers (OPS and Nanoscan) was used to analyze aerosols and the resultant particle concentrations were to identify filter efficiencies	Study suggests that filtration efficacy of the face masks improved to 80% (<300 nm particle) and 90% (>300 nm particles) when multiple layers were used in different combination of cotton with silk, chiffon, flannel	Moderate
Neupane, 2019, Nepal ^[15]	Examined filtering efficacy of cloth masks and surgical masks against aerosol particles	Kalanki, Kathmandu	Standard surveillance	1500 people were observed while wearing face mask and type of mask. Filtering efficiency was measured and also studied the effects of washing, drying, and stretching on quality of mask	Study reported that cloth masks' filtering capacity varied between 63% and 84% and surgical masks shown 94% filtering efficiency It was also demonstrated that filtering efficiency was deteriorated after 4 th washing and drying cycle	High
Chughtai, 2016, Vietnam ^[16]	To examine the different factors affecting Hospital HCWs compliance with the use of medical and cloth masks	Demographic, clinical, and diary card data from randomized controlled trial in Vietnam were used	Standard surveillance	A multivariable log binomial model was used with GEE to identify RR for potential confounders	Study concluded that discomfort and breathing problems while caring for patients with respiratory illness was positively associated (adjusted RR 1.14, 95% CI: 1.07-1.20) with compliance rates with mask among hospital HCWs	High
Shakya, 2016 USA ^[17]	To examine the efficacy of four different types of masks (3 types of cloth masks and 1 type of surgical mask)	University of Massachusetts Amherst, USA	Standard surveillance	Whole diesel exhaust and 5 monodispersed aerosol sphere were used to assess face mask performance	Study analyzed that the cloth masks were tested for lab-generated whole diesel exhaust and reported the filtration efficiency) ranged from 15% to 57% Standard N95 mask provided highest protection against lab generated particles while cloth masks shown marginal benefits in protecting people from <2.5 µm particles.	High
Jung, 2014, Taiwan ^[18]	To examine The filter capacity for different types of mask using KFDA and the NIOSH protocol and to compare the test results	China Medial University, Taiwan	Standard surveillance	Four types of masks were used which comprised of 44 mask with a TSI 8130 Automatic Filter Tester penetration and pressure drop	Study results reported no significant difference in penetration between the KFDA and NIOSH protocols ($P=0.1223$) Very little protection was offered by general masks, medical masks, and handkerchiefs against respiratory infections	High

Contd...

Table 2: Contd...

First author, year, province	Study aim	Setting	Surveillance protocol	Methodology	Outcome	Quality
Rengasamy, 2010, USA ^[19]	To examine filtration performance of N95 respirator with the fabric materials of five major types (cloth masks, T-shirts, towels, scarves and sweatshirts) against submicron-size aerosol particles	Pittsburgh, PA, USA	Standard surveillance	Fabric materials were compared with N95 respirator filter media for penetration level on varied face velocities (5.5 and 16.5 cm/s)	Aerosols penetration level was significantly higher for both cotton cloth and fabric materials than N95 respirator filter media Cloth masks and other fabric materials may provide minimal protection against virus-containing nanoparticles in exhaled air.	Moderate
Dato, 2006, USA ^[20]	To determine usability of handmade, reusable, cotton mask against viral exposure	Pittsburgh, Pennsylvania, USA	Standard surveillance	Prototype mask was prepared with 100% heavy weight cotton T-shirt (made in Honduras); 1 outer layer ($\approx 37 \times 72$ cm) and 8 inner layers (<18 cm ²). The Portacount Plus Respirator Fit Tester with N95-Companion was used to measure aerosol concentration	N95 respirator needs fit factor of 100 for effective prevention and the prototype mask got a fit factor of 67 and hence provides substantial protection from aerosols with minimum leakage	Moderate
Van der Sande, 2008, Netherlands ^[21]	To assess the efficacy of different types of mask (personal respirators, surgical masks and homemade masks) in preventing viral exposure	Netherlands	Standard Surveillance	Reduction potential of transmission by personal respirators, surgical masks and homemade masks worn by volunteers and simulated patients during variety of activities was assessed	All type of masks could reduce risk of infection and aerosol exposure. However, personal respirators were most effective followed by surgical masks while homemade masks were found to be least effective	Moderate

AIV=Avian influenza virus, GEE=Generalized estimating equation, RR=Relative risks, HCWs=Health-care workers, CI=Confidence interval, OPS=Optical particle sizer, KFDA=Korean food and drug administration, NIOSH=National institute for occupational safety and health

The cotton cloth face masks which are made up of multiple alternative layers of cotton and any of these-silk, chiffon, or flannel fabric that are well fitted on face to ensure minimal or no leak may provide filtration efficacy as high as >90%. The two-layered cotton fabric face mask with 240 threads per centimeter reported a filtering efficiency of $99.5 \pm 0.1\%$; which is close to that of N95 masks ($99.9\% \pm 0.1\%$) for >300 nm size particle.^[14]

There is lack of strong well-designed evidences on efficacy of cloth face mask in the prevention of viral infections and moreover, the findings are conflicting on some aspects such as quality of cloth, design of mask, fitness on face, compliance, and other factors. The compliance of wearing a face mask is as low as <50%^[11] and it may be due to feeling of suffocation and hindrance in communication.

Cloth face mask is less efficacious as compared to surgical mask and N95 masks; they must be preserved for the frontline health-care providers and high risk people. Therefore, cloth face mask maybe used by people in

high-risk situations like closed, crowded public spaces where there is high risk of close physical proximity with other people. However, wearing face mask may give a false sense of security to the wearer, which may contribute to low hand hygiene compliance, poor respiratory etiquettes, breaching norms of social distancing, and risk of repeated touching of nose and face to adjust the face mask.^[32] Therefore, people must be educated that cloth face mask should be used as complimentary measure of infection prevention along with meticulous hand washing, social distancing, respiratory etiquettes and avoid touching nose, face, or mask without hand washing.

Study limitations and novelty

This review paper discussed the efficacy of cloth face masks in prevention of infection caused by viruses in hospital and community settings. With authors' best knowledge, this review included highest numbers of studies to make a conclusion on the same subject.

We did not find any study, which compares the efficacy of cloth masks in the prevention of SARS-CoV-2 infection.

Table 3: Summary on efficacious use of cloth mask in community setting

Factors	Facts
Filtration efficiency of small sized aerosols (0.08 and 0.22 µm)	Small particle filtration efficiency of cloth mask made of different fabric varies from 2% to 38% ^[19]
Comparison of filtration efficiency of cloth mask with gold standard (N95 respirator) and surgical mask (small sized aerosols [0.08 and 0.22 µm])	N95 respirator >95%; Surgical masks - 55%; Multi-layered cloth mask - 38%; Handkerchiefs - 2% (single layer) to 13% (four layers) ^[18]
Efficacy of cloth mask in combating viral infection transmission	Less efficacious - half as efficacious as the N95 mask, 25% lesser than surgical mask (N95 > surgical mask > cloth face mask) ^[24] Minimally protective in casual community contacts ^[25] Moderate protection in household contacts if both patient and other family member wear mask ^[25]
Factors enhancing efficacy of cloth mask ^[2,11,18,19]	Type of cloth: Filtration efficacy of towel - 40%, sweat shirt - 20%-40%, cotton cloth/scarf - 10%-20% and T-shirts - 10% ^[19] Multilayers in mask: Three layer with middle layer of breathable filter of anti-microbial finish like coffee filter ^[2,18] Fit test of mask on face with least possible leak Moisture-free mask Hand hygiene compliance before donning/doffing or touching mask Avoid repeated touching of mask Proper wearing and removal technique (not touching front of mask) Compliance with continuous mask wearing Regular washing in detergent, drying in sunlight, ironing and using a fresh mask daily or when moist or visibly soiled Avoid bleach or harsh chemical wash, which may damage cloth fabric and affect filtration efficacy of mask
Summary recommendations	SARS-CoV-2 is actively spread by asymptomatic and presymptomatic individuals. Although cloth masks are less efficacious, still it is advisable to use them as a complimentary measure of infection control in crowded indoor or outdoor spaces, along with meticulous hand hygiene, respiratory etiquettes, social distancing (>2 m), and avoidance of repetitively touching one's face, nose, eyes, and mouth ^[25] Surgical mask is advised for suspects of SARS-CoV-2 infection and their informal care givers ^[24,26,27] N95 respirator and surgical mask are more efficacious but must be spared for use by frontline health-care workers ^[2,28]

Furthermore, only two randomized controlled trials were included that examined the efficacy of different masks. However, one of them was under powered and conducted among four participants. Because of the rapidity of this article, we were not able to search other databases or article archives such as CINAHL, Google Scholar, and ClinicalTrial.gov.

Conclusion

Cloth face masks are less efficacious as compared to medical grade masks; however, something is better than nothing; therefore, it may be transiently used in closed, crowded indoor, and outdoor public spaces during highly contagious viral pandemics like COVID-19. However, the importance of meticulous hand hygiene, respiratory etiquettes, social distancing (>2 meters), and avoidance of repetitively touching one's face, nose, eyes, and mouth as basic measures to prevent SARS-CoV-2 transmission cannot be overemphasized. Nonetheless, the cloth masks are not found efficacious for infection prevention in hospital setting; therefore, its use for health-care workers should not be recommended.

The efficacy of cloth mask can be improved by multilayer cloth mask made of cotton in combination with synthetic cloth material, which has proper fitting on face, and must be regularly changed. Furthermore, a well-designed randomized controlled trial must be conducted to assess the efficacy of cloth face mask.

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Conflicts of interest

There are no conflicts of interest.

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