Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

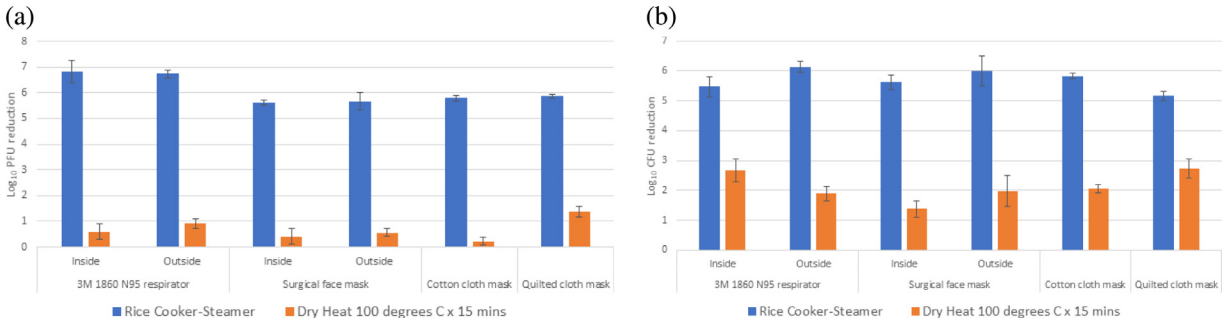

Fig 1. Efficacy of treatment in a rice cooker-steamer including 8-10 minutes of heating and 5 minutes of steam vs dry heat at 100°C for 15 minutes in an oven for decontamination of methicillin-resistant *Staphylococcus aureus* (MRSA) and bacteriophage MS2 on 3M 1860 N95 respirators, surgical face masks, and cotton and quilting fabric cloth face masks. 10-μL aliquots containing 10^6 colony-forming units (CFU) or plaque-forming units (PFU) of the test organisms in the simulated mucus suspension were spread to cover an area of 1-cm^2 on inner and outer surfaces of the N95 respirators and surgical face masks and on 1 surface of the cloth masks. Error bars indicate standard error.

inoculated sections of the face masks and N95 respirators were vortexed for 1 minute in 1 mL of phosphate-buffered saline with 0.02% Tween and serial dilutions were plated on selective media to quantify viable organisms.[3] All tests were performed in triplicate. Log_{10} reductions were calculated in comparison to untreated controls. A reduction of 3-log10 or greater in recovery of organisms inoculated onto masks or respirators was considered effective for decontamination.[3]

As shown in Figure 1, the steam treatment resulted in a greater than 5 log_{10} reduction in bacteriophage MS2 and methicillin-resistant *S aureus* applied to the outer and inner surfaces of the face masks and respirators, whereas dry heat at 100°C for 15 minutes did not result in a greater than 3 log_{10} reduction of either organism at any of the inoculated sites on any masks or respirators. No visible changes were observed in any of the masks or respirators after 5 cycles of decontamination.

Our results demonstrate that a short cycle of steam treatment applied via a commonly used kitchen rice cooker-steamer can be very effective for decontamination of face masks and N95 respirators. Dry heat at the same temperature levels was much less effective, consistent with previous evidence that moist heat or microwave-generated steam is more effective than dry heat for inactivation of viruses.[4,5] Notably, the short cycle of steam treatment was substantially more effective than ultraviolet light treatment for N95 decontamination and nearly as effective as aerosolized peracetic acid and hydrogen peroxide.[3]

The major limitation of our study is that we did not examine the effect of treatment on respirator or face mask performance. However, there is some evidence that short cycles of steam treatment may have minimal effect on filtration and fit performance.[2] Further testing is needed to evaluate the impact of steam treatment on performance of N95 respirators and surgical face masks.

In summary, our results demonstrate that steam treatment using a rice cooker-steamer is effective for decontamination of face masks and N95 respirators. Given the recommendation that cloth face masks be worn in public settings, steam treatment using these readily available kitchen items could provide safe and effective decontamination of cloth masks. Further studies are needed to evaluate steam treatment for N95 respirators and surgical face masks. Investigations of moist heat are also needed as 20 minutes of exposure to moist heat at 65°C has been reported to be effective with minimal adverse effects on respirator performance.[3,4]

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Steam treatment for rapid decontamination of N95 respirators and medical face masks

To the Editor:

Decontamination and reuse of personal protective equipment such as N95 respirators is not recommended but may be considered

in crisis situations such as shortages encountered during the coronavirus disease 2019 (COVID-19) pandemic.[1] A variety of decontamination technologies are under investigation and some vaporous hydrogen peroxide technologies have received emergency use authorization for respirator decontamination from the Food and Drug Administration.[1,2] For many technologies, relatively long-treatment cycles are required and respirators must be transferred to a central in-house or off-site processing area. Thus, it is often not feasible to decontaminate respirators after each use. Rather, potentially contaminated N95 respirators may be reused multiple times with once daily or even less frequent decontamination.

To minimize the risks associated with reuse of respirators, it would be beneficial to provide rapid decontamination at the point-of-care between each reuse. Short cycles of ultraviolet-C light could be used, but efficacy may be limited against organisms associated with irregular, soft surfaces such as respirators.[3] Steam treatment also has the potential to rapidly reduce non–spore-forming organisms.[1,4] We previously reported that a 13-15-minute steam treatment was effective for decontamination of face masks and N95 respirators.[4] Here, we investigated the efficacy of shorter steam treatments that could potentially allow decontamination between each use.

We studied 3M 1860 N95 respirators (3M; Saint Paul, MN) and medical procedure face masks (Precept; Arden, NC). The test organisms included methicillin-resistant *Staphylococcus aureus* (MRSA), *Geobacillus stearothermophilus* spores, and the nonenveloped, single-stranded RNA virus bacteriophage MS2.[3,4] Ten-μL aliquots containing $\sim 10^6$ colony-forming units (CFU) or plaque-forming units of the test organisms suspended in 8% simulated mucus were inoculated onto 1-cm^2 areas on both the outer or inner surfaces of the respirators and face masks.[3,4] The inoculated masks and respirators were subjected to 100°C steam treatments of 2, 10, or 30 seconds by placing them inside a steamer (Aroma; San Diego, CA) for the specified time during the steam cycle. After treatment, the inoculated sections were cut out and processed to quantify viable organisms.[3,4] All tests were performed in triplicate. Log_{10} reductions were calculated in comparison to untreated controls. A reduction of 3-log_{10} or greater was considered effective for decontamination.[3-5] To assess the impact on respirator performance, qualitative and quantitative (Portacount Respirator Fit Tester, TSI Incorporated, Shoreview, MN) fit testing was performed before and after N95 respirators were subjected to 20-30-second steam treatments.

To assess the real-world efficacy of rapid steam treatment, we collected used medical procedure masks from personnel. Two-cm^2 sections of mask material were cut out before and after a 30-second steam treatment, processed as described previously, and plated on nonselective blood agar plates to quantify total bacterial counts. For plates with CFU too numerous to count, the CFU count was designated as 1,000 CFU.

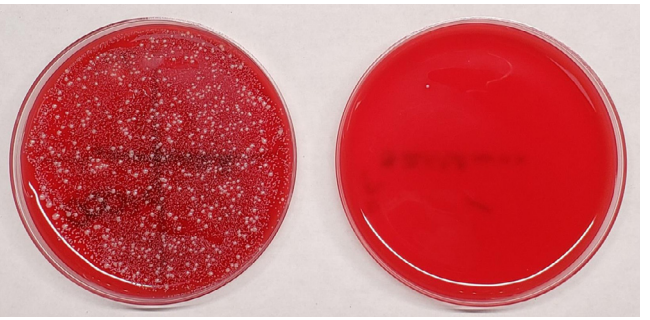

Fig 2. Pictures of blood agar culture plates showing organisms recovered before and after a 30-second 100°C steam treatment for the one mask of 30 tested that had a positive culture after treatment. Pretreatment the total colony-forming units (CFU) of bacteria were too numerous to count and *Staphylococcus aureus* was recovered. Post-treatment one colony of coagulase-negative staphylococci was recovered.

As shown in Figure 1, the 10- and 30-second steam treatments met criteria for decontamination of bacteriophage MS2 and MRSA on N95 respirators, whereas the 2-second treatment did not. The steam treatments did not substantially reduce *G. stearothermophilus* spores. Similar results were obtained with inoculated medical procedure masks (data not shown). N95 respirators passed fit testing after 20-30-second steam treatments. After steam treatment, the respirators were slightly damp to touch, but this resolved within 5 minutes at room temperature or within 2 minutes when placed in a dry oven at 70°C.

All 30 used medical procedure masks cultured were contaminated with bacteria with an average of 2.4 log_{10} CFU recovered, predominantly *Streptococcus* species and coagulase-negative staphylococci. *Staphylococcus aureus* was recovered from 3 (10%) masks. The 30-second steam treatment eliminated all bacteria from 29 of 30 (97%) masks. Figure 2 shows pictures before and after treatment for the one mask that had a positive culture after treatment with one colony of coagulase-negative staphylococci recovered.

In summary, steam treatment resulted in rapid decontamination of bacteriophage MS2 and MRSA on N95 respirators and medical procedure masks. The reductions in bacteriophage MS2 met the current Food and Drug Administration Enforcement Policy for Face Masks and Respirators of a >3 log_{10} reduction of viruses, but the requirement for a >6 log_{10} inactivation of bacterial spores was not met.[5] Nevertheless, steam treatment deserves further investigation because the short-treatment cycles and ease of use could allow for rapid decontamination of respirators or face masks at the point-of-

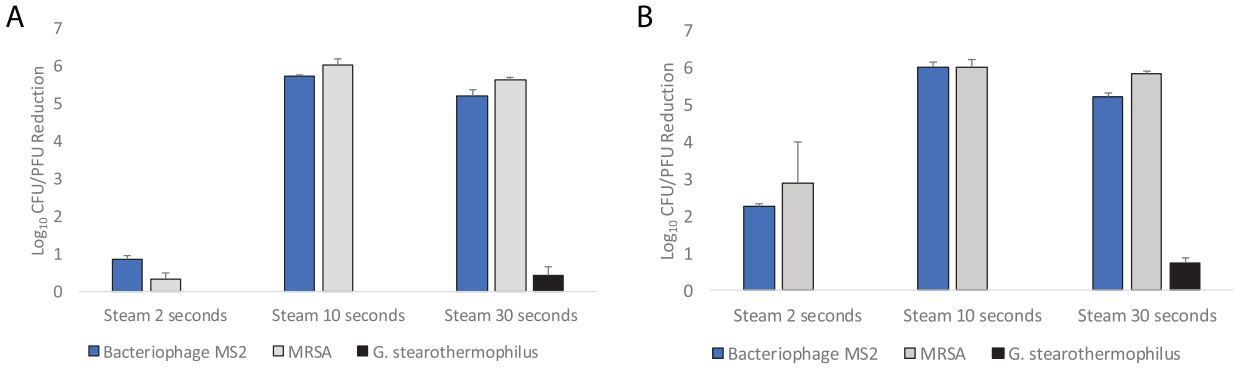

Fig 1. Efficacy of 100°C steam treatment for decontamination of methicillin-resistant *Staphylococcus aureus* (MRSA), bacteriophage MS2, and *Geobacillus stearothermophilus* spores inoculated on the outside surface (A) and inside surface (B) of 3M 1860 N95 respirators. Error bars indicate standard error.

care between each use. Twenty cycles of steam treatment did not adversely affect fit testing performance, consistent with previous reports that short cycles of steam treatment may have minimal effect on N95 filtration and fit performance.[1,4] Further work is needed to assess the impact of short cycles of steam treatment on filtration efficiency and to develop technologies that could provide steam treatments for respirators and face masks in health care settings.

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Application of fluorescence method in the process of personal protective equipment removal

To the editor,

More than 1.2 million cases of Coronavirus disease 2019[1] had been confirmed worldwide as of April 6, 2020. With the increase in overseas returnees and visitors to China, Hangzhou sets up a working group, including health care workers and staffs from public security, transportation, foreign affairs, and other nonmedical system, responsible for quarantine work. Proper wear and removal of personal protective equipment (PPE) becomes a critical measure to ensure the safety of frontline personnel. This study intends to carry out the practice of pollutant simulation, so as to grasp the key point of PPE removal and guarantees the safety of frontline staffs.

We trained 140 staffs from the working group for the theory of PPE in batches, followed by one-to-one field practice of wear and removal of PPE. Forty-six frontline staffs from nonmedical systems were selected to carry out the pollutant simulation test. According to the characteristics of the phosphors which can be identified by naked eyes under ultraviolet irradiation, we dissolved the phosphors in gel like ethanol as pollutant. We applied the phosphors on the outer surface of the gloves, forearms of the whole-body protective gowns, the outer surface of the gown hat, and the bare outer surface of kn95 respirator. After removing the PPE, we irradiated the clothes and the exposed skin through the ultraviolet lamp to show the risk points during the removal process.

In the pollutant simulation test, 21 staffs polluted the upper chest, accounting for 45.7% of the total, followed by 20 and 15 staffs polluted the hands and the front chest, accounting for 43.5% and 32.6% of the total, respectively. The number of people with face and back pollution was less than 10%. See Table 1 for details.

Table 1
Analysis of contaminated sites in pollutant simulation test

Contaminated sites	Number of people contaminated	Proportion of pollution (%)
Upper chest	21	45.7
Bare hands	20	43.5
Anterior chest	15	32.6
Upper limbs	6	13.0
Inner surface of protective gowns	6	13.0
Lower limbs	5	10.9
The face	2	4.3
The back	1	2.2

The correct use of PPE is an effective way to ensure the safety of personnel, and improper wear and removal will bring potential harm to users.[2] In this study, 45.7% of the workers caused the upper chest pollution during the unloading process of PPE, and the main pollution source was from the lower edge of outer surface of kn95 respirator. When the user lowered his head in the removal process, the chest was contaminated. Therefore, in the wear process, it is necessary to protect the external surface of the kn95 respirator with the placket seal.

During the removal of PPE, 43.5% users contaminated their hands. In this study, 50% of the workers' hand hygiene actions were not standardized, and 39.1% of the workers forgot to do hand hygiene at least once when they took off PPE. Hand hygiene is considered the most economical, convenient, and efficient way to control hospital infection,[3,4] it is of great significance to enhance the awareness of hand hygiene.[5] To reduce the risk of infection, we should pay more attention to the removal of PPE without contamination as well as its supply.

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