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Emergency Forum

N95 RESPIRATOR CLEANING AND REUSE METHODS PROPOSED BY THE INVENTOR OF THE N95 MASK MATERIAL

Pascal S. C. Juang, MD and Peter Tsai, PHD

Department of Emergency Medicine, Hoag Memorial Hospital, Newport Beach, California
Corresponding Address: Pascal S.C. Juang, M.D., Emergency Medicine Attending Physician, 1 Hoag Dr, Newport Beach, CA 92658

Editorial Comment— This article is timely and we thank Dr. Juang for his diligence and desire to protect frontline health care providers. These appear to be simple methods for conserving N95 masks that are supported by some evidence as well as supported by the developer of the mask. We are publishing this in an expedited manner and readers should be aware that for obvious reasons this article has not gone through our regular peer-review process. Readers should also be aware that as of this writing, these methods are not officially approved by regulatory agencies. Nonetheless, even the Centers for Disease Control and Prevention notes that in times of crisis, alternative recommendations for the use of respirators like the ones in Dr. Juang's article may need to be considered when there are shortages of personal protective equipment that could put health care providers at risk. We will leave it to readers of the *Journal* to decide if the recommendations in this article are applicable to their situation.

Stephen Hayden, MD, Editor-in-Chief

INTRODUCTION

There is currently a global shortage of N95 respirators. Many health care workers (HCWs) on the front lines of the battle against COVID-19 are scrambling to resupply or are currently reusing N95, surgical, and homemade masks. I propose methods to clean and reuse N95 masks at little or no cost. N95 masks can be rotated every 3–4 days, heated for 60 min, steamed or boiled for 5 min, and then air-dried. These methods retain 92.4–98.5% filtering efficiency (FE). Using soap and water or medical grade alcohol significantly decreases the FE of the masks (54% and 67%, respectively) (1). These methods are recommended by the inventor of the N95 mask material, Dr. Peter Tsai, and are supported by research regarding surface stability time of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), World Health Organization technical briefs discussing boiling viral pathogens, and the National Institutes of Health research discussing SARS-CoV-2 inactivation times using dry heat on N95 masks. In addition, these methods meet the U.S. Food and Drug Administration (FDA) and Centers for Disease Control and Prevention (CDC) emergency use authorization (EUA) criteria for N95 mask cleaning and reuse. In clinics and hospitals around the world that are experiencing N95 respirator shortages, these methods can be implemented immediately, with minimal cost and equipment, to protect HCWs from COVID-19.

N95 masks are made in several layers. The middle filtering layers are made of polypropylene fibers with an embedded electrostatic charge. FE is achieved by both the mechanical structure of the polypropylene filter layer and the electrostatic charge. The electrostatic charge can augment the mechanical filtering efficiency by as much as 10 to 20 times.

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Figure 1. (A) Use of a hospital blanket warmer to heat N95 masks to 70°C (158°F) for 60 min. (B) There may be other, better methods to hang N95 masks, but note that masks may need to be > 6″ from the walls of the heater to prevent mask degradation, depending on the temperature of the surface of the walls.

N95 Masks Can be Rotated, 1 Mask Every 3–4 Days

Use 3–4 masks, numbered on the outside as 1–4, for each day. They can be used each day in numerical order. All SARS-CoV-2 viruses on the mask will be dead in 3 days (2). Masks should be kept at room temperature (21–23°C [70–73°F]) and 40% humidity. There is no change in the mask's properties.

N95 Masks Can be Heated at 70°C (158°F) for 60 Min

Masks will retain 98.5% FE after heating for 24 h, and masks may be heated multiple times without a loss of FE. Hang the mask in an oven using plastic or wooden clips. If the mask contacts or is < 6" from hot metal, there may be severe material compromise and charge loss. For damaged elastic bands, equivalent elastic may be restapled onto the mask. Alternatively, blanket warmers commonly found in hospitals may be used (Figure 1). Masks may be hung using a wooden dowel with end caps (Figure 2).

N95 Masks Can be Boiled for 5 Min

Masks will retain 92.4% FE after boiling. The elastic band should not be immersed in boiling water. Do not stir while boiling to avoid disturbing the physical structure of the mask. Charge loss is insignificant, and wet masks *do not* decrease FE of the filtering layer. Air-drying masks is recommended. At the time of this writing, FE decrease because of facial fit/contour loss as a result of heat drying or wearing the mask when wet is unknown.

Caution—Mask contour may change depending on the materials used in the outer layers. Suboptimal fit may result in unfiltered air entrance around the edges of the mask. If the inner surface of mask is made with paper or tissue, this method may result in loose fibers and a loss of strength. The short- and long-term effects of loose fiber inhalation are unknown.

N95 Masks Can be Steam Cleaned at 125°C (257°F) for 5 Min

Masks will retain 91.7–98.5% FE after steaming. Charge loss is insignificant. Charge decay is seen with longer steaming time.

Figure 2. Assembly of a wooden dowel with end caps used to hang N95 masks.

NOT RECOMMENDED: Using Soap and Water (54% FE) and Alcohol (67% FE)

Medical grade alcohol erases charges and may decrease FE 10 times. Gamma radiation of masks is not recommended.

In the *New England Journal of Medicine*, van Doremalen et al. provide evidence that the virus will not survive on plastic for >3 days (2). Since the half-life of the virus is 6.8 h, it is unlikely that there is a clinically significant amount of viable virus on the mask before the full 3-day period. Masks can reasonably be rotated every 3 days. A summary of that research appears below:

- Up to 3 h postaerosolization (median half-life 1.1–1.2 h)
- Up to 4 h on copper (median half-life 1.1–1.2 h)
- Up to 24 h on cardboard (median half-life approximately 3.5 h; estimate from graph)
- Up to 2 days on stainless steel (median half-life 5.6 h)
- Up to 3 days on plastic (median half-life 6.8 h)
- Survival time tested at 70–73°F and 40% humidity

There is strong evidence indicating that SARS-CoV-2 will not survive the cleaning methods described above. The World Health Organization technical brief states that most viruses are killed in <2 min after water temperature reaches 70°C (158°F) (3). The recommended boiling method at 100°C (212°F) will significantly shorten viral survivability and result in a quick turnaround time for safe reuse. The CDC's reuse guidelines cite a 2011 study by Heimbuch et al. concluding that warm moist heat at 65°C for 30 min eliminated H1N1 virus on the surface of N95 masks (4,5). An abstract published by Chin et al. in March 2020 demonstrated that no SARS-CoV-2 survived after subjected to heat (70°C [158°F] for 5 min) (6). The National Institutes of Health validated treatment with dry heat (70°C [158°F]) for 60 min and noted that this method eliminated viable SARS-CoV-2 from N95 masks (7). Because of the novelty and rapidly evolving knowledge regarding SARS-CoV-2, these recent studies have not been peer-reviewed. Independent laboratories are investigating to further evaluate this dry heating method. Dry heating may require >60 min or augmentation with moist heat may be recommended in the future. Therefore, there is scientific evidence that supports the N95 mask cleaning and reuse methods described herein.

The FDA granted EUA to the Battelle N95 cleaning system (Battelle, Columbus, Ohio) for emergency use on March 28, 2020. This uses hydrogen peroxide (H_2O_2) vapor (2.5 h) to clean ≤80,000 masks per day. The FDA also granted EUA for the STERRAD H_2O_2 system (Advanced Sterilization Products, Inc, Irvine, California) on April 13, 2020. However, the Battelle system is currently available only in Ohio, New York, Boston, Chicago, and Washington, and distribution is controlled by the U.S. Department of Health and Human Services and the Federal Emergency Management Agency. The limited access and cost of these systems is a barrier to smaller hospitals and clinics, especially for HCWs and facilities with limited financial resources. Therefore, these may not be available in all places that are in need.

Currently, the methods recommended by Dr. Tsai are not approved by any regulatory agency, and the short- and long-term effects of N95 respirator reuse after cleaning are unknown. It is possible that the edge contour of the mask may change slightly using the heating, steaming, and boiling methods. The contour may change by simply reusing the masks without using these methods. Subsequently, improper fit may decrease efficacy of the mask. Nonetheless, these methods meet the CDC's EUA criteria and are supported by a growing body of evidence (4). Please see pertinent excerpts below from the CDC (4):

- Decontamination and subsequent reuse of filtering facepiece respirators (FFRs) should only be practiced as a crisis capacity strategy.
- In absence of manufacturer's recommendations, third parties may also provide guidance or procedures on how to decontaminate respirators without impacting respirator performance. Decontamination might cause poorer fit, filtration efficiency, and breathability of disposable FFRs as a result of changes to the filtering material, straps, nose bridge material, or strap attachments of the FFR. The CDC and the National Institute for Occupational Safety and Health do not recommend that FFRs be decontaminated and then reused as standard care. This practice would be inconsistent with their approved use, but we understand in times of crisis, this option may need to be considered when FFR shortages exist.
- An effective FFR decontamination method should reduce the pathogen burden, maintain the function of the FFR, and present no residual chemical hazard.
- When information from the manufacturer or a third-party is available showing that respirators can be successfully decontaminated without impacting respirator performance, then FFRs decontaminated following those recommendations can be worn for any patient care activities.

During this COVID-19 pandemic, many HCWs around the world have limited options and desperately need N95 respirators. These HCWs may not be able to wait for regulatory agency approval of these cleaning methods. Clinicians in the field may determine if they will use these research data to clean and reuse N95 respirators. As an Emergency Physician on the front lines of this pandemic, I am acutely aware that the alternative of using no mask or ineffective masks will have grim repercussions.

I present these methods and suggest that where there are N95 respirator shortages around the world clinicians consider using one or more of these methods as a *bridge* until sufficient N95 masks are available. I also call upon the FDA and the CDC to grant EUA for these methods that are supported by a growing body of scientific evidence. Good luck to us all.

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