EFFECTS OF ULTRAVIOLET C (UVC) LIGHT AND DRY HEAT ON FILTRATION PERFORMANCE OF N95 RESPIRATOR MASK

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Abstract

Background: The emergence of the Coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) creates one of the most pressing issues with a severe shortage of personal protective equipment (PPE) particularly N95 respirators in healthcare settings worldwide. Recently, possible strategies to decontaminate disposable N95 respirators, including using ultraviolet C (UVC) irradiation and heat treatment, were reported to consider safely reusing the respirators. However, both methods create potential risks to reduce the ability of the respirator filter especially when exposed to these methods multiple times resulting in infectious agents passing through the filter.

Objective: The study aimed to ensure the effectiveness of UVC and dry heat to decontaminate N95 respirators.

Methods: N95 respirators were exposed continually to UVC and dry heat at 70°C. Then the ability of the aerosol penetration was assessed by introducing an aerosol containing a rotavirus used as a delegate for SARS-CoV2. The existence of the rotavirus at both external (front) and internal surfaces (back) of the N95 respirators was investigated using RT-PCR.

Results: UVC and dry heat administered at a 30-minute cycle up to 5 cycles did not change the filtration performance of the N95 respirators. Our results suggested that the reuse of disposable N95 respirators decontaminated by either UVC or dry heat could be possible under the test conditions used.

Conclusion: To reuse N95 respirators, UVC and dry heat were useful to apply amid the pandemic of respiratory diseases.

Keywords: COVID-19, N95 respirator mask, Ultraviolet C, Dry heat

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Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the cause of an infectious respiratory disease named coronavirus disease 2019 (COVID-19).[1] Due to the increase in the number of cases and expansion of geographic areas, WHO has declared the global spread of COVID-19 as pandemic.[2] To date, no effective vaccination and specific antiviral treatment for COVID-19 is available.[3] Therefore, this infectious respiratory disease is of critical concern for health-care workers facing the high risk of exposure to infection with SARS-CoV-2. According to current evidence, the transmission of the virus from person to person mainly occurred through respiratory droplets and contact routes.[3-5] (However, airborne transmission might be possible.[6] To reduce the risk of respiratory infection in health-care settings, the US Centers for Disease Control and Prevention recommended healthcare workers to wear respiratory protection while treating patients.[7] The N95 respirator is a respiratory protection device that is the most commonly used in healthcare settings due to high filtering efficiency against airborne infectious agents and a tight-fitting face piece.[8, 9] The N95 respirator is originally designed for single use to avoid contamination. During the event of COVID-19 pandemic, supplies of N95 respirators have experienced a serious shortage worldwide. Therefore, decontaminating and reusing N95 respirators have been recommended as a crisis capacity strategy to preserve available supplies for healthcare settings.[10] Several methods have been explored for possible application in healthcare settings including ultraviolet C (UVC) and dry heat.[11-13] However, both methods are at risk to reduce the ability of the respirator to filter out infectious agents especially when exposed to these methods multiple times. This study aimed to evaluate the possible loss of filtration efficiency of N95 respirators due to multiple exposures to UVC and dry heat. This study aimed to ensure the effectiveness of UVC and dry heat to decontaminate N95 respirators during respiratory disease pandemics.

Methods

Virus and viral quantity

The RIX4414 strain of the human rotavirus G1P[8] Wa strain (Rotarix®, GlaxoSmithKline Biologicals SA, Belgium) was used in this study to be a representative of SARS-CoV-2. The full dose (1 mL) of Rotarix vaccine suspension contained the viral quantity at least 106 CCID50 as mentioned in the pharmaceutical product information sheet.

Decontamination by Ultraviolet C

The surgical N95 respirator model 1870+ (3M, St. Paul, MN, USA) was used in this study. The N95 respirator was exposed to ultraviolet C (UVC) light (wavelength 254 nm) in a chamber 295 (w) x 375 (D) x 425 (H) mm. The N95 respirator was exposed to UVC on both external and internal sides (15 minutes per side) with a total duration of 150 minutes (5 cycles). After UVC exposure, the N95 respirator was placed on the solid board with sealing at the back for filtration test.

Decontamination by dry heat

Hot air incubator (Pol-Eko aparatura, Poland) was switched on until the temperature of the device stabilized at 70°C. After this, the N95 respirator was placed in a paper bag and placed in the incubator for 30 min per cycle. After each cycle, the N95 respirator was cooled down to room temperature before re-incubating under the same condition for 5 cycles (150 minutes). The filtration test was performed after the N95 respirator cooled to room temperature.

Table 1. RT-PCR detection for G1 and P[8] of rotavirus

Decontamination method	G1	P[8]
N95: 5 cycles of dry heat exposure	Not detected	Not detected
N95: 5 cycles of UVC exposure	Not detected	Not detected
Control positive	Detected	Detected
Control negative	Not detected	Not detected

Filtration test

To determine the filtration efficiency of the N95 respirators after being exposed to UVC and dry heat, a nebulizer attached with a face mask (Ningbo Runmai Medical Technology Co., Ltd., Zhejiang, China) was used in this study. The nebulizer was filled with a 1 mL unit dose of Rotarix set at 60 psi oxygen at 10 L/min. to deliver the aerosol of the Rotarix into the N95 respirators. To avoid contamination of the N95 respirators with residual Rotarix, the N95 respirators were laid and sealed on a support surface before the trial. After administering one dose of Rotarix via the nebulizer, the swab samples were immediately collected from both outer and inner surface of the N95 respirators and placed in a tube containing viral transport media to submit to the National Institute of Health of Thailand to detect VP7 and VP4 genes (defining G and P types, respectively) of the rotavirus by RT-PCR, as previously described.(14) We investigated the existence of the rotavirus at both external (front) and internal surfaces (back) of the N95 respirators.

Results

After five cycles of N95 respirators treatment by UVC and dry heat, no burning smell of the rubber mask compound was found. Next, the ability of aerosol particles to penetrate through the N95 respirators was determined by testing the filtration efficacy of N95 respirators. The results of RT-PCR for rotavirus are shown in Table 1. At the front, the rotaviral RNA was detected of both decontamination methods, while the back of N95 respirators, the rotaviral RNA was undetected.

Discussion

The emerging SARS-CoVs-2 resulting in the COVID-19 pandemic is considered a serious public health concern worldwide and has created a critical shortage of N95 respirators required for a component of PPE. The filtration mechanism of N95 respirators are based on mechanical filtration and electrostatic attraction.[15, 16] Related studies have reported that sterilizing with UV light could potentially be used to disinfect disposable N95 respirators.[10-13] The UV light is part of the electromagnetic radiation covering wavelength spectrum from 100 to 400 nm and is classified as UVA (320–400 nm), UVB (280–320 nm) and UVC (200–280 nm). UVC was reported to possess a high germicidal efficiency for disinfection with a broad spectrum against microorganisms, including viruses, bacteria and fungi. UVC is particularly damaging to microorganisms because they are absorbed by their nucleic acid. The UVC absorption induces the formation of pyrimidine dimers resulting in their inability to replicate.[17] Moreover, UVC has been reported to have the ability to decontaminate N95 respirators exposed to the bacteriophage MS2 and influenza viruses.[18-21] In 2020, Chotiprasitsakul et al.'s preliminary report revealed no significant change to the structure of the N95 polymer fibers was observed after UVC exposure (DOI: https://doi.org/10.21203/rs.3.rs-67838/v1).

However, decontaminating N95 respirators using UVC exposure might reduce the potential of N95 filtration.[22] Moreover, the number of cycles for decontamination seemed to be limited by N95 respirator model and the UVC dose

required to inactivate the pathogens.[11] Recently, Chin et al. reported that SARS-CoV-2 could be inactivated at 70°C for 5 minutes.[23] Nevertheless, no scientific evidence for re-use of the N95 respirators after decontaminating using the dry heat strategy. To extend the supporting scientific evidence of both strategies, we re-exposed the surgical N95 respirator model 1870+ with UVC (254 nm, 8 W) in the cabinet and dry heat (70°C for 30 minutes) for 5 cycles and subsequently evaluated the effect of both methods. Herein, the rotavirus was used as a representative viral particle to determine the filtration performance of N95 respirators due to their safety, high stability and sizes closely fitting SARS-CoVs-2.[24-26] Interestingly, we found that the aerosol containing rotaviral particles generated by the nebulizer could not pass through the filter of the N95 respirators after exposure to either UVC or dry heat up to 5 times. The physical degradation of the respirator materials including the changes in the layer structure of the materials was not investigated in this study. However, our results suggested that UVC and dry heat did not change the filtration performance of the N95 respirators and both methods were appropriate to apply to decontaminate N95 respirators to re-use during the pandemic crisis with respiratory infectious diseases.

Conclusion

Treating the respirators for 30 minutes per cycle with both UVC (254 nm, 8 W) cabinet and dry heat (70°C) did not influence the filtration properties within a reasonable number of treatment cycles (up to 5 cycles). Therefore, both methods could mitigate the N95 respirators shortage during the pandemic of respiratory diseases.

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