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.

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Letter to the Editor

Disinfection of N95 respirators by ionized hydrogen peroxide during pandemic coronavirus disease 2019 (COVID-19) due to SARS-CoV-2

Sir,

Coronavirus disease 2019 (COVID-19) due to SARS-CoV-2 has been spreading globally, and the World Health Organization declared a pandemic on 11th March 2020 [1]. The number of confirmed cases was 693,224 with 33,106 (4.8%) deaths as of 30th March 2020. The overwhelming number of infected cases not only paralyses the healthcare system, but also poses a significant risk to healthcare workers (HCWs). In Hong Kong, we adopted a proactive infection control approach, escalating the response according to the rapidly evolving epidemiology to minimize the risk of nosocomial transmission [2,3]. However, limited supply of personal protective equipment (PPE), especially N95 respirators, remains a great challenge. Although we have already adopted extended use of N95 respirators in accordance with the US Centers for Disease Control and Prevention (CDC) [4], we have to prepare for the worst-case scenario of lacking a supply of N95 respirators.

Therefore, we attempted to disinfect N95 respirators using SteraMist Binary Ionization Technology solution delivered through a SteraMist Surface Unit, registered with the US Environmental Protection Agency [5]. The main constituent is 7.8% H_2O_2 solution, which is converted to ionized H_2O_2 (iHP) after passing through a cold plasma arc, and moves like a gas over the surfaces of N95 respirators. The by-product of iHP is oxygen and water in the form of humidity.

The experiment was conducted in a well-ventilated room with six air changes per hour inside a biosafety level 2 microbiology laboratory, with the operator wearing a coverall protective gown. Four N95 respirators (two 3M1870+ and two 3M1860s) were hung horizontally (facing outer and inner surfaces), and each was inoculated with 10 μL of three different concentrations of influenza A virus subtype H1N1 [1,000,000 50% of tissue culture infectious dose ($TCID_{50}$) mL^{-1}, 100,000 $TCID_{50}$ mL^{-1} and 10,000 $TCID_{50}$ mL^{-1}] in the presence of 1% fetal calf serum to mimic organic soil contamination in the clinical setting to the outer and inner surfaces (i.e. 10,000 $TCID_{50}$, 1000 $TCID_{50}$ and 100 $TCID_{50}$ per spot). iHP was sprayed three times in a 'to-and-fro' manner at a distance of 24 inches for a total of appropriately 6 s. The viruses were also applied in a similar manner to a cover glass that served as the control on a non-porous surface. N95 respirators inoculated with influenza A virus without disinfection were used as the positive control. One hour later, the pieces of N95 respirators with viral inoculation were cut out. The virus was eluted from the N95 respirators for viral culture in Madin-Darby Canine Kidney (MDCK) cells. Cytopathic changes of MDCK cells were observed daily for 7 days by light microscopy. None of the iHP-treated pieces of N95 respirators demonstrated cytopathic changes suggesting the presence of live influenza A virus (Table I). The samples were subcultured again on MDCK cells for a further 7 days, and no cytopathic changes were observed; this was confirmed by lack of detection of influenza A antigen following immunofluorescence staining. This experiment showed that iHP could kill influenza A virus at moderate to high levels of inoculum. Influenza A virus was chosen for this study because it is an enveloped RNA virus that has similar virological characteristics as coronaviruses.

Disinfection of disposable PPE can be attempted whenever the supply is limited during pandemics [6,7]. Reuse of N95 respirators has been proposed by CDC [4], but this carries a risk

Table I
Ionized hydrogen peroxide (iHP) disinfection of N95 respirators inoculated with influenza A virus subtype H1N1

Dose of virus inoculation per spot	iHP spray					No iHP spray	
	1870+ outer surface	1870+ inner surface	1860s outer surface	1860s inner surface	Cover glass	1870+ outer surface	Cover glass
10,000 $TCID_{50}$	No growth	No growth	No growth	No growth	No growth	Growth	Growth
1000 $TCID_{50}$	No growth	No growth	No growth	No growth	No growth	Growth	Growth
100 $TCID_{50}$	No growth	No growth	No growth	No growth	No growth	No growth	No growth
No virus	No growth	No growth	No growth	No growth	No growth	No growth	No growth

$TCID_{50}$, 50% of tissue culture infectious dose.

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of contamination and infection of HCWs. Disinfection of N95 respirators may provide an alternative option. The disinfection process is faster using SteraMist, a hand-held device, than the conventional platform, which uses a higher concentration of H_2O_2 vapour (30% − 35%) and requires concealment of the air ventilation system and longer cycle times. Ultraviolet germicidal irradiation has also been used for the disinfection of N95 respirators, but it has been shown to degrade polymers, leading to a small increase in particle penetration [8]. It is important to test the particulate filtration efficiency of N95 respirators to determine the maximum number of disinfection cycles regardless of the method of disinfection. HCWs should be reminded not to reuse N95 respirators immediately after disinfection. In this study, the level of H_2O_2 on the inner surface of N95 respirators was 0.6 ppm (below the safety limit of $<$1 ppm) at 2 h and undetectable at 3 h. The speed of H_2O_2 release from N95 respirators may be variable and affected by the air current. More importantly, HCWs should be well informed regarding the potential risk of exposure to other chemicals or inert ingredients which may persist in the porous material of N95 respirators. This may pose a dilemma to HCWs who need to balance the risk and benefit of reusing N95 respirators with or without disinfection. Further investigation into the disinfection of N95 respirators is warranted.

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None declared.

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