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Skin and eye protection against ultraviolet C from ultraviolet germicidal irradiation devices during the COVID-19 pandemic

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Abstract

With the COVID-19 pandemic depleting personal protective equipment worldwide, various methods including ultraviolet C (UVC) germicidal irradiation (UVGI) have been implemented to decontaminate N95 filtering facepiece respirators. These devices pose a risk for UVC exposure to the operator with reported adverse effects generally limited to the eyes and skin. Our hospitals are currently using UVC devices for N95 decontamination with a few reported cases of face and neck erythema from exposure. Because sunscreens are designed and tested for UVA and UVB protection only, their effects on blocking UVC are largely unknown. Therefore, our objective was to determine if various sunscreens, UV goggles, and surgical mask face shields minimize UVC exposure from UVGI devices. Our study clearly demonstrated that healthcare workers responsible for the disinfection of PPE using UVGI devices should always at least utilize clear face shields or UV goggles and sunscreen to protect against side effects of UVC exposure.

With the SARS-CoV-2 (COVID-19) pandemic depleting personal protective equipment (PPE) worldwide, various methods including ultraviolet C (UVC) germicidal irradiation (UVGI) have been implemented to decontaminate N95 filtering facepiece respirators (FFR).[1] UVC induces DNA damage, inactivating various pathogens including viruses. The depth of penetration is limited, so the efficacy of its germicidal effect is limited to surfaces. These devices pose a risk for UVC exposure to the operator with reported adverse effects generally limited to the eyes and skin.[2] Our hospitals are currently using UVC devices for N95 decontamination with a few reported cases of face and neck erythema from exposure. Because sunscreens are designed and tested for UVA (315–400 nm) and UVB (280–315 nm) protection only, their effects on blocking UVC are largely unknown. Therefore, our objective was to determine if various sunscreens as well as polycarbonate UV goggles and a surgical mask face shield made from 4 mil polyester film with anti-fog coating on both sides could minimize UVC exposure from UVGI devices (254 nm).

A UVC light radiometer (UVC Light Meter 850010, Sper Scientific LTD., Scottsdale, AZ) was used to measure the irradiance of a UVGI unit (Daavlin desktop UVC lamp, Daavlin, Bryan, OH) at baseline and through a clear plastic bag to confirm transmission of UVC radiation (Fig. 1a). Following this, three sunscreens (A = Zinc 21.6% [Sheer Zinc Dry-Touch Sunscreen, SPF 50, Neutrogena, Los Angeles, CA], B = Chemical [avobenzone 3%, homosalate 10%, octisalate 5%, octocrylene 7%] [Anthelios 60 Melt-in Sunscreen Milk, SPF 60, La Roche-Posay LLC, New York, NY], C = Pigmentary Titanium Dioxide 11.01% [Anthelios 50 Mineral Ultra-Light Tinted Sunscreen Fluid, SPF 50, La Roche-Posay LLC, New York, NY]) were applied at 2 mg/cm^2 to the clear plastic surface (Fig. 1b). The irradiance was then measured for each sunscreen. A pair of UV goggles and a clear face shield from a disposable surgical mask (Procedure Mask with Anti-Fog Foam Strip and Wraparound Eye Shield, Cardinal Health, Waukegan, IL) were also tested to determine the amount of UVC transmitted. Measurements were taken five separate times and averaged by the memory function built into the light meter.

The results are summarized in Table 1. The baseline irradiance measurement of the UVC lamp was 22.72 mW/cm^2 and through the clear plastic surface was 19.45 mW/cm^2. For sunscreens A, B, and C, the transmitted irradiance to the UVC light meter dropped to 0.01, 0.02, and 0.01 mW/cm^2, respectively. Below the face shield, the irradiance was measured at 0.01 mW/cm^2.

During the COVID-19 pandemic, decontamination of N95 respirators involves the administration of at least 1 J/cm^2 of UVC

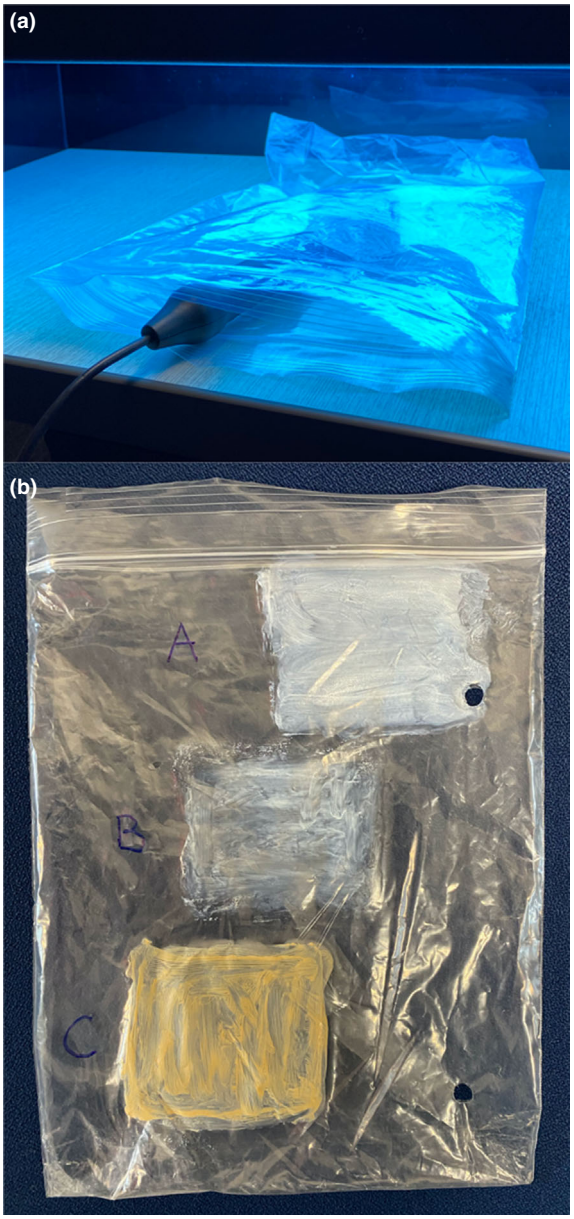

Figure 1 (a) Radiometer inside clear plastic bag under UVC lamp and (b) three sunscreens A, B, and C applied on the clear plastic bag

(254 nm) to achieve a minimum 3 log reduction of microorganisms reported in the literature.[3] However, exposure to UVC radiation has been shown to induce DNA damage in human cells *in vitro* and cause squamous cell carcinoma in rats and mice.[4] It is approximated that only 5% of UVC penetrates the stratum corneum compared to 15% of UVB and 50% of UVA.[5] Solar radiation, as it reaches the surface of the earth, contains no UVC as it is completely absorbed by the ozone layer. As such, clinically, UVC has not been associated with keratinocyte skin cancers or melanoma in humans.[4] UVC from artificial light

Table 1 Radiometer measurements with various barriers

Barriers	Irradiance (mW/cm^2)
Baseline	22.72
Clear plastic bag	19.45
Product A: Zinc 21.6%	0.01
Product B: Chemical (avobenzone 3%, homosalate 10%, octisalate 5%, octocrylene 7%)	0.02
Product C: Pigmentary titanium dioxide 11.01%	0.01
Ultraviolet goggles	0.01
Face shield	0.01

sources is readily absorbed by the skin and eyes, and the severity of injury varies based on exposure time, intensity and distance from source, wavelength of UVC, and sensitizing agents (e.g. silver nanoparticles can sensitize cells to UVC radiation for cancer treatment).[6,7] Furthermore, it has been estimated that skin is most susceptible to UV-induced erythema in wavelength range of 200–250 nm.[6] Consequently, the operator of the UVGI device could potentially be at risk for skin reactions including erythema, photoaging, and skin cancer as well as photokeratitis or conjunctivitis if repeated and chronic exposure to UVC occurs.[2] For these reasons, it is important to protect the skin and eyes from exposure to UVC from UVGI devices.

Since UVC is absorbed prior to penetrating the Earth's atmosphere, sunscreens have been primarily designed and tested for protection against UVA and UVB. The effects of photoprotection of sunscreens from UVC is largely unknown. One study examining the non-radiative relaxation pathways of oxybenzone after UVB and UVC excitation found that oxybenzone displayed broadband photoprotection including the UVC waveband.[8] Another study found that shadowing from titanium dioxide nanoparticles during photocatalytic disinfection resulted in a "sun block" effect, reducing the antifungal efficacy of UVGI.[9] These findings lend support to our direct irradiance measurements using a UVC light meter.

Given the ongoing COVID-19 pandemic, UVC can be anticipated to play a continuing large role in PPE disinfection. It is therefore important to establish its safety to the operators of the UVGI devices given the widespread use. Our study clearly demonstrated that healthcare workers responsible for the disinfection of PPE using UVGI devices should always at least utilize clear face shields or UV goggles and sunscreen to protect against side effects of UVC exposure.

Conflict of interest

ABL and SN are sub-investigators for Biofrontera, L'Oreal, and Beiersdorf. IK is a sub-investigator for Beiersdorf, Estee Lauder, L'Oréal, Ferndale laboratories, Allergan, and Johnson & Johnson and has served as a consultant for Johnson and Johnson, and Beiersdorf. DO is an investigator for Biofrontera. HWL is an

investigator for Beiersdorf, L'Oreal, LITE study which is funded by PCORI, and home phototherapy machines are provided by Daavlin, and served as consultant for Pierre Fabre, ISDIN, Ferndale, and Galderma, and has participated as a speaker in general educational session for Pierre Fabre, Eli Lilly, Johnson & Johnson, and Ra Medical System. IHH is an investigator for Beiersdorf, Estee Lauder, Ferndale Healthcare Inc., Allergan, Johnson & Johnson, LITE study which is funded by PCORI, and home phototherapy machines are provided by Daavlin. AET and APM have no relevant conflicts of interest to report.

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