An influenza pandemic could lead to a shortage of Filtering Facepiece Respirators (FFRs), leaving health care workers unprotected. Past research on FFR decontamination and reuse (FFR-DR) strategies indicate ultraviolet germicidal irradiation (UVGI) is effective at killing influenza on FFRs. This study expands this research by: 1) optimizing UVGI dose for influenza kill on the presence of soiling agents, 2) optimizing the dose to reduce exposure time, and 3) evaluating 15 FFR models to understand universal application of the technology.

For UVGI dose optimization, triplicate 3M 1870 coupons were contaminated with influenza and either sebum or mucin. Test coupons were exposed to 254-nm UV-C dose ranging from 1 × 10³ – 2 × 10⁶ µJ/cm². Influenza virus was extracted and quantified using a median tissue culture infectious dose (TCID50) assay. A UVGI device was built to apply the optimized UV dose to an intact FFR in ~1 min. Triplicate samples of 15 FFR models were contaminated as described above on three facemask locations and one strap location per FFR. After UV treatment, coupons were cut from the FFRs, and remaining viable virus extracted and quantified. The optimized dose was determined to be ~1 × 10⁶ µJ/cm². Whole FFR exposure demonstrated high variability in UVGI decontamination between FFR models and surface type, with log reductions ranging from 0.00 – 4.85 log10 TCID50. The mean log reduction on the facemask portion of all 15 FFR models was 3.42 ± 1.08 log10 TCID50 and 2.48 ± 1.29 log10 TCID50 for straps. Only two of the FFR models demonstrated a 3-log mean log reduction for all soiling-surface combinations. These data suggest that FFR-DR using UVGI is possible, but not universal. Some FFRs are not compatible, presumably due to material incompatibilities. These data are critically important for regulators and hospitals to understand in the event FFR-DR technologies are deployed during a pandemic. Studies are currently underway to evaluate FFR durability and performance following multiple UVGI cycles and to evaluate logistical parameters for implementing UVGI-based FFR-DR technology into health care settings.

Inoculated areas were then overlaid with soiling agent, depending on the condition being tested: Artificial skin oil (sebum): 2.5 or 5.0 mg
Influenza virus was extracted and quantified using a TCID50 assay according to WHO protocol. Whole FFR exposure demonstrated high variability in UVGI decontamination between FFR models and surface type, with log reductions ranging from 0.00 – 4.85 log10 TCID50. The mean log reduction on the facemask portion of all 15 FFR models was 3.42 ± 1.08 log10 TCID50 and 2.48 ± 1.29 log10 TCID50 for straps. Only two of the FFR models demonstrated a 3-log mean log reduction for all soiling-surface combinations. These data suggest that FFR-DR using UVGI is possible, but not universal. Some FFRs are not compatible, presumably due to material incompatibilities. These data are critically important for regulators and hospitals to understand in the event FFR-DR technologies are deployed during a pandemic. Studies are currently underway to evaluate FFR durability and performance following multiple UVGI cycles and to evaluate logistical parameters for implementing UVGI-based FFR-DR technology into health care settings.

METHODOLOGY

UVGI DOSE OPTIMIZATION

For UVGI dose optimization, triplicate 3M 1870 FFR coupons (3.8 cm dia) were used for both control and test samples. Coupons were inoculated with ten 1-µL droplets of ~8-9 log10 TCID50 H1N1 influenza. Each replicate was inoculated with ten 1-µL droplets of ~8-9 log10 TCID50 influenza. Inoculated areas were then overlaid with soiling agent, depending on the condition being tested:

- No soiling agent
- Artificial saliva (mucin): 50 or 100 µL
- Artificial skin oil (sebum): 2.5 or 5.0 mg

Tested coupons were then exposed to 254-nm UV-C radiation at various times to achieve the following doses:

- 1 × 10³ µJ/cm²
- 5 × 10³ µJ/cm²
- 1 × 10⁴ µJ/cm²
- 2 × 10⁴ µJ/cm²

RESULTS

For UVGI optimization, the minimum UVGI dose demonstrating a 3-log reduction in viable H1N1 influenza in the presence of protective factors was 1 × 10⁶ µJ/cm². Influenza virus was extract-and quantified using a TCID50 assay. A UVGI device was built to apply the optimized UV dose to an intact FFR in ~1 min. Triplicate samples of 15 FFR models were contaminated as described above on three facemask locations and one strap location per FFR. After UV treatment, coupons were cut from the FFRs, and remaining viable virus extracted and quantified.

Inoculated areas were then overlaid with soiling agent, depending on the condition being tested:

- No soiling agent
- Artificial saliva (mucin): 50 or 100 µL
- Artificial skin oil (sebum): 2.5 or 5.0 mg

Tested coupons were then exposed to 254-nm UV-C radiation at various times to achieve the following doses:

- 1 × 10³ µJ/cm²
- 5 × 10³ µJ/cm²
- 1 × 10⁴ µJ/cm²
- 2 × 10⁴ µJ/cm²

Conclusions

• An increase in UV exposures diminishing returns at 1 × 10⁶ µJ/cm² for H1N1 influenza on N95 and FFP2 masks. UVGI can be effective against H1N1 influenza in the presence of soiling agents, but respirator shape, respirator material, and UV light arrangement may significantly affect decontamination efficacy.
• Two main factors limit the ability to demonstrate a higher log reduction value with a corresponding higher UV dose: 1) the level of viable influenza recovered extracted from the control coupons, and 2) the detection limit of the TCID50 assay.
• FFRs and UVGI can be effective at reducing UV light exposure to select agent viruses will be conducted to determine the decontamination efficacy.
• Durability and performance testing will be performed using 15 N95 FFR models exposed to multiple UV cycles to determine any functional loss that could occur as a result of UVGI exposure.

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The published material represents the position of the authors and not necessarily that of the FDA.