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Reply by Bueno de Mesquita et al. to Davidson

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To the Editor:

We are grateful for the opportunity to offer clarifications about our *AnnalsATS* Viewpoint, entitled “Far-UVC: Technology Update with an Untapped Potential to Mitigate Airborne Infections” in response to Dr. Bruce Davidson’s letter. Our Viewpoint was not a detailed review of germicidal ultraviolet (GUV) but rather focused on safety, utility, and potential application of far-UVC (200-230 nm wavelengths). We agree and describe in our Viewpoint that current LED GUV wavelengths are longer (254 and 265 –270 nm), which must be kept overhead because they are more likely to cause adverse health effects if lower room exposures exceed wavelength-specific exposure limits. We emphasized the need for research and development on the use of shorter wavelength (200-230 nm) far-UVC LED sources, because the encouraging safety profile of far-UVC allows for use directly in occupied breathing spaces, offering efficient air disinfection where it is needed most.

All chamber studies of disinfection by GUV are approximations of real-world conditions, conventionally using a variety of aerosol generating and capturing technologies, with culture, not infection, as the end point. We agree with Dr. Davidson that artificial saliva, or even better, culture-derived respiratory lining fluid (1) would improve generalizability in such aerosol experiments. Ultimately, air disinfection should be tested under real world conditions. For example, an ongoing NIH-funded EMIT-II randomized controlled trial (2) uses natural human infectious aerosol sources and secondary human infection as an end point to provide information about GUV efficacy.

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GUV is not meant to replace air filtration and ventilation. We pointed out that "although well-functioning heating, ventilation, and air conditioning systems are essential, GUV provides enhanced protection at a sustainable cost." Our Viewpoint emphasized the additional benefit provided by far-UVC to achieve enough equivalent air changes per hour, in addition to baseline ventilation and/or filtration, to reduce exposure to infectious agents near individuals' breathing zones. Adequate ventilation and filtration are critical for maintaining air quality and reducing potentially harmful infectious or chemical exposures in any shared indoor air space. GUV disinfects a greater volume of air per unit of time compared with ventilation or filtration, which are flow limited, not because of "dilution with outside air," as inadvertently stated in the original piece. We did not mean to suggest that ventilation and filtration are not important—they are essential.

Our Viewpoint referenced evidence about far-UVC safety and efficacy, addressed the potential indoor chemistry issue, and called for additional research. A recent study by Kalliomäki and colleagues (currently under peer review) measured ozone in hotel quarantine rooms. The rooms had ventilation rates of $\leq$1.4 ACH and realistic use of far-UVC lamps delivering average fluence rates of 1.7-1.8 μW/cm2 (50-51 mJ/cm2 dose for 8-hr exposure – below ACGIH limits but double the ICNIRP limit for workers) (3). They reported a 5.7 ppb indoor ozone increase with far-UVC use in furnished rooms, consistent with other work. This was 6-12 ppb lower than measured outdoor ozone levels. The increase in indoor ozone was three orders of magnitude smaller than what Dr. Davidson noted in his letter. Kalliomäki et al reported no relationship between far-UVC use and ultrafine particle concentrations. We agree with Dr. Davidson on, and

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emphasize in our Viewpoint, the need for more real-world measurements of ozone and secondary toxicant generation under far-UVC use scenarios.

One of the co-authors (EN) disclosed providing technical advice on GUV efficacy and safety to GUV companies during the COVID-19 crisis, in accordance with his institutional guidelines. This information was not available ahead of print as is common with peer reviewed publications that offer early access online.

Our commentary aimed to make the respiratory community aware of the potential for air disinfection by more recently developed far-UVC, and to identify research and development priorities. Given ongoing waves of COVID-19 into 2024, as well as influenza, RSV, and other respiratory viruses, and more frequent pandemics on the horizon, there is a certain urgency to thoughtfully and safely develop and deploy effective tools to control airborne pathogens.

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