

1 **UV-C light completely blocks highly contagious Delta SARS-CoV-2 aerosol transmission in**  
2 **hamsters**

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23 **Keywords:** SARS-CoV-2, COVID19, UV-C, transmission, aerosol, hamster

24 **Abstract:**

25 Behavioral and medical control measures are not effective in containing the spread of SARS-

26 CoV-2. Here we report on the effectiveness of a preemptive environmental strategy using UV-C

27 light to prevent airborne transmission of the virus in a hamster model and show that UV-C

28 exposure completely prevents airborne transmission between individuals

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## 31 **Introduction**

32 The COVID-19 pandemic has officially caused more than 5.4 million deaths worldwide as of  
33 December 28, 2021.<sup>1</sup> Epidemiological and experimental data suggests that the primary mode of  
34 transmission of the virus is through airborne particles.<sup>2-4</sup> Medical countermeasures, such as  
35 vaccines and monoclonals antibody therapies were rapidly developed, but have had limited  
36 impact on the overall control of the pandemic. While the developed vaccines are highly  
37 effective against preventing severe COVID-19 and hospitalization, their transmission-blocking  
38 potential on population level appears limited. Currently, 44.65% of the global population are  
39 fully vaccinated and an estimated 285 million people have been infected with SARS-CoV-2.<sup>1</sup>  
40 This has drastically changed SARS-CoV-2 immune landscape and likely promoted the  
41 emergence of Variants of Concern (VoC) escaping antibody immunity, fueling the current  
42 global spikes in infection rates.<sup>5</sup> These rapid increases in SARS-CoV-2 prevalence prompt crude  
43 control measures such as: travel restrictions, large-scale quarantining and “lock downs” of entire  
44 populations leading to economic and public health burden.<sup>6</sup> The inability to control the ongoing  
45 SARS-CoV-2 pandemic has put the focus on the development of pathogen agnostic non-medical  
46 intervention strategies. These non-medical intervention strategies should ideally be practical,  
47 effective under multiple conditions, not depend on the cooperation of individuals, not contribute  
48 to virus evolution and prove efficacious for multiple epidemic and pandemic pathogens. One  
49 measure that has the potential to decrease the concentration of infectious airborne pathogens in  
50 enclosed spaces is ultraviolet (UV) light. Ultraviolet light, in particular UV-C light (wavelengths  
51 in the range of 200 nm – 280 nm) has germicidal properties. Several studies have shown that  
52 UV-C light can be used to inactivate SARS-CoV-2 on surfaces using a UV-C germicidal lamp.<sup>7-9</sup>

53 Here we report on the effectiveness of UV-C light in blocking transmission of airborne SARS-  
54 CoV-2 in a hamster model.

## 55 **Results**

56 To test the ability of UV-C light to prevent infection of naïve hamsters by naturally aspirated  
57 aerosols we employed a modified version of an aerosol transmission system described  
58 previously.<sup>4</sup> In this system two cages are separated by a 1250 mm X 73 mm tube resulting in a  
59 size exclusion of airborne particles  $\geq 10 \mu\text{m}$ . The central portion of the tube is quartz enclosed in  
60 a HDPE box containing a UV-C light source (Figure 1). The length of the tube inside the box is  
61 66.2 cm and the air traveling from the infected animals to the naïve animals had a residence time  
62 of 10.7 seconds in the tube. A 934.5 L/hr airflow, approximately 30 cage air exchanges per hour,  
63 is maintained throughout the experiment resulting in a UV-C dose exposure of the pathogen-  
64 containing airborne particles of approximately  $21.4 \text{ mJ/cm}^2$ .

65 Briefly, for each trial, 2 hamsters were inoculated intranasally (IN) with  $8 \times 10^4$  TCID<sub>50</sub> SARS-  
66 CoV-2 strain nCoV-WA1-2020 (EPI\_ISL\_404895) (prototype lineage A SARS-CoV-2) or  
67 hCoV-19/USA/KY-CDC-2-4242084/2021 (EPI\_ISL\_1823618) (VoC Delta). At 1 day post  
68 infection (dpi) 2 infected hamsters were placed in the upstream (donor) cage and 2 naïve  
69 hamsters were placed in the downstream (naïve) cage. After a 4-hour exposure the exposed  
70 naïve hamsters were moved to individual cages and the donor hamsters were euthanized after an  
71 oropharyngeal swab was collected.

72 To determine whether the naïve exposed sentinel hamsters became infected, oropharyngeal  
73 swabs were collected on days 1, 2 and 3 post exposure (DPE) and analyzed for the presence of  
74 subgenomic viral RNA (sgRNA, marker for active SARS-CoV-2 replication) and genomic viral  
75 RNA (gRNA) by qRT-PCR. The experiment was repeated 4 times for the following conditions:

76 UV-C light treatment, no UV-C light treatment with variant nCoV-WA1-2020 or hCoV-  
77 19/USA/KY-CDC-2-4242084/2021 (Delta). When testing under UV-C conditions, the light was  
78 turned on 1 hour prior to introducing the animals to the system.  
79 All the animals in the no UV-C treatment groups became infected as early as 1 DPE. gRNA was  
80 detected in all animals as early as 1 DPE for both the lineage A and the Delta VOC and  
81 continued through DPE 3 (Figure 2, A & C). No gRNA was detected in either of the UV-C  
82 groups (Figure 2, A & C). sgRNA was also detected on DPE 1 – 3 in the no UV-C treatment  
83 groups, but not in any of the animals in the UV-C groups (Figure 2, B & D). To conclusively  
84 demonstrate absence of transmission of SARS-CoV-2 in both UV-C treatment groups the  
85 binding antibody titers against the SARS-CoV-2 spike protein (S) were determined on sera  
86 obtained at 14 DPE. Both no UV-C light treatment groups had high antibody titers ( $\geq 52,000$  in  
87 all animals,  $n = 16$ ), but both no UV-C light treatment groups displayed a complete lack of  
88 binding antibody titers against SARS-CoV-2 S ( $< 400$  in all animals,  $n = 16$ ).

## 89 **Discussion**

90 As the SARS-CoV-2 pandemic approaches its third-year, additional non-medical intervention  
91 strategies are urgently needed. Especially in areas and locations where there is a higher risk of  
92 SARS-CoV-2 transmission, such as hospitals, COVID-19 testing centers, schools and other  
93 indoor areas effective preemptive environmental intervention measures are needed to protect  
94 health care workers and people at risk of developing severe COVID19. Non-medical  
95 intervention such as social distancing rely on the assumption that small airborne respiration  
96 droplets will settle to the ground within about 2 meters from the source. However, true aerosols  
97 ( $< 10 \mu\text{m}$ ) in diameter will remain suspended, floating on air currents for an extended amount of  
98 time, can travel more than 2 meters and remain suspended for minutes to hours. In addition,

99 other non-medical countermeasures, such as mask wearing, are highly dependent on compliance  
100 and as such have had varying levels of effectiveness across different cultural, political, and  
101 religious environments.

102 Here we have demonstrated that a preemptive environmental intervention measure, using UV-C  
103 irradiation, can prevent the aerosol transmission of SARS-CoV-2 between hamsters. This work  
104 suggests that UV-C could be used to decrease the concentration of viable air-borne virus in  
105 various environments used in conjunction with existing control measures and where other  
106 methods are less likely to work. Extensive literature is available for pathogen inactivation, using  
107 either bacterial spore inactivation tests, bacteria or respiratory viruses by UV-C treatment.<sup>10,11</sup>  
108 There are several UV-C systems that have been developed and are already being employed.<sup>12,13</sup>  
109 The experiments described here recapitulate a system in which ducted air is treated and returned  
110 to the room; the efficiency of this type of system is dependent on the number of room-air  
111 exchanges per hour and the ventilation system processes. Another UV-C system that has been  
112 employed in areas with a high incidence of tuberculosis (TB) is upper-room ultraviolet  
113 germicidal irradiation.<sup>14</sup> Upper-room ultraviolet germicidal irradiation has the potential to treat  
114 up to 24 room air changes per hour equivalents where comfort level ventilation systems handle  
115 between 1 and 2 room air exchanges per hour.<sup>15</sup>

116 Preemptive environmental interventions in public spaces, that are not dependent on the  
117 compliance of the at-risk population, would potentially be a highly cost-effective non-medical  
118 countermeasure to help control the current pandemic. In addition, given the pathogen agnostic  
119 nature of UV-C germicidal irradiation it has the potential to curb airborne transmission of fungal,  
120 bacterial, and viral pathogens and even everyday maladies like the common cold.

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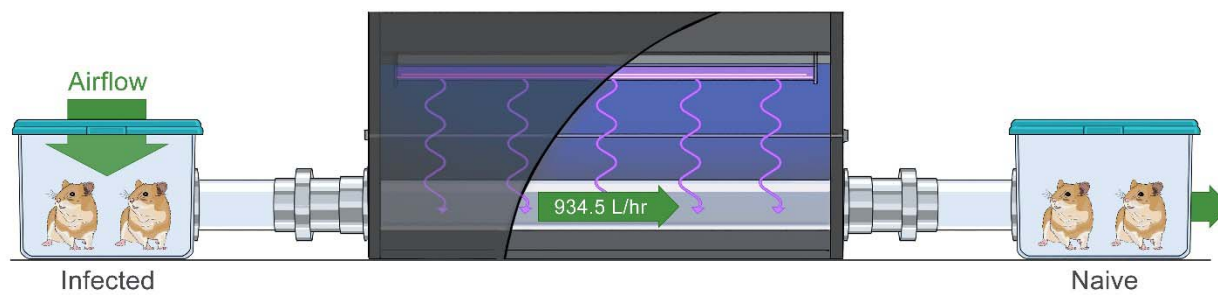
180 **Figure 1. Experimental aerosol transmission with UV-C irradiation setup.** Two cages are separated  
181 with a 1250 mm X 73 mm i.d. tube. The center portion of the tube is 662 mm of UV transparent quartz  
182 surrounded by a HDPE box housing a UV-C light source. Two donor hamsters, infected intranasally with  
183  $8 \times 10^4$  TCID<sub>50</sub> SARS-CoV-2 of either lineage A or the Delta variant one day prior to the experiment,  
184 were placed in the upstream cage and two naïve sentinel hamsters were placed in the downstream cage  
185 with a 934.5 L/hr airflow for 4 hours. The arrow indicates the direction of the airflow.

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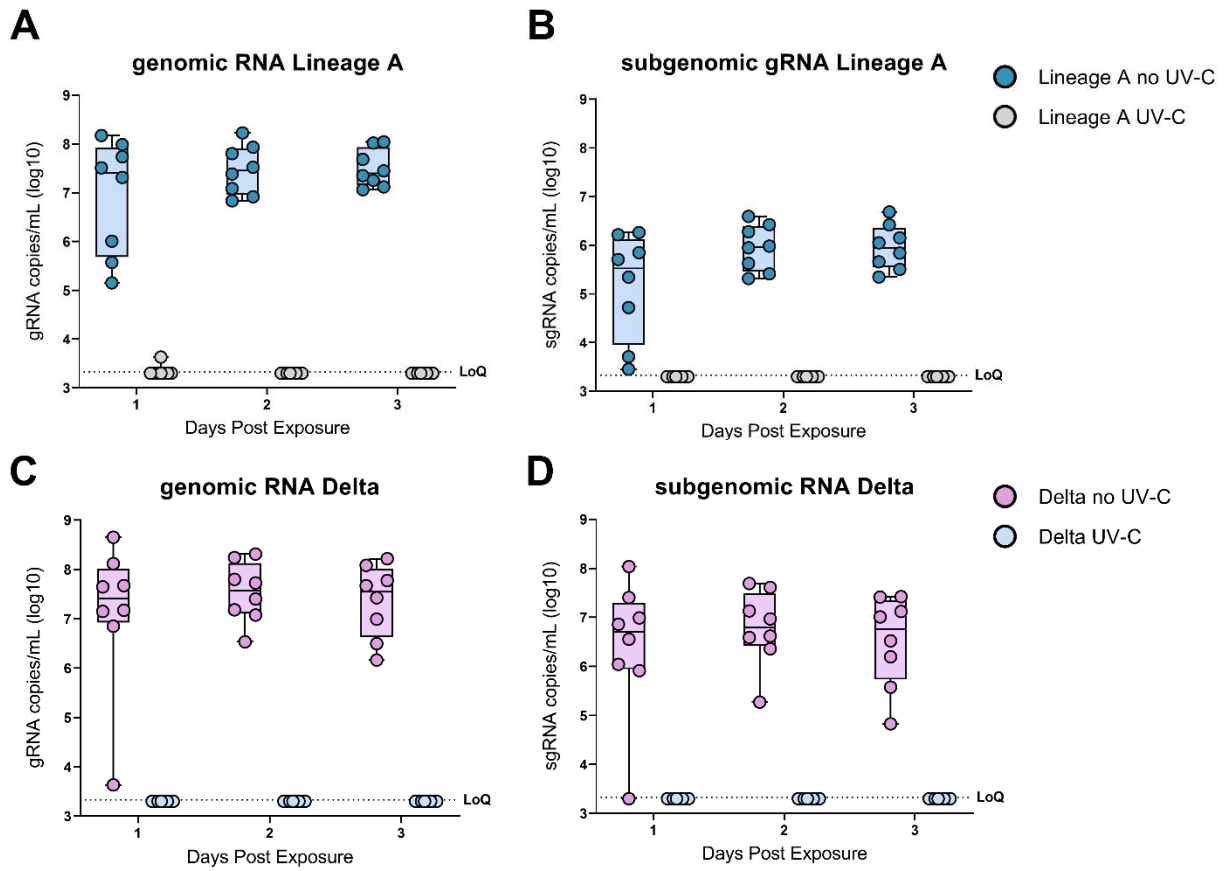
188 **Figure 2. UV-C irradiation blocks SARS-CoV-2 aerosol transmission in hamsters.** A & B) Boxplot  
189 (minimum to maximum) of genomicRNA and subgenomicRNA Lineage A SARS-CoV-2 RNA in  
190 oropharyngeal swabs collected on 1-, 2- and 3-days post exposure. Blue dots represent the no UV-C  
191 treatment group (n = 8) and grey dots represent the UV-C treatment group (N=8). C & D) Boxplot  
192 (minimum to maximum) of genomicRNA and subgenomicRNA Delta SARS-CoV-2 RNA in  
193 oropharyngeal swabs collected on 1-, 2- and 3-days post exposure. Pink dots represent the no UV-C  
194 treatment group (n = 8) and light-blue dots represent the represent the UV-C treatment group (N=8).  
195 Dotted line = limit of detection.

196 **Figure 1.**



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198 **Figure 2.**



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