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Brief Report

Modeling COVID-19 infection risks for a single hand-to-fomite scenario and potential risk reductions offered by surface disinfection

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We used a quantitative microbial risk assessment approach to relate $\log_{10}$ disinfection reductions of SARS-CoV-2 bioburden to COVID-19 infection risks. Under low viral bioburden, minimal $\log_{10}$ reductions may be needed to reduce infection risks for a single hand-to-fomite touch to levels lower than 1:1,000,000, as a risk comparison point. For higher viral bioburden conditions, $\log_{10}$ reductions of more than 2 may be needed to achieve median infection risks of less than 1:1,000,000.

While droplet and bioaerosol transmission are considered the main contributors to COVID-19 transmission,[1] SARS-CoV-2 detection on surfaces[2] indicates the potential for fomite-mediated transmission and the need for surface disinfection in multibarrier mitigation approaches. Data indicate that surfaces most likely to facilitate coronavirus transmission are surfaces which are frequently touched by many people (eg, door and tap handles) and that disinfection practices should be targeted at these surfaces.[3,4]

Disinfectant efficacy on surfaces contaminated with coronavirus has been evaluated,[5,6] but the $\log_{10}$ reductions obtained have not been quantitatively linked to infection risk reduction. This challenges health authorities in specifying disinfectant dilutions and contact times required to reduce viral bioburden to safety target levels, but risk assessment bridges the divide between environmental virus quantification and implementation of health targets. Here we use a quantitative microbial risk assessment (QMRA) approach to estimate and compare COVID-19 infection risks after single hand-to-fomite-to-mucosal membrane contacts for high and low levels of viral bioburden and variable disinfection efficacy.

METHODS

We estimated infection risks for a single hand-to-fomite and hand-to-facial mucosal membrane (mouth, eyes, and nose) contact scenario, where reduction efficacy of the virus was varied between 1 and 5 $\log_{10}$. We then compared estimated infection risks to 1:10,000 and 1:1,000,000 risks. This approach has been used in previous QMRAs for relating surface disinfection efficacies against bacteria and viruses to estimated health outcomes.[7,8]

A Monte Carlo approach was used to account for variability and uncertainty in the following: transfer efficiencies, fractions of the hand used for surface and face contacts, viral bioburden, disinfection $\log_{10}$ reductions, and surface areas of the hand and of fomites available for contact (Supplementary Table S1). Ten-thousand iterations were used.

Currently, data are lacking describing infective virus bioburdens on fomites in part due to detection limits for current culture assays

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being higher than viral concentrations on surfaces.[9] Therefore, we assumed a range of viral bioburden (0.1 to 10,000 genome copies (gc)/cm^2) to evaluate the effect of variable viral bioburden on infection risk reductions offered by various $\log_{10}$ viral bioburden reductions and used 1 gc/cm^2, an assumed limit of detection, to compare low versus high viral bioburden conditions. To account for variations in the level of infectivity of viral genome copies, bioburdens were adjusted to assume either 1% or 10% of gc/cm^2 were infective.

As shown in the supplementary notes, the viral concentration on hands for each scenario was estimated from the viral bioburden, which was adjusted for the total surface area of fomites available for contact. For every estimated viral concentration on hands, a dose was then calculated for the subsequent hand-to-facial mucous membrane contact. These doses were then inputted into an exact beta-Poisson dose-response curve for relating estimated doses to probability of infection. Spearman correlation coefficients were used to evaluate the strength of monotonic relationships between model inputs and infection risk. Model equations and sensitivity analysis results are provided in Supplementary Materials.

RESULTS

Under low viral bioburden conditions (<1 genome copies (gc)/cm^2), the median infection risks were below 1:1,000,000, regardless of whether there was $\log_{10}$ reduction or whether 1% or 10% of the genome copies were assumed to be infectious (Fig 1). For the scenarios where there were high viral bioburdens (1-10,000 gc/cm^2) and there was no $\log_{10}$ reduction in viral bioburden, few infection risks were below 1:1,000,000 regardless of whether 1% or 10% of genome copies/cm^2 were infective. Under these same high viral bioburden conditions, median infection risks were below 1:1,000,000 when viral bioburden was reduced by 1 to 5 $\log_{10}$ (Fig 1).

For low viral bioburdens and 1% infectivity of detected RNA, all infection risks where disinfection with a 1-5 $\log_{10}$ reduction was used were below 1:1,000,000 (Fig 2). Note that infection risks with no $\log_{10}$ reduction for this scenario were nearly all below 1:1,000,000 as well. When 10% of gc/cm^2 were assumed to be infective and concentrations were <1 gc/cm^2, nearly all infection risks estimated for disinfection scenarios were below 1:1,000,000 whereas 1:1,000,000 was in the interquartile range of infection risks for the no $\log_{10}$ reduction scenario (Fig 2).

For higher viral bioburden scenarios (1-10,000 gc/cm^2), median infection risks for surfaces treated with disinfectant to produce 1-5 $\log_{10}$ disinfection reductions were below 1:1,000,000 when it was assumed 1% of gc/cm^2 were infective. When 10% of gc/cm^2 was assumed infective, 2-5 $\log_{10}$ reductions were required to reduce median infection risk to less than 1:1,000,000.

DISCUSSION

These simulations indicate that under low viral bioburden conditions, minimal $\log_{10}$ reductions may be needed to achieve risks less than 1:1,000,000. For higher viral bioburden conditions, $\log_{10}$ reductions of more than 2 may be needed to achieve median risks of less than 1:1,000,000, especially when assuming 10% of gc/cm^2 represent infective virus (Fig 2).

The CDC recommends a 1000 ppm bleach dilution for those isolated in home care for nonporous surface disinfection, where appropriate.[10] Sattar (1989) quantified a >3 $\log_{10}$ reduction of human coronavirus 229E with a 1000 ppm and a 5000 ppm bleach dilution.[5] Other biocidal agents, such as 70% ethanol, have demonstrated similar $\log_{10}$ reductions in carrier tests with coronaviruses.[6] Our model demonstrates that a 2-3 $\log_{10}$ reduction would, in most cases, result in risks less than 1:1,000,000 for high-viral bioburden scenarios if 1% of gc/cm^2 is assumed to be infective. However, this reduction range would be less adequate in achieving risks below 1:1,000,000 when a higher fraction of infective virus is expected (Fig 2). More data are needed describing the relationship between molecularly detected virus and infectious virus concentrations, as this affects infection risk estimates and required $\log_{10}$ reductions needed to protect health at specific risk-informed levels. While 1:1,000,000 was used as a conservative point of comparison for estimated risks, this is a *de minimis* risk level. Improvements to risk comparisons in future work include comparing infection risks estimates to rates of increased number of

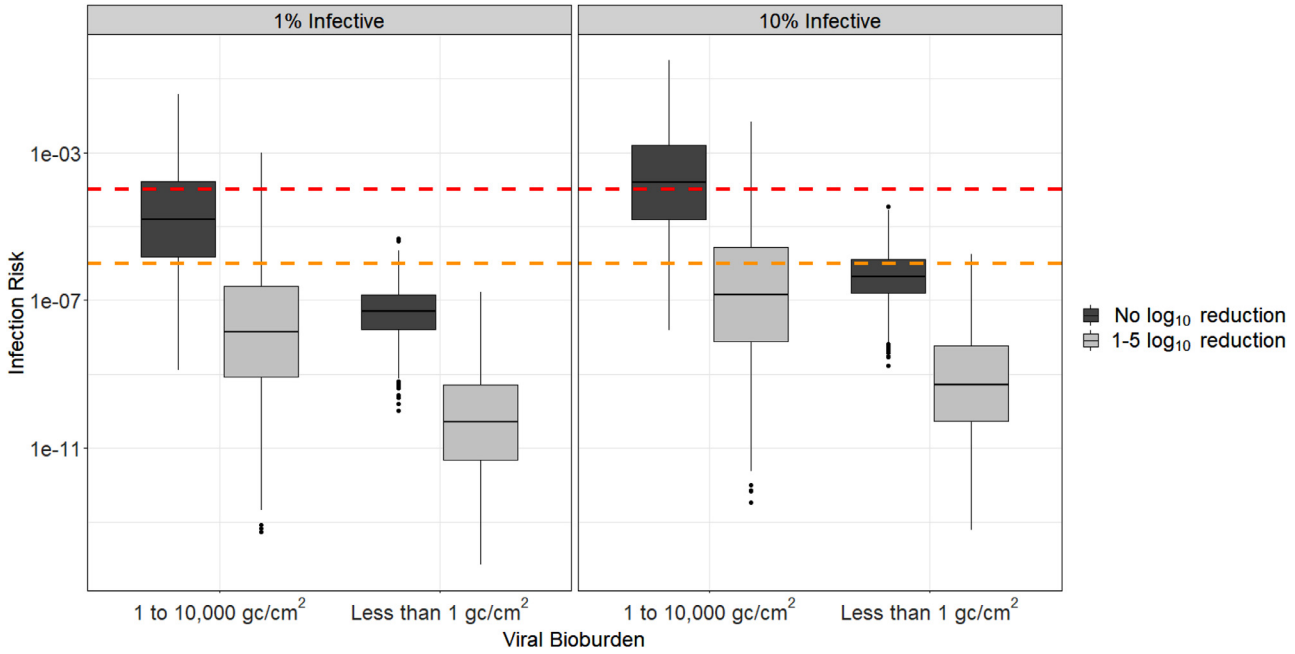

Fig 1. Infection risk distributions for low and high surface bioburdens, associated with either no $\log_{10}$ reduction or a 1-5 $\log_{10}$ reduction of bioburden on surfaces, and assuming either 1% or 10% of detected viral genome copies were infectious*. *Red and orange dashed lines represent 1/10,000 and 1/1,000,000 risk targets, respectively

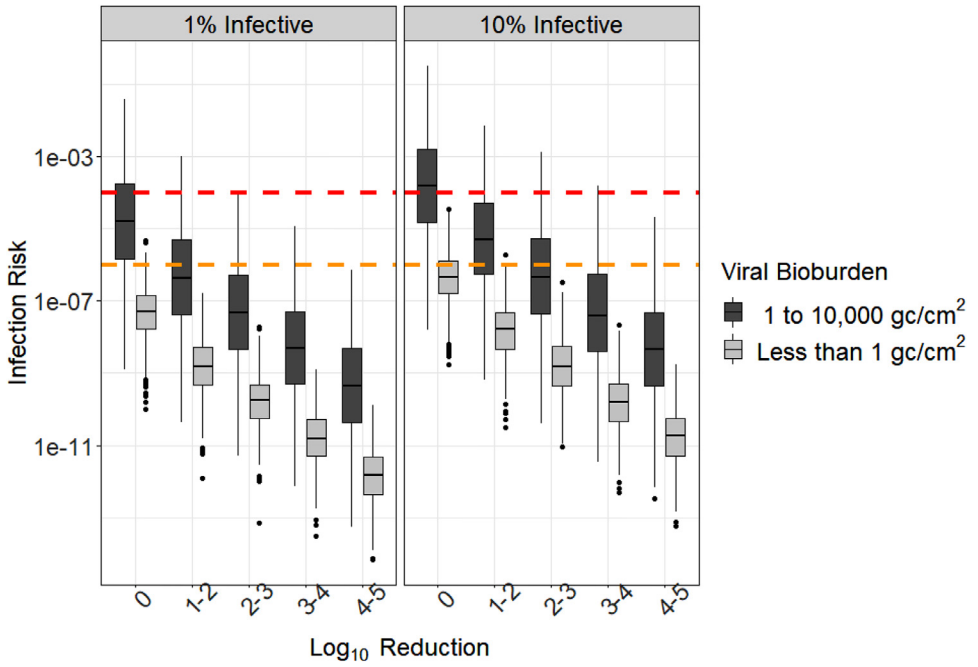

Fig 2. Infection risk distributions for low and high surface bioburdens associated with no $\log_{10}$ reduction or a range of $\log_{10}$ reductions achieved by use of disinfectant* assuming either 1% or 10% of detected viral genome copies were infectious. *$\log_{10}$ reduction ranges include no reduction (0 $\log_{10}$), greater than or equal to 1 and less than or equal to 2 $\log_{10}$, greater than 2 and less than or equal to 3 $\log_{10}$, greater than 3 and less than or equal to 4 $\log_{10}$, and greater than 4 and less than or equal to 5 $\log_{10}$ reduction. Red and orange dashed lines represent 1/10,000 and 1/1,000,000 risk targets, respectively.

illness cases. To better inform scenario-specific targeted surface hygiene, data are needed for (1) SARS-CoV-2 bioburden on different environment-specific (home or health care) fomites and (2) fomite-specific touch frequencies.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.ajic.2020.11.013.

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