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BRIEF REPORT

Quantifying the Impact of Lifting Community Nonpharmaceutical Interventions for COVID-19 During Vaccination Rollout in the United States

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Using a mathematical model, we estimated the potential impact on mortality and total infections of completely lifting community nonpharmaceutical interventions when only a small proportion of the population has been fully vaccinated in 2 states in the United States. Lifting all community nonpharmaceutical interventions immediately is predicted to result in twice as many deaths over the next 6 months as a more moderate reopening allowing 70% of prepandemic contacts.

Keywords. COVID-19; COVID-19 vaccines; mathematical model; SARS-CoV-2; variants.

More than a year after the start of the global coronavirus disease 2019 (COVID-19) pandemic, the situation is evolving rapidly, with vaccines available to all individuals over 16 years old and variants of concern rapidly emerging throughout the world. In particular, more transmissible variants such as B.1.1.7 have been increasing their presence in the United States [1]. There is a renewed enthusiasm within communities that life will soon return to normal. These positive expectations are fueled by evidence of high efficacy of COVID-19 vaccines and progress toward mass vaccination. Three highly effective vaccines (Pfizer, Moderna, and J&J) have been issued Emergency Use Authorization and distributed across the United States, with ~32% of Americans fully vaccinated by May 4, 2021 [1]. In parallel with the massive vaccination effort, multiple states are also considering the pace at which community nonpharmaceutical interventions (NPIs), for example, mask mandates, school closures, and closure or reduced capacity operations of businesses, can be relaxed. The Centers for Disease Control and Prevention (CDC) repeatedly warned that this should be a slow process and that vigilance is required in light of the spread of more infectious and virulent severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) variants [2]. In this piece, we used a mathematical model to quantify the potential negative impact that rapid dismantling of existing NPIs could have on the population-level effectiveness of vaccination programs and the potential fourth epidemic wave that could result from these measures. We quantified these effects in 2 states that have had very different management approaches to the COVID-19 pandemic, Florida and Washington.

METHODS

Here we leveraged an age-structured deterministic model of SARS-CoV-2 transmission and vaccination that we previously developed [3]. For each of the 16 age groups in the model, we track susceptible, exposed, asymptomatic, presymptomatic, symptomatic, and recovered individuals classed by disease severity. Symptomatic individuals have 1 of 3 fates: They become mildly symptomatic, hospitalized in a non–intensive care unit ward, or hospitalized requiring intensive care.

We calibrated our model for each of the 2 states by considering state-specific demographics [4, 5], infection prevalence [6], proportion of the population previously infected [6], vaccination rates, and vaccinated proportions with 1 and 2 doses of vaccine in different age groups [7, 8] as of May 4, 2021 (Supplementary Table 1). We assumed levels of vaccine efficacy against COVID-19 consistent with phase 3 trial results [9, 10] and that vaccine efficacy will be maintained against more transmissible strains. Based on parameter sets from preestablished distributions (full details in the Supplementary Data) and 1000 simulations, we report the mean number of deaths per million (deaths/1M) and 95% uncertainty intervals (UIs) (description in the Supplementary Data). We evaluated public health outcomes under 4 different scenarios, where we assumed that the ensemble of NPIs in place after May 4, 2021, would result in 30% (resembling lockdown), 50%, 70%, or 100% (lifting all NPIs) of prepandemic nonhousehold physical contacts, that is, interactions sufficient for transmission of infection in the absence of masking, hereafter "contacts." We chose as a reference a reopening scenario where some NPIs are maintained, resulting in 70% of prepandemic contacts (a 30% reduction in nonhousehold contacts). This could be achieved, for example, by continuing to enforce mask mandates as well as some additional restrictions such as moderate reduced capacity in indoor spaces. We explored 2 scenarios: 1

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in which the ensemble of circulating variants does not result in increased viral transmission and a second assuming that more transmissible variants become more prevalent, resulting in 20% increased viral transmission (full description of the methods in the Supplementary Data).

RESULTS

For Washington state, immediately lifting all NPIs (resuming prepandemic contact levels) is estimated to result in 3 times more deaths than the reference scenario, 68 deaths/1M (UI, 46–92) vs 21 deaths/1M (UI, 14–28) (Figure 1A). Furthermore, this would result in a big fourth epidemic wave (1655 active infections per 100 000 at peak; UI, 897–2285) (Figure 2A). If more transmissible variants become more prevalent, resulting in 20% increased viral transmission, then immediately lifting all NPIs would result in 2.5 more deaths than the reference scenario (50 deaths/1M; UI, 38–67; vs 127 deaths/1M; UI, 87–166) (Figure 1B) and an even larger epidemic wave (3082 active infections per 100 000 at peak; UI, 1604–4081; vs 1048 active infections per 100 000 at peak; UI, 582–1533), which would likely force another round of distancing restrictions (Figure 2B).

We repeated the analysis using Florida-specific parameters: Lifting all NPIs to prepandemic levels resulted in 6 times more deaths than the reference scenario (338 deaths/1M; UI, 227–443; vs 55 deaths/1M; UI, 33–77) (Figure 1C) and a moderate epidemic wave (1102 active infections per 100 000 at peak; UI, 614–1449) that was avoided in the reference scenario and under stricter NPIs (Figure 2C). Under increased transmission, lifting all NPIs resulted in twice as many deaths as the reference scenario (531 deaths/1M; UI, 341–725; vs 246 deaths/1M; UI, 166–321) and a bigger epidemic wave (2171 active infections per 100 000 at peak; UI, 1113–2912; vs 682 active infections per 100 000 at peak; UI, 406–881) (Figure 2D).

Under stringent NPIs, subsequent waves were largely avoided over the 6-month period for both states (Figure 2).

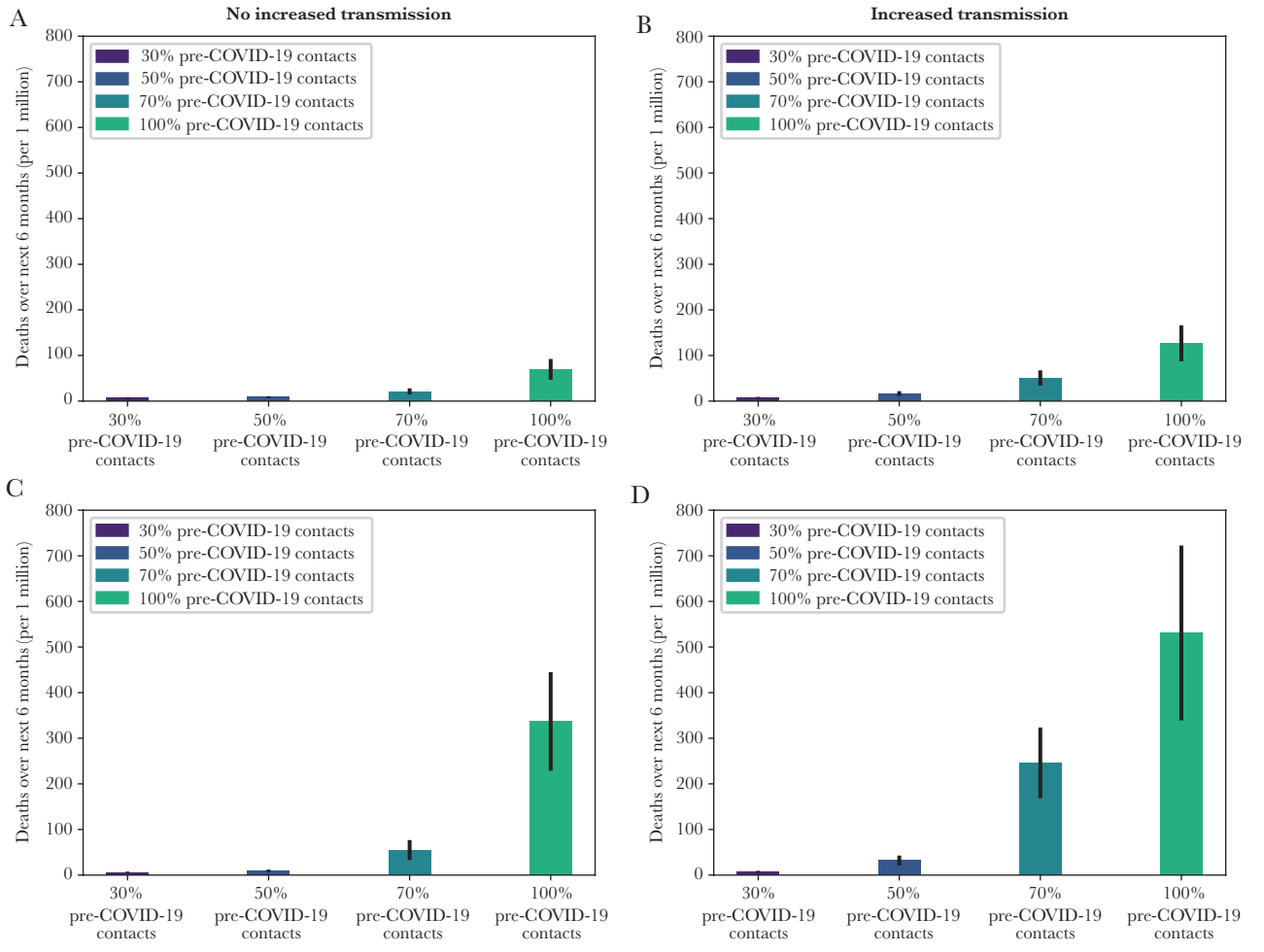

Figure 1. Estimated mean number of deaths over a 6-month period (per 1 million) for 4 different levels of NPIs restricting nonhousehold contacts, resulting in 30%, 50%, 70%, or 100% of prepandemic contacts (lifting all NPIs) in Washington state (A and B) and in Florida (C and D), assuming no increased viral transmission (left column) or 20% increased viral transmission (right column). Error bars represent 95% uncertainty intervals. Abbreviation: NPI, nonpharmaceutical intervention.

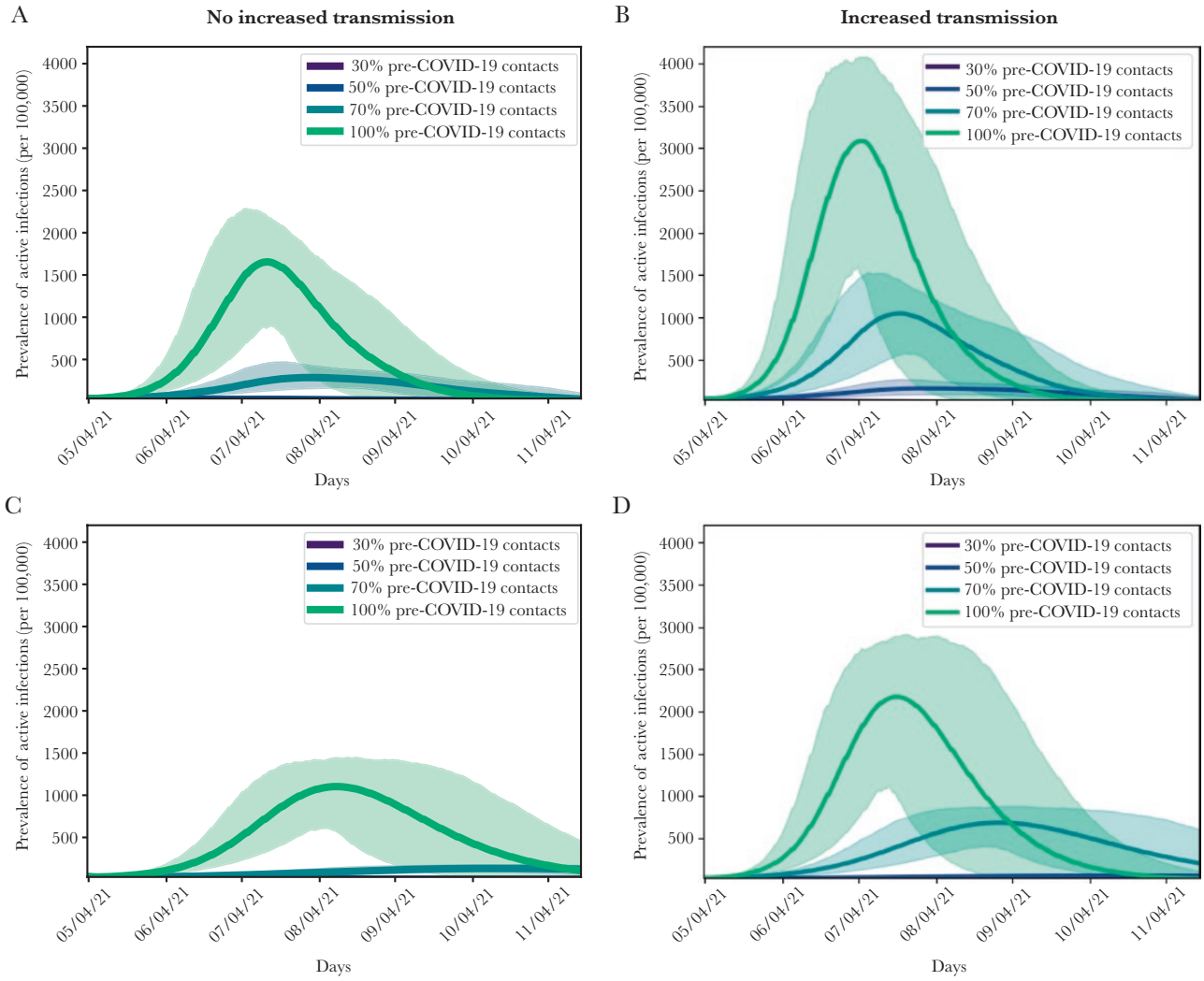

Figure 2. Prevalence of active infections (per 100 000) since May 4, 2021, for 4 different levels of NPIs restricting nonhousehold contacts, resulting in 30%, 50%, 70%, or 100% of prepandemic contacts (lifting all NPIs) in Washington state (A and B) and in Florida (C and D) with no increased viral transmission (left column) or 20% increased viral transmission (right column). The shaded areas represent 95% uncertainty intervals. Abbreviation: NPI, nonpharmaceutical intervention.

Keeping 50% of prepandemic contacts resulted in 59% and 83% fewer deaths than the reference scenario in Washington and Florida, respectively (9 deaths/1M; UI, 6–11; and 9 deaths/1M; UI, 7–12), while further reducing contacts to 30% of prepandemic contacts resulted in 68% and 89% fewer deaths than the reference scenario (7 deaths/1M; UI, 6–11; and 6 deaths/1M; UI, 5–8; for Washington and Florida, respectively). These results were more notorious under 20% increased transmission: In Washington state, stringent NPIs resulted in 85% or 68% fewer deaths than the reference scenario (7 deaths/1M; UI, 6–9; and 17 deaths/1M; UI, 11–22) when keeping contacts to 30% and 50% of prepandemic levels, respectively. In Florida, keeping contacts to 30% or 50% of prepandemic levels resulted in in 97% and 87% fewer deaths than the reference scenario (7 deaths/1M; UI, 5–10; and 32 deaths/1M; UI, 22–43) (Figure 1).

DISCUSSION

Here, we used recent numbers for vaccination rates and proportions vaccinated in Washington and Florida to provide a simple yet useful quantification of the impact of partial or total lifting of NPIs while vaccines are being rolled out. Our results suggest that under current transmission levels, a full reopening of society that restores prepandemic levels of physical interaction could result in at least 3 times more deaths as compared with a partial reopening where mask mandates and some moderate restrictions are kept in place until a larger proportion of the population has been vaccinated. Additionally, it is plausible that uncontrolled viral transmission will facilitate the establishment of new variants, some of which are known to be more virulent [11]. Our results suggest that if a new, more transmissible variant like B.1.1.7 becomes more prevalent, resulting in 20% increased

viral transmission, lifting all NPIs would result in twice as many deaths as a partial reopening even if existing vaccines are equally effective against this variant. These results buttress and provide quantitative evidence in support of the case being made by a number of other authors that complete reopening of society is premature [12].

Our results are in line with several modeling studies to date that have suggested that population effectiveness of COVID-19 vaccination will be limited if the epidemic is not controlled using other means during rollout [13–17]. We previously demonstrated that if an epidemic outbreak were to occur during the vaccination rollout before a substantial proportion of the active population was immunized, it would substantially decrease the population impact of vaccination both in terms of transmission and mortality reduction [3, 18]. In an earlier analysis, we showed that in the absence of emerging variants physical interactions should never increase beyond 70% of the pre-COVID-19 levels in order to prevent a new epidemic wave in 2021 [19].

Our work has several limitations. We assumed that the vaccination rate would remain constant throughout the ensuing 6-month period. Increasing numbers of vaccine doses are expected to be available in the next weeks or months, and rollout might accelerate. We assumed a fixed level of NPIs, although NPI utilization during the pandemic has been variable in space and time and new NPIs could be potentially imposed in the face of expanding numbers of infections. We also assumed that vaccines would remain highly efficacious against new variants, but studies suggest that decreased vaccine efficacy against certain variants is possible [20, 21], which may increase the projected gap between scenarios with and without emerging variants. We assumed that a more transmissible variant would result in a 20% increased overall transmission, but this percentage will be highly dependent on the competition between circulating strains, their fitness vis-à-vis vaccines, and potential cross-immunity. As of May 4, 2021, genetic sequencing data suggest that B.1.1.7 was 39% and 64% prevalent in Washington and Florida, respectively [22, 23]. Assuming B.1.1.7 is 50% more transmissible [24], this would result in a 19% and 32% viral transmission increase, respectively. In this sense, our results for Florida are conservative. This highlights the need for close monitoring of the prevalence of emerging variants, for evaluation of their infectivity and virulence, and for studies estimating possible decreases in vaccine efficacy. All this information should be taken into account when decisions regarding decreasing or lifting NPIs are being made.

The need to lift NPIs is urgent, particularly in light of impacts to the education system and the economy. Here, we demonstrate that as vaccines are rolled out, it is imperative to gradually lift the NPIs currently in place in order to safeguard the population impact of vaccination. A risk-stratified approach that takes into account the level of preexisting immunity as well as the proportion of the population vaccinated is needed to safely remove all restrictions.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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Patient consent. The present work is a simulation study. Hence, this study does not include factors necessitating patient consent.

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