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BRIEF REPORT

Modeling the Impact of Vaccination Strategies for Nursing Homes in the Context of Increased Severe Acute Respiratory Syndrome Coronavirus 2 Community Transmission and Variants

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Using an agent-based model, we examined the impact of community prevalence, the Delta variant, staff vaccination coverage, and booster vaccines for residents on outbreak dynamics in nursing homes. Increased staff coverage and high booster vaccine effectiveness leads to fewer infections, but cumulative incidence is highly dependent on community transmission.

Keywords. Covid-19; nursing homes; booster dose; vaccination.

Nursing home (NH) residents and staff were among the first to receive coronavirus disease 2019 (COVID-19) vaccines in the United States owing to the high risk of severe disease and spread in this congregate setting [1]. Vaccination has contributed to dramatic decreases in overall NH cases; however, in July 2021 cases began increasing again [2]. Studies have found decreased vaccine effectiveness (VE) in NHs over time [3], which may be due to waning, decreased effectiveness against the Delta variant, increased community importation as COVID-19 incidence has increased, or a combination of factors.

On 5 September 2021, the average vaccination coverage among NH residents was 84% in the United States; however, coverage among NH staff was approximately 64%, with wide variability across facilities [4]. Vaccination mandates are being considered for healthcare facilities receiving Centers for Medicare & Medicaid Services reimbursement, including NHs [5]. As efforts to increase staff coverage continue and booster doses for residents are made available, it is important to understand the potential impact of these additional vaccine doses to set vaccine program priorities.

Here we examine the impact of high community prevalence and the more infectious Delta variant of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) on the expected distribution of infections among people in NH settings. We then look at the effects of different vaccination strategies for NH residents and staff, evaluating a range of levels of staff coverage and different scenarios of booster effectiveness.

METHODS

We build on a previously published model of a NH with 100 residents and 100 staff [6, 7]. The model incorporates data on resident turnover, with a median stay of 30 days, [8] and census at 100% capacity. Transmission of SARS-CoV-2 is stochastic, based on the probability of transmission given contact, the number of daily contacts, and the total number of infected individuals (Supplementary Table 1). Our model assumes that all infections are with the Delta variant of SARS-CoV-2, the dominant variant across the United States in August 2021 [9].

Staff have a daily probability of infection from the community, which we vary to reflect different community prevalence levels. We conduct nonoutbreak screening testing of unvaccinated staff twice per week, in line with guidance for NHs located in counties with substantial community transmission [10]. When a case is identified, all residents and staff in the NH are tested twice weekly for the outbreak's duration. Residents have a daily probability of interacting with a visitor from outside the NH population [11].

We include 3 effects of a 2-dose vaccine in the model, based on data from messenger RNA vaccine studies (Supplementary Table 1). First, the vaccine confers protection against infection, reducing the probability of infection given exposure. Second, we incorporate protection against infectiousness (ie, transmission); this is a measure of the relative infectiousness of vaccinated infected individuals (ie, breakthrough infections) compared to unvaccinated infected individuals. Third, we model VE against progression to symptoms among vaccinated individuals who get infected. VE against symptomatic disease, the primary end point in the vaccine trials, is a combination of VE against infection and VE against progression to symptoms (Supplementary Table 1). Given the potential impact of age on VE, we compare a scenario in which the VE against infection is lower for residents than for staff [12–14] with a scenario in which it is equal.

We compare 2 vaccination strategies: (1) varying staff vaccination coverage between 40% and 100% and (2) giving a booster dose to all vaccinated residents (assuming coverage in residents remains at 80%). The VE against infection following a

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booster is uncertain, so we consider a range from 60% to 90%. At the beginning of each simulation, we assume that everyone who is vaccinated has already received 2 doses; in scenarios with a booster, it is given on the first day and takes 14 days to take effect.

We show results from 100 simulations after 2 months. Our primary outcomes of interest are the cumulative incidence of symptomatic infections and the cumulative incidence of all infections (symptomatic and asymptomatic) in residents. We also look at these measures in residents and staff combined. The code is available at https://github.com/rek160/NHboosters.

RESULTS

We estimated the distribution of cumulative incidence among residents after a 2-month period, disaggregated by symptom status and vaccination status (Supplementary Figure 1). We focused initially on the impact of VE against infection among residents and of staff importation rate, in the absence of booster doses. In these simulations, resident vaccination coverage is 80% and staff vaccination coverage is 60%. There is a median of 216 unique residents over this period (interquartile range, 209–224 residents). Across the 100 simulations, stochasticity leads to varying numbers of infections; however, we demonstrate important trends by comparing the distributions. A higher staff importation rate results in more infections among all residents. Higher VE against infection among residents leads to similar trends in the distribution of infections by vaccine and symptom status but lower cumulative incidence. The 20% of residents who are unvaccinated contribute almost as many symptomatic infections as the 80% who are vaccinated (mean, [standard error], 1.30 [0.06] and 1.85 [0.08], respectively). The majority of infections in vaccinated residents are asymptomatic owing to the vaccine's efficacy against symptomatic disease.

We evaluated the impact of varying staff coverage and booster effectiveness on the cumulative incidence among residents. In these simulations, booster doses are provided to all vaccinated residents, including incoming residents. We found that increased staff coverage led to fewer infections, and the cumulative incidence was highly dependent on community transmission. Providing boosters to residents led to fewer infections, with the magnitude of the impact of boosters increasing with higher VE. The trends were similar when comparing the cumulative incidence of symptomatic infections (Figure 1A) with the cumulative incidence of all infections (Figure 1B).

We observed similar trends when looking at symptomatic infections (Supplementary Figure 2*A*) and total infections (Supplementary Figure 2*B*) in residents and staff combined. However, there was a larger impact of increasing staff coverage as these metrics capture the direct protection of the vaccine in staff in addition to the indirect protection provided to residents. When VE against infection in residents was equivalent to VE against infection in staff (Supplementary Figures 3 and 4), we saw similar trends but lower cumulative incidence. When we assume that VE against infectiousness is higher, we also saw similar trends but lower cumulative incidence (Supplementary Figures 5 and 6).

DISCUSSION

Several factors influence the risk of SARS-CoV-2 outbreaks in NHs, and multifaceted approaches are required to protect this vulnerable population. We find that maximizing vaccine coverage among NH staff remains a critical tool for preventing infections, supporting the Centers for Medicare & Medicaid Services interim final rule [15]. While boosters for residents can reduce infections, our simulations show the magnitude of the effect depends on their efficacy, which remains uncertain. Early evidence suggests boosters increase VE in people aged ≥60 years, although the durability of this increased protection is unknown [16, 17]. However, even with high-efficacy boosters, when community transmission is high, our simulations suggest that symptomatic infections in NHs will continue.

Community transmission is among the main drivers of infections in NHs, highlighting that control of community transmission and continued infection prevention and control measures remain important, as others have found in NH populations [18]. Our results demonstrate that an increase in NH infections does not necessarily indicate lower or waning VE if community transmission is rising.

The largest reduction in transmission occurred in simulations with both high staff coverage and high booster efficacy. Direct comparison of the 2 strategies is challenging because the impact of each strategy depends on assumptions about VE. In addition, the 2 strategies require different numbers of vaccines: increasing staff coverage will require fewer doses in most NHs than providing boosters to all vaccinated residents, given the high rate of resident turnover.

Our results are subject to several limitations. As described elsewhere [5, 7], while our model incorporates data on contact structure from NHs and separately models contacts between residents and staff, we do not further differentiate between types of contacts. We also assume that all residents and staff have never been infected, which may underestimate the level of immune protection (particularly for the unvaccinated). The increase in VE against symptomatic disease from boosters in our simulations could be achieved through multiple combinations of increases in VE against infection and VE against progression to symptoms.

Studies of boosters have found large reductions in severe disease from boosters beyond their protection against infection [16]. However, given limited data on protection against any symptoms (not only severe), for simplicity, we have chosen to model increases in VE against symptomatic disease through an increase in VE against infection, leaving VE against progression to symptoms constant. This may result in slight overestimation

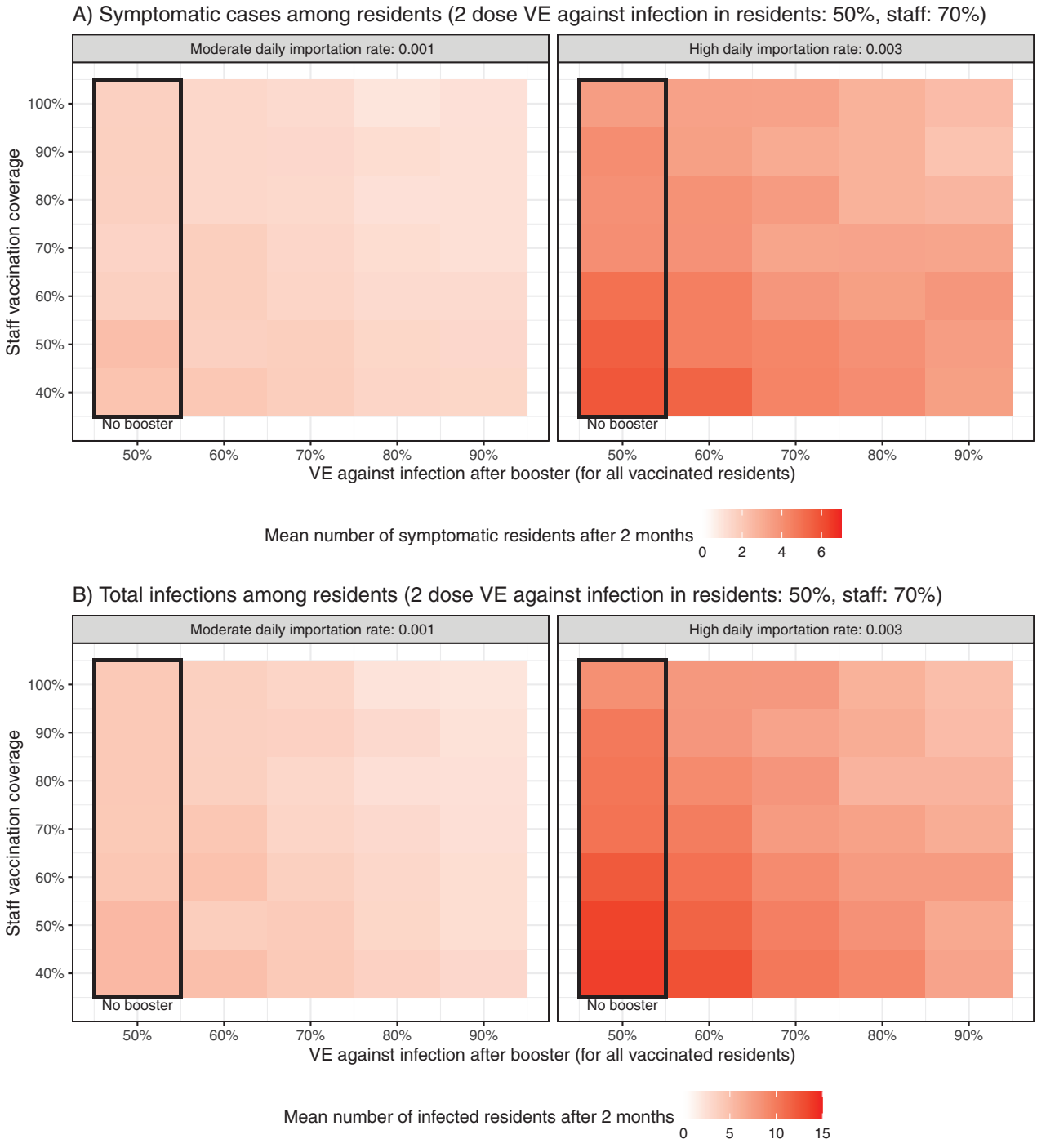

Figure 1 *A,* Symptomatic severe acute respiratory syndrome coronavirus (SARS-CoV-2) infections among residents (2-dose vaccine effectiveness [VE] against infection, 50% in residents and 70% in staff). *B,* Total SARS-CoV-2 infections among residents (2-dose VE against infection, 50% in residents and 70% in staff). Shown are the average cumulative numbers of infections across 100 simulations of symptomatic residents (*A*) and symptomatic and asymptomatic residents (*B*) after 2 months, varying staff coverage (*rows*), booster VE (*columns*), and staff importation rates (*panels*).

in total infections prevented, but the results for symptomatic cases should hold. Although they are important end points, given limited data and heterogeneity in hospitalization criteria between facilities, we do not model severe disease or deaths and instead distinguish only between asymptomatic and symptomatic infection. This may underestimate the impact of vaccines on disease severity, because symptomatic infections among vaccinated individuals may be less severe.

Supplementary Data

Supplementary materials are available at *Clinical 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.

Notes

Disclaimer. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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