Disparities in SARS-CoV-2 Vaccination-to-Infection Risk During the COVID-19 Pandemic in Massachusetts

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Introduction

Effective vaccine-based containment strategies for SARS-CoV-2 require equitable coverage of communities at greatest risk of infection.1 Adapting a concept from HIV-prevention efforts,2 we examined the alignment of vaccination and SARS-CoV-2 risk in Massachusetts by creating and applying a vaccination-to-infection risk (VIR) ratio.

Methods

We aggregated community SARS-CoV-2 testing and vaccination data from the Massachusetts Department of Public Health and the Boston Public Health Commission from January 29, 2020, through June 24, 2021. Data were available for 293 distinct communities (278 cities and towns, and 15 Boston neighborhoods) with a cumulative population of 6,755,622 (98.6%). We adhered to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines. This study involved the use of public anonymized data and was therefore designated as exempt by the Mass General Brigham Institutional Review Board.

We considered each community's cumulative incidence of confirmed SARS-CoV-2 infections to be the best available indicator of future infection risk. We used 2 approaches to assess vaccination equity: VIR ratio and Lorenz curves. The VIR ratio was calculated for each community as the quotient of the number of fully vaccinated individuals divided by the cumulative number of confirmed SARS-CoV-2 infections. Communities with VIR ratios below the statewide mean have lower vaccination coverage relative to their infection risk. Lorenz curves, which assess equity in resource distribution,3 were used to describe vaccination relative to COVID-19 burden and calculate summaries of inequity (Gini index) and magnitude of vaccine reallocation required to achieve equity (Hoover index).

We used population estimates from the Massachusetts Department of Public Health and the American Community Survey to determine community age, race, and ethnic composition. Socioeconomic vulnerability was estimated using the Socioeconomic Status domain of the Social Vulnerability Index (census tract ranks aggregated by community). We fit a negative binomial model using robust sandwich estimators to assess associations between community VIR ratios and a priori-selected predictors: proportion 65 years or older (an early vaccination eligibility criterion), proportion identified as Black and/or Latinx individuals (<20% or ≥20%), quartile of socioeconomic vulnerability, and community size (<7500 or ≥7500 residents). Analyses were conducted in R, version 4.0.5 (R Foundation), and a 2-tailed P < .05 was considered statistically significant.

Results

As of June 24, 2021, 649,379 (8.9%) SARS-CoV-2 infections had been confirmed in 6,755,622 residents of included communities, and 3,880,706 (57.4%) were fully vaccinated. Cumulative incidence of confirmed SARS-CoV-2 infection (minimum, 1.6%; maximum, 24.1%) and complete vaccination (minimum, 26.5%; maximum, 99.6%) varied considerably between communities.
Figure 1. Vaccination-to-Infection Risk (VIR) Ratio Among the 100 Largest Massachusetts Communities, Ordered by Socioeconomic Vulnerability

The VIR ratio is calculated as the cumulative number of fully vaccinated individuals divided by the cumulative number of confirmed SARS-CoV-2 infections in each community reported from January 29, 2020, through June 24, 2021. Mean VIR by socioeconomic quartile: low, 10.8; low to moderate, 7.36; moderate to high, 5.40; and high, 2.99. Socioeconomic vulnerability was estimated using the Socioeconomic Status domain of the Centers for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI).
Communities with increased socioeconomic vulnerability had lower VIR ratios indicating less equitable vaccination relative to infection risk (Figure 1).

In multivariable analysis, decreased vaccination relative to infection risk was independently associated with increasing socioeconomic vulnerability (adjusted relative risk [aRR], 0.82 per quartile increase; 95% CI, 0.76-0.87; \( P < .001 \)) and when more than 20% of the community identified as Black and/or Latinx individuals (aRR, 0.73; 95% CI, 0.62-0.86; \( P < .001 \)). Improved community vaccine coverage was associated with higher community proportion of residents 65 years or older (aRR, 1.11 per 5% increase in proportion; 95% CI, 1.03-1.20; \( P = .007 \)) and community size fewer than 7500 residents (aRR, 1.48; 95% CI, 1.30-1.68; \( P < .001 \)).

Lorenz curves indicated considerable inequity, with an estimated Gini coefficient (1, complete equity; 0, complete inequity) of 0.51 between communities and 0.47 by race and ethnicity of individuals (Figure 2). An estimated 810 000 full vaccination courses would need to be diverted to undervaccinated communities to achieve equity.

**Discussion**

In this cohort study, analysis of SARS-CoV-2 vaccination indicated structural disparity in vaccine distribution with lower vaccine coverage to infection risk in communities with increased socioeconomic vulnerability and larger proportions of Black and Latinx individuals. While a limitation of this study is that these analyses do not directly assess the mechanisms of disparity, Massachusetts prioritized large hospital systems and mass vaccination sites\(^4\) rather than strategies to mitigate structural racism recommended by others.\(^5,6\) In conclusion, disparities in vaccine coverage highlight ongoing inequities in the approach to COVID-19 and imperil efforts to control the pandemic.
ARTICLE INFORMATION

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