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Association of Social Vulnerability, COVID-19 vaccine site density, and vaccination rates in the United States

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ABSTRACT

The COVID-19 pandemic has disproportionately impacted Americans in socially vulnerable areas. Unfortunately, these groups are also experiencing lower vaccination rates. To understand how strategic vaccine site placement may benefit high vulnerability populations, we extracted vaccine site locations for 26 U.S. states and linked these data to county-level adult vaccination rates and the CDC 2018 Social Vulnerability Index rankings. We fit quasi-Poisson regression models to compare vaccine site density between the highest and lowest SVI domain quartiles, and assessed whether greater vaccine site density mediated or modified the relationship between social vulnerability and vaccination rates. We found that high vulnerability counties by socioeconomic status had more vaccine sites per 10,000 residents, yet this higher vaccine site density did not reduce socioeconomic disparities in vaccination rates. Persistent vaccination inequities may reflect other structural barriers to access. Our results suggest that targeted vaccine site placement in high vulnerability counties may be necessary but insufficient for the goal of widespread, equitable vaccination.

1. Introduction

The COVID-19 pandemic has disproportionately impacted socially vulnerable populations across the U.S.1 Unfortunately, these groups have also had lower vaccination rates.2,3 If vaccine sites are strategically placed in high vulnerability counties, as several state implementation plans attempted,4–6 this may facilitate equitable distribution.7 Yet, the potential benefits of county-level targeted site placement may be offset by non-residents receiving vaccines at these sites or by other structural barriers limiting access for populations at greatest risk.8,9

Across metropolitan and non-metropolitan U.S. counties, we examined relationships between social vulnerability, vaccine site density (sites per 10,000 residents), and vaccination rates as of April 2021. We sought to understand how vaccine site placement may benefit high vulnerability populations by assessing whether greater vaccine site density mediated or modified the relationship between social vulnerability and vaccination rates.

2. Materials and methods

We determined county-level vaccine site density by extracting COVID-19 vaccine site addresses from health department websites of the 26 states with reliable data (i.e., regularly updated and inclusive of vaccine site types ranging from state mass vaccination sites and local health department clinics to private medical offices and pharmacies) as of 4/1/2021. We validated county assignments as needed using a geocoding application (Geocodio) (details in Appendix).

We linked vaccine site density data to county-level adult vaccination rates from the U.S. Centers for Disease Control and Prevention (CDC) as of 4/1/202110; the CDC 2018 Social Vulnerability Index (SVI) domains (socioeconomic status [SES], household composition/disability, minority status/language, and housing/transportation)11; and urbanicity, defined by the U.S. Department of Agriculture’s 2013 Urban Influence Codes.12

We fit quasi-Poisson regression models to compare vaccine site density between the highest and lowest SVI domain quartiles. We fit

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linear regression models to assess associations between SVI domains and county vaccination rates, controlling for percent population >65-years-old. For the SVI domain most strongly associated with vaccination rates (based on partial R^2), we added county-level vaccine site density to the model as a potential mediator. We then assessed if site density modified the relationship between social vulnerability and vaccination rates by adding interaction terms between the continuous SVI domain index score and indicators for counties in the highest and lowest quartiles of vaccine site density. Comparing the slopes of the SVI domain index score between counties with the highest and lowest vaccine site densities allowed us to see whether disparities in vaccination rates were worse in counties with few vaccination sites. In secondary analyses, we stratified counties by urbanicity. All models were population-weighted and included state fixed effects to account for heterogeneity in vaccine policy.

We used R Statistical Software, v4.0.5 and considered 2-sided P < 0.05 significant. The Mass General Brigham Review Board waived study review.

3. Results

We identified 22,480 vaccine sites across 1738 counties (mean 2.17 per 10,000 residents, SD 2.22; median 1.50, IQR 0.85–2.73). States with the highest mean county-level site densities were North Dakota (8.15) and Alaska (4.62); those with the lowest were Massachusetts (0.53) and Rhode Island (0.66).

Overall SVI was not associated with vaccine site density (Table 1). However, the most vulnerable counties by SES and household composition/disability SVI domains had higher vaccine site density than the least vulnerable (adjusted risk ratio [aRR] 1.25; 95%CI 1.16–1.34 and 1.33; 95%CI 1.25–1.42, respectively). The most vulnerable counties by minority status/language had lower vaccine site density (aRR 0.73; 95% CI 0.67–0.79).

Among included counties, mean adult vaccination rate was 19.6% (SD 8.5). The SES domain had the strongest association with vaccination rates (partial R^2 = 0.069); counties in higher SES vulnerability quartiles (Q2-Q4) had 1.8, 2.2, and 3.9 percentage-point lower vaccination rates, respectively, than counties in the least vulnerable quartile (Table 2). When including vaccine site density in the model, each additional vaccine site per 10,000 residents was associated with a 0.65 percentage-point increase in vaccination rates. However, site density did not mediate the association between SES vulnerability and vaccination rate overall or within metropolitan and non-metropolitan counties.

Across levels of SES vulnerability, counties with high vaccine site density had higher vaccination rates than counties with low site density (Fig. 1). However, vaccine site density did not modify the relationship between SES and vaccination rates: there was no significant difference in the slope of the SVI SES domain index score between counties with low and high site density. These patterns persisted within metropolitan counties and within non-metropolitan counties.

4. Discussion and conclusions

In this cross-sectional study of COVID-19 vaccination rates and vaccine site density across the United States, counties with high SES vulnerability had greater vaccine site density than those with low vulnerability. As expected, greater vaccine site density was associated with higher vaccination rates for counties at all levels of SES. However, greater vaccine site density did not reduce socioeconomic inequities in vaccination rates.

The most vulnerable counties by socioeconomic status had more vaccine sites per capita, which may reflect targeted placement efforts or increased prevalence of community vaccination venues in low-income areas. Counties with high vulnerability by minority status/language had fewer sites, perhaps due to downstream consequences of structural racism on the geographic maldistribution of underlying infrastructure to establish sites. For these counties, unavailability of vaccine sites may have compounded other structural barriers to vaccine uptake.

Consistent with other studies, we found a strong association between socioeconomic vulnerability and low vaccination rates that has persisted

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Table 1

| Social Vulnerability Indexa | Social Vulnerability Indexb | Non-metropolitan | Metropolita | Non-metropolitan | Metropolitan | Non-metropolitan | Metropolitan | Metropolitan | Metropolitan | Non-metropolitan | Metropolitan | Non-metropolitan | Metropolitan | Non-metropolitan | Metropolitan | Non-metropolitan | Metropolitan |
|---------------------------|---------------------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|-------------|-------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|
| Q1                        | Q2                        | Q3              | Q4          | Adjusted Risk Ratio for Q4/Q1 (95% CI) | Q1 (0.985) | Q2 (0.963) | Q3 (1.13) | Q4 (1.10) | (0.963) | (1.13) | (0.963) | (1.13) | (0.963) | (1.13) | (0.963) | (1.13) | (0.963) | (1.13) |
| 1.22 (1.08) | 1.34 (1.07) | 1.12 (0.960) | 1.29 (0.963) | 1.06 (0.985), (0.963) | 1.13 (0.963) |
| 0.853 (0.957) | 0.786 (0.760) | 1.11 (1.24) | 1.00 (1.10) | 0.968 (0.865), (0.796) | 1.01 (0.760) |
| 2.03 (1.93) | 2.23 (1.53) | 1.11 (1.10) | 1.25 (1.23) | 1.08 (0.961), (1.22) | 1.08 (0.961) |
| 1.21 (1.10) | 1.23 (1.12) | 1.25*** | 1.05 (1.12) | 1.16, (1.34, (1.12) | 1.04 (0.940) |
| 2.03 (1.55) | 1.42 (1.24) | 1.25*** | 1.05 (1.24) | 1.06 (0.936), (1.21) | 1.06 (0.936) |
| 1.05 (1.16) | 1.39 (1.86) | 1.33*** | 1.05 (1.42) | 1.21 (1.25, (1.42) | 1.21 (1.25, (1.42) |

Data extracted on April 1, 2021.

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*a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *v*, *w*, *x*, *y*, *z*
Table 2
Association of adult COVID-19 vaccination rate with socioeconomic vulnerability and vaccine site density.

|                      | All Counties | Metropolitan Counties | Non-metropolitan Counties |
|----------------------|--------------|-----------------------|--------------------------|
|                      | N = 1483     | N = 595               | N = 888                  |
| A                    | A            | A                     | A                        |
| B                    | B            | B                     | B                        |
| Socioeconomic Status, Q2 | -1.81*** (0.274) | -1.86*** (0.273)     | -1.72*** (0.390)       |
| Socioeconomic Status, Q3 | -2.24*** (0.290) | -2.32*** (0.289)     | -2.23*** (0.414)       |
| Socioeconomic Status, Q4 | -3.93*** (0.419) | -4.16*** (0.423)     | -4.59*** (0.732)       |
| Vaccine Sites per 10,000 Residents | 0.654*** (0.194) | 0.997* (0.481)       | 0.609*** (0.166)       |

Data extracted on April 1, 2021.
***p < 0.001, **p < 0.01, *p < 0.05.
Q1 = least vulnerable quartile; Q4 = most vulnerable quartile. Standard errors in parenthesis.
Regression coefficients in columns labeled as (A) included SES vulnerability quartiles as predictors and vaccination rate as the outcome. Regression coefficients in columns labeled as (B) additionally included vaccine site density as a potential mediator. All regressions are weighted by county population, adjusted for state fixed effects, and adjusted for the proportion of the population ≥65 years old.

* County-level vaccination rate was defined as percent of the population ≥18 years old with a completed vaccination series. Counties in Texas and one county in Alaska did not have vaccination rate data and were not included.

Metropolitan and non-metropolitan designations were determined from the 2013 Urban Influence Codes: 1–2 were classified as “Metropolitan”, while 3–12 were classified as “Non-Metropolitan.”

The Socioeconomic Status domain of the Social Vulnerability Index includes income, poverty, employment, and education variables.

Fig. 1. Association of Adult COVID-19 Vaccination Rate with Socioeconomic Vulnerability in Counties with High and Low Vaccine Site Density.

The county-level vaccination rate by socioeconomic vulnerability rank in the lowest (N = 408) and highest (N = 359) vaccine site density quartile. County-level vaccination rate was defined as percent of the population ≥18 years old with a completed vaccination series. Counties in Texas and one county in Alaska did not have vaccination rate data and were not included.

The linear model to compare slopes between low and high site density counties included vaccination rate as the outcome, and SES vulnerability, a binary variable for high vaccine site density counties, and their interacted term as predictors. The regression was weighted by county population and adjusted for state fixed effects and the proportion of the population ≥65 years old.

Our results suggest that targeted vaccine site placement in high vulnerability counties may be necessary but insufficient for the goal of widespread, equitable vaccination. Vaccines should be strategically allocated in tandem with policy interventions to address structural access barriers.

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Reproducible Research Statement

Study protocol: Not applicable. Statistical code: Available upon request from Ms. Thakore (Nitya.Thakore@nyu-langone.org). Data availability: Vaccine site location data are available upon request from Ms. Thakore.
(Nitya.Thakore@nyulangone.org). Other datasets analyzed for this study are readily available from the public repositories listed in the references.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Dr. Ganguli reports consulting fees from F-Prime and Blue Cross Blue Shield Massachusetts for work unrelated to this research. No other authors have relevant conflicts of interest to report.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.hjdsi.2021.100583.

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