Brief Communications

Interactive, on-line visualization tools to measure and drive equity in COVID-19 vaccine administrations

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Received 18 April 2021; Revised 29 July 2021; Editorial Decision 2 August 2021; Accepted 2 September 2021

ABSTRACT

Equitable distribution of vaccines is necessary to ensure those at highest risk of illness are protected from COVID-19 (coronavirus disease 2019). Unfortunately, there is significant evidence that vaccines have not been reaching the most vulnerable. At our large hospital system, we created interactive online tools to measure and visualize equitability of vaccine administrations and to help stakeholders identify populations at highest risk within state-designated eligible vaccine groups. Using race, ethnicity, gender, and social vulnerability, we are able to measure and reflect our vaccine administration performance against the communities that we serve. With our visualization tools, stakeholders have been able to target interventions to improve equity in vaccine administrations, including improvements in race, ethnicity, and social vulnerability. We plan to use the data elements incorporated in our electronic health record and data warehouse due to the COVID-19 pandemic to guide further population health efforts at decreasing disparities.

Key words: equity, dashboard, visualization, COVID-19 vaccine

INTRODUCTION

On January 11, 2021, University of North Carolina (UNC) Health began online scheduling of coronavirus disease 2019 (COVID-19) vaccinations for the general population 75 years of age and over. Within days, vaccine sites reported that vaccines were not being administered to local communities, but rather to more advantaged people traveling to their sites from surrounding counties. This misallocation of vaccines created racial, ethnic, and socioeconomic disparities, similar to patterns seen around the state and country.1–3 Because marginalized communities are at higher risk for COVID-19 infection,2 inequities in vaccinations would accentuate these disparities in infection rates. In response to these concerns, UNC governance created a task force, COVER-NC (Covid Vaccine Equity Reimagined for North Carolina) to address inequities in vaccine administration.

The COVER-NC task force requested race, ethnicity, and language (REaL) visualization of vaccine equity at each site. However, REaL data became inadequate as a measure of equity as eligibility expanded to include groups (such as teachers and high-risk individuals) for which we lacked accurate population level REaL data for comparison to our vaccinated group.4 This report summarizes the efforts to analyze and visualize inequity across multiple domains of race, ethnicity, gender, socioeconomic status, and other social vulnerability factors.

MATERIALS AND METHODS

Setting and population

UNC Health is a large academic health care system with eleven hospitals and over 6000 providers in central North Carolina. Vaccines
were distributed by the North Carolina Department of Health and Human Services to UNC Health in December 2020. On January 11, 2021, vaccines became available to the public in eligibility groups starting with patients \( \geq 75 \) years of age.\(^4\) The analysis and tools described were applied to all UNC community vaccinations.

**Visualizing inequity by race and ethnicity**

For Group 1b (age \( \geq 75 \)) and Group 2a (age \( \geq 65 \)) patients,\(^4\) we created a visualization tool focusing on the Community Reflection Index (CRI), defined as a measure of how well vaccine administration reflects the demographic makeup of the communities surrounding vaccine sites. The CRI is calculated as the ratio of the proportion of vaccine administrations delivered to a specific demographic group (observed) to the proportion of the community that group represents according to public census data (expected),\(^5\) using a 10-mile radius as a catchment area around vaccine sites.

The expected community demographics were calculated from the Public Use Microdata Sample (PUMS)\(^6\) provided by the Census Bureau. Survey respondents were mapped to vaccine eligibility groups using age and North American Industry Classification System codes for essential workers.\(^6\) Geography is available at the Public Use Microdata Area level, with each area having a population of 100 000 people. For each vaccine site, the expected community demographics are the average of the demographics for each Public Use Microdata Area that intersects a 10-mile radius around the site, weighted by the area of the intersection and population size.

CRI observed-to-expected ratios \(<1\) indicate underrepresentation of vaccine administrations in the target population, while CRI values \(>1\) indicate overrepresentation. Community representation changed slightly throughout the study period as additional vaccine sites were added.

**Visualizing inequity across multiple domains using the Centers for Disease Control and Prevention Social Vulnerability Index**

The Centers for Disease Control and Prevention publishes the Social Vulnerability Index (SVI), a methodology for ranking U.S. census tracts by their relative vulnerability across 15 social factors, including poverty, unemployment, household composition, minority status, and access to transportation.\(^7\) Tracts are ranked within each census variable, and scores are aggregated into an overall ranking. Rankings are reported as a ratio ranging from 0 to 1 indicating the portion of tracts in the same state with lower overall vulnerability. Higher values indicate greater vulnerability. We elected to use the overall SVI designation for each census tract in the state of North Carolina to meet our project objectives.

**Data sources and governance**

COVER-NC’s leadership reported on progress and received feedback twice weekly from system informatics and operational governance. UNC Health operates a robust enterprise data warehouse that serves to integrate external and internal data sources for use within Epic@UNC and for external analytics and visualization tools, research, and financial applications. We geocoded addresses for all UNC Health patients to map them to a latitude, longitude, and census tract and stored the data in our enterprise data warehouse. Geo-coding can be an imprecise process that is highly dependent on address record quality. A review of the geocoding results showed that more than 92% of patient records yielded high precision geo-coding matches using a combination of address and ZIP code or city.

We then linked patient level geocoded data to the Centers for Disease Control and Prevention SVI for their census tract. The resulting patient SVI mappings were used to visualize socially vulnerable patient clusters and the overall profile of the vaccinated population in relation to the SVI profile of communities surrounding UNC Health vaccine sites.

The maturity of analytics tools and Data Governance at UNC Health has evolved considerably over the last 5 years. The most recent advance was the deployment of a new data warehouse platform and Data Governance tools that occurred between late 2019 and early 2020. The timing of this deployment was fortuitous because it augmented our capabilities external to the EHR, accelerating our ability to deliver the data and insights that the COVER-NC leadership needed to take swift action during the pandemic.

**Data visualization**

UNC Health uses Tableau as our primary enterprise data visualization platform, and UNC Health’s enterprise data warehouse acted as the consolidated data source for vaccination records, geocoded addresses, and U.S. Census data. The dashboards created for COVER-NC are refreshed nightly and made available for broad self-service access across the organization, governed by role- and group-based security policies. Dashboard users included vaccine clinics, centralized scheduling, marketing, mobile unit managers, physicians, nurses, and system leaders and widely publicized at operational meetings and in newsletters.

Governance pushed for tools within Epic so that frontline workers could easily identify high-risk patients. The matched SVI for each geocoded address was incorporated as a discrete data element in Epic@UNC for use in any Epic Reporting Workbench report.

**RESULTS**

Initial analysis using the CRI confirmed reports that patients in the early stages of the vaccination operations did not reflect the racial or ethnic makeup of the vaccine site communities. By January 25, 2021, 2 weeks after the start of large scale patient vaccination, UNC Health had administered 35 722 first-dose vaccines to patients. Black patients represented 4.44% of vaccine administrations but made up 16.71% of the community surrounding vaccine sites, yielding a CRI of 0.27, a significant underrepresentation of the population. Hispanic patients were similarly underrepresented with a CRI of 0.55 (Figure 1).

Evaluation of the SVI showed vaccinated patients were disproportionately drawn from geographies with less social vulnerability. As of January 25, 2021, using a 1-sample \( t \) test comparing against the theoretical population, there was a significant difference in the average vaccinated SVI (0.3599) compared with the community SVI (0.4760) (\( t = -84.9, P < .001 \)) (Figure 2).

Based on these quantified findings, the COVER-NC program began deploying targeted interventions to address identified disparities, initially focusing on race and ethnicity but later expanding to focus on socially vulnerable communities as defined by the SVI dashboard (Figure 3). The interventions included partnerships with local community organizations to recruit eligible patients, deployment of mobile vaccination units to underserved communities, reserving appointment slots for people in underrepresented groups, targeted outreach to existing vulnerable UNC Health patients, and marketing
campaigns focused on education and awareness for underrepresented groups.

As equity interventions were deployed,\textsuperscript{8} the COVER-NC leadership requested additional analytics focused on tracking the efficacy of the various intervention programs. Efforts were expanded to include trending the change in equity measures over time. These tools, combined with operational analyses tied to specific outreach programs, allowed the COVER-NC team to continuously adjust intervention strategies and communicate progress to frontline staff, health system leaders, and public policy leaders.

While it is difficult to attribute gains in equitable vaccine administration to any one initiative, UNC Health has made significant progress. As of July 3, 2021, UNC Health had administered 201,282 first doses of vaccine across all age groups. For patients

\textbf{Figure 1.} Snapshot of the Community Reflection Index tracker showing progress toward more equitable distribution of vaccinations to North Carolina’s Group 2 (over 65 years of age) population. An exploded detail box shows the data for Black or African American people as of January 25, 2021. Lines below the 1.0 centerline indicate populations that are underrepresented in vaccine administration relative to the community. The closer to 1.0 it is for each racial group and gender, the more equitable vaccine administration is.

\textbf{Figure 2.} Analysis of social vulnerability for census tracts within a 20-mile radius of University of North Carolina (UNC) Health vaccine hubs. The darker areas represent areas of more vulnerability and correspondingly higher Social Vulnerability Index (SVI).


≥65 years of age, there were significant improvements in vaccinating Black, Hispanic (Table 1), and more vulnerable populations. A 2-sample t test comparing the average SVI on January 25 (0.3599—less vulnerable) with the average SVI on July 21 (0.4403—more vulnerable) showed there was a significant improvement in vaccinating more vulnerable patients (\( t = -32.6, P < .001 \)).

**DISCUSSION**

Our results show that transparency and broad access to visualization is important when addressing equity. Shared visualization of disparities facilitated the alignment of resources for the COVER-NC task force and helped reinforce organizational commitments to interventions that were effective at reducing disparities. Users spanned the healthcare system, from individual practices to marketing to mobile unit managers. Because an SVI was attached to individuals, practices ran reports focusing on high SVI patients to target for outreach. Marketing and mobile unit teams used the geomapping tools and coordinated outreach to census tracts.

Data visualization is dependent on data capture. For a significant number of patients, data for race, ethnicity, and language were not complete. Staff were taught to ask race, ethnicity, and language questions sensitively and respectfully through a “words that work” campaign rolled out by our quality coaching staff. A “hard stop” was built into the electronic health record to ensure that staff collected REaL data and that patients were given the option to self-report race and ethnicity when using the online scheduling portal.

Finally, our data show that inequity can be measured using tools that incorporate, but do not rely solely on, REaL data. In states such as North Carolina with large swaths of both urban and rural poverty, other markers of equity can easily be incorporated into the electronic health record and transformed into effective data visualizations.

Our analysis has some limitations. SVI measures a community’s vulnerability, not an individual’s vulnerability. We assumed that patients vaccinated from a census tract will, on average, have vulnerability factors similar to the community.

We intentionally created different community representations for the CRI and SVI tools. This had to do with different operational objectives and logistical concerns as vaccinations progressed. We created the CRI first using a 10-mile radius from the vaccine site to determine community composition. Early, when vaccine supply was low, our vaccine sites were being judged by our ability to distribute every allocated dose. While the goals of the COVER-NC team were to vaccinate as many marginalized people as they could, the scheduling team had trepidation that arranging transportation for people who lived far from vaccine sites could lead to missed appointments. Thus, we were trying to measure impact in the geographic areas in which the teams were working. As vaccine supplies increased and eligibility expanded, we determined that to reach more vulnerable patients, we would have to expand our marker of vulnerability to rural areas further from vaccine sites. Therefore, we expanded the community definition for SVI to a 20-mile radius, increasing the community SVI from 0.4281 to 0.4760.

**Table 1. CRI illustrates improvements toward equity in the ≥65-year-old vaccinated population**

| Demographic          | Date     | Vaccination | Community | CRI      | \( \chi^2 \) | P value |
|----------------------|----------|-------------|-----------|----------|--------------|---------|
| Black or African American | 1/25/2021 | 4.44%       | 16.71%    | 0.27     | 2630.3       | <.001*  |
|                      | 7/21/2021 | 11.80%      |           | 0.71     | 1056.4       | <.001b  |
| Hispanic             | 1/25/2021 | 1.27%       | 2.09%     | 0.55     | 103.22       | <.001*  |
|                      | 7/21/2021 | 1.70%       |           | 0.81     | 32.617       | <.001b  |

CRI: Community Reflection Index.

* Differences at baseline between the percent of Blacks or Hispanics receiving the vaccine and their representation in the population using a 1-sample proportion test.

b Two sample proportion test assessing change over time (January 25 CRI to July 21 CRI) shows significant increase in the percent of Blacks and Hispanics vaccinated, with the percent vaccinated more closely reflecting the groups’ percentage in the population and a CRI closer to the goal of 1.0.
As part of COVER-NC, we allocated vaccines for distribution to external community partners serving vulnerable populations (churches, community health clinics) to increase equitable distribution, build trust, and reach those at highest risk. For these persons, we designated the vaccine administration site address as their proxy address. This may have misrepresented an individual patient or household’s vulnerability. The number of vaccines distributed this way was <7% and was unlikely to have significant impact on the SVI of our administered population.

Future applications of this work include using the geocoded precision markers to alert operational staff of inaccurate patient addresses, using the visualized socially vulnerable patient clusters to inform hiring of community health workers, and leveraging the SVI for population health reports to match socially vulnerable patients with the appropriate support.

CONCLUSION
Vaccine and health equity is measurable. Data visualization can illuminate concerns and create momentum for change in allocation, scheduling, and prioritizing vaccines. Geocoding patient addresses allows community measures, such as SVI, to be applied to equity challenges in other populations or inform population health teams working to reach marginalized community members.

FUNDING
This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

AUTHOR CONTRIBUTIONS
All authors contributed substantially to this report, including meeting all 4 requirements of authorship: substantial contributions to the design of the work, analysis, or interpretation of data for the work; drafting and revising the work; providing final approval of the version to be published; and agreeing to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST STATEMENT
The authors have no competing interests to declare.

DATA AVAILABILITY STATEMENT
The data underlying this article cannot be shared publicly because this data is protected health information. Aggregated data will be shared on reasonable request to the corresponding author. Relevant aggregated data is included in the article. Census level SVI data can be found at https://svi.cdc.gov/Documents/Data/2018_SVI_Data/SVI2018Documentation.pdf.

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