A prioritization algorithm for healthcare personnel for the CDC's COVID-19 Phase 1a vaccine distribution plan

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Abstract

We developed an algorithm that can be used to equitably distribute COVID-19 vaccinations to healthcare personnel (HCP) during Phase 1a of the Center for Disease Control and Prevention's (CDC) coronavirus vaccine distribution plan, if not enough vaccine is available to immunize an entire group of employees with similar job-related risk exposure. The algorithm prioritizes individuals with the highest risk of mortality using Social Vulnerability Index (SVI) and age.

Key Words: COVID-19, vaccine

Background

On December 1, 2020, the Advisory Committee on Immunization Practices voted to include residents of long-term care facilities and healthcare personnel (HCP) in Phase 1a of the Center for Disease Control and Prevention's (CDC) coronavirus vaccine distribution plan. Within this initial phase, and within all subsequent phases of the vaccine roll-out, the National Academies of Sciences, Engineering, and Medicine, in its Framework for Equitable Allocation of COVID-19 Vaccine,[1] suggests using an index such as the Social Vulnerability Index (SVI) to prioritize individuals living in locations identified as vulnerable in order to incorporate variables that are most linked to the disproportionate impact of COVID-19 on people of color. As our tertiary healthcare system plans to implement Phase 1a amongst its own employees by categorizing staff into groups of similar job-related risk exposure, we have looked to the Framework for direction on how to operationalize SVI within these groups for equitable distribution, should initial supply of vaccine be limited. However, the Framework's guidance is directed only at the state-level; namely, that 10 percent of the vaccine be reserved for those in the top 25 percent of the SVI distribution within a state. Furthermore, although "Age 65+" is one of the metrics incorporated into the SVI, no guidance is provided in the Framework regarding how to prioritize vaccine among individuals 18-69 years old, the age group that would typically be represented on a workforce. We decided to create a vaccine prioritization algorithm to rank Phase 1a HCP with similar job-related risk exposure by risk of mortality to COVID-19 according to SVI and age. We also evaluated whether SVI was a suitable proxy in our health system to recognize the disproportionate impact of COVID-19 on people of color by prioritizing individuals living in locations identified as vulnerable, as recommended by the National Academies Framework.

Algorithm Development

To create an algorithm that approximates the relationship between race/ethnicity and age on risk of mortality due to COVID-19, using SVI as a proxy for race/ethnicity, we examined national and state-level data stratified across these variables.

Risk of Mortality by Race/Ethnicity + Age

Bassett's national mortality rate statistics per 100,000 person-years by age strata and race/ethnicity demonstrate the importance of stratifying on age when calculating racial variation in mortality rates.[2]

Race/Ethnicity: We compiled the numbers provided by Bassett into two race/ethnicity groups, non-Hispanic White (NH White) and People of Color (POC), which included non-Hispanic Black, Hispanic, non-Hispanic American Indian/Alaska Native, and non-Hispanic Asian or Pacific Islander populations, for ease in modeling and consistency with a similar statistic in the publicly available Wisconsin SVI data. Mortality rates for the POC population range from 4 to 7.7 times those of the NH White population for the six age categories representing 15–74-year-olds (Table 1).

Age: Although national COVID-19 death data is only publicly available for broad age categories, we sought to create a model that would take advantage of the continuous age data we possess for HCP and, therefore, assumed the statistics provided by the national data pertained to the average age of a given category. We determined the increase in mortality risk by Average Age of Category for both the NH White and POC populations, finding both to approximate exponential curves (Figure 1). The mortality rate for NH White/69.5 years is 360 times that of NH White/19.5 years, while the mortality rate for POC/69.5 years of 1434 is 239 times the value of 6 for POC/19.5 years (Table 2).

Race/Ethnicity & Age: Furthermore, calculating risk ratios of race/ethnicity and age-specific mortality risk compared to NH White/15-24 years clarifies that the relationship between age and race/ethnicity is multiplicative (Table 2). Multiplying the mortality risk of 360 for NH White/69.5 years by 4, the risk ratio due to race/ethnicity for persons 69.5 years, brings us to the mortality risk for POC/69.5 years of approximately 1440.

Risk of Mortality by SVI

We could find no data describing the relationship between SVI, race/ethnicity, and COVID-19 mortality risk, so we merged Wisconsin SVI data[3] to the state's COVID-19 census tract data.[4] We then examined the relationships between SVI and % POC across census tracts, as well as the relationship between SVI and Age over 65 years, by averaging these statistics for each WI SVI decile (Tables 3 and 4; Figure 2). These census data suggest that SVI is a suitable proxy for % POC across census tracts, but not for age 65+. COVID-19 deaths per 100,000 increase linearly by a factor of 5.9 from WI SVI decile 1 to 10.

Algorithm Logic and Recommendations

We determined that race/ethnicity approximates a linear effect across age categories on risk of mortality due to COVID-19, while age approximates an exponential effect, with the relationship between race/ethnicity and age on risk of mortality being multiplicative. Furthermore, COVID-19 deaths per 100,000 increase approximately linearly by a factor of 5.9 from Wisconsin SVI decile 1 to SVI decile 10 which is consistent with the factor by which mortality rates for POC populations are higher than those of the NH White population.

Therefore, for our algorithm based on risk of mortality, we multiply the exponential equation for the effect of age on risk of mortality for the NH White population (Figure 1) by the linear equation for WI SVI decile (Figure 2). In place of WI SVI decile, the algorithm uses actual WI SVI values transformed so the midpoint of each decile's range matches the scale and value of its decile, allowing use of the continuous SVI data we planned to generate from HCP addresses (Table 4). For example, multiplying by 10 and adding 0.5 transforms the range of values in the first WI SVI decile from (0, 0.0999) with a midpoint of 0.05 to (0.5,1.499) with a midpoint of 1.

It was assumed that the algorithm would produce average risk scores on a similar scale as those representing the risk ratios of age-specific mortality risk compared to NH White/15-24 Years in Table 2, where a higher score indicates higher priority.

$$[0.0978e^{(0.1224*Age_{HCP})}] * (0.5303*((WI\ SVI_{HCP} * 10) + 0.5) + 0.5723)$$

Algorithm in Practice

We recognized that if we want to follow the recommendations in the Framework, we should ensure that employees with addresses that fall in the top 25% of the SVI distribution within the state are in one of the early prioritization groups. Therefore, we evaluated the algorithm above to determine if it appropriately prioritized these employees.

Our human resources department provided us with a sample dataset of the age, address, race/ethnicity, and job title for each of 236 employees, representing a group with similar job-related exposure eligible for vaccination in Phase 1a. Using geocoded home addresses, we established a WI SVI for each employee based on census tract. Although our sample dataset did not contain out-of-state addresses, we plan to use national SVI values as WI SVI values for such cases, acknowledging that national values are lower than state values for Wisconsin addresses. Figure 3 shows, by quartile, which employees in the sample dataset would be prioritized using the algorithm, according to age rank in the dataset and WI SVI.

Notably, 26 employees in the 236 in our sample have addresses that fall in the top 25% of the SVI distribution within the state. Of these 26 employees, 11 would be in the 1st quartile of vaccination, 10 in the 2nd and 5 in the 3rd using our algorithm, compared to 8 in the first quartile, 10 in the 2nd, 3 in the 3rd, and 5 in the last if employees were ranked on age alone.

As planned, the algorithm produces average risk scores that are on a similar scale to the risk ratios of age-specific mortality risk compared to NH White/15-24 Years shown in Table 2 (Table 5).

Conclusion

We developed an algorithm to equitably prioritize COVID-19 vaccinations among Phase 1a HCP with similar job-related risk exposure is based on national and state risk of mortality data rather than arbitrary cut-offs. Its use at our organization was approved and will be implemented shortly, when human resources provides lists of employees with similar risks of exposure, starting with the group having the highest exposure. Future work will include extending this methodology to patients by adding risk of mortality based upon comorbidities to the model. A tool to calculate

COVID-19 vaccine prioritization values from SVI and age will be available at the University of [redacted].

Conflict of Interest

The authors have no conflicts of interest to report.

References

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Table 1. Age-specific mortality rate per 100,000 person-years

Age Category	NH White	POC	Risk Ratio (POC to NH White)
15-24	0.3	1.7	5.7
25-34	1.2	8.2	6.8
35-44	3.2	24.5	7.7
45-54	11.1	70.5	6.4
55-64	69.9	334.2	4.8
65-74	108	430.1	4.0

Table 2. Risk ratios of age-specific mortality risk compared to NH White/15-24 Years

Age Category	Average Age of Category	NH White	POC
15-24	19.5	1	6
25-34	29.5	4	27
35-44	39.5	11	82
45-54	49.5	37	235
55-64	59.5	233	1114
65-74	69.5	360	1434

Figure 1. Risk ratios of age-specific mortality risk compared to NH White/15-24 Years by Average Age of Category

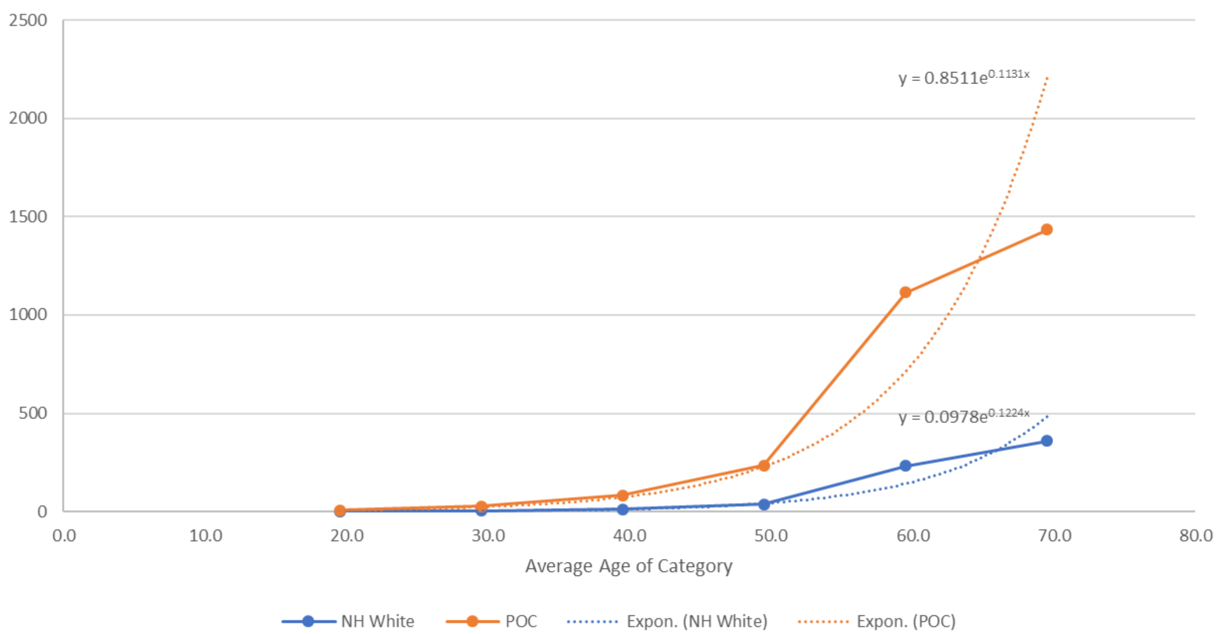

Table 3. Demographic and COVID-19 Statistics by WI SVI Decile (Statistics represent averages of census tract data for each WI SVI decile)

WI SVI Decile	% POC*	% 65+	Deaths per 100,000
1	7%	16%	6.5
2	9%	16%	11.4
3	10%	17%	15.7
4	10%	17%	13.2
5	11%	17%	17.7
6	13%	16%	36.1
7	16%	18%	24.2
8	23%	16%	28.5
9	36%	14%	34.9
10	63%	11%	38.6

*POC is termed Minority in the WI SVI source dataset

Table 4: Ratios of statistics in Table 4 compared to WI SVI Decile 1

WI SVI Decile	WI SVI* Decile Midpoint	% POC**	% 65+	Deaths per 100,000
1	0.05	1.0	1.0	1.0
2	0.15	1.3	1.0	1.8
3	0.25	1.4	1.1	2.4
4	0.35	1.4	1.1	2.0
5	0.45	1.6	1.1	2.7
6	0.55	1.9	1.0	5.6
7	0.65	2.3	1.1	3.7
8	0.75	3.3	1.0	4.4
9	0.85	5.1	0.9	5.4
10	0.95	9.0	0.7	5.9

*WI SVI is termed RPL_THEMES in the WI SVI dataset
**POC is termed Minority in the WI SVI source dataset

Figure 2. Ratio of Deaths per 100,000 by WI SVI Decile (with metric compared to metric at WI SVI Decile = 1)

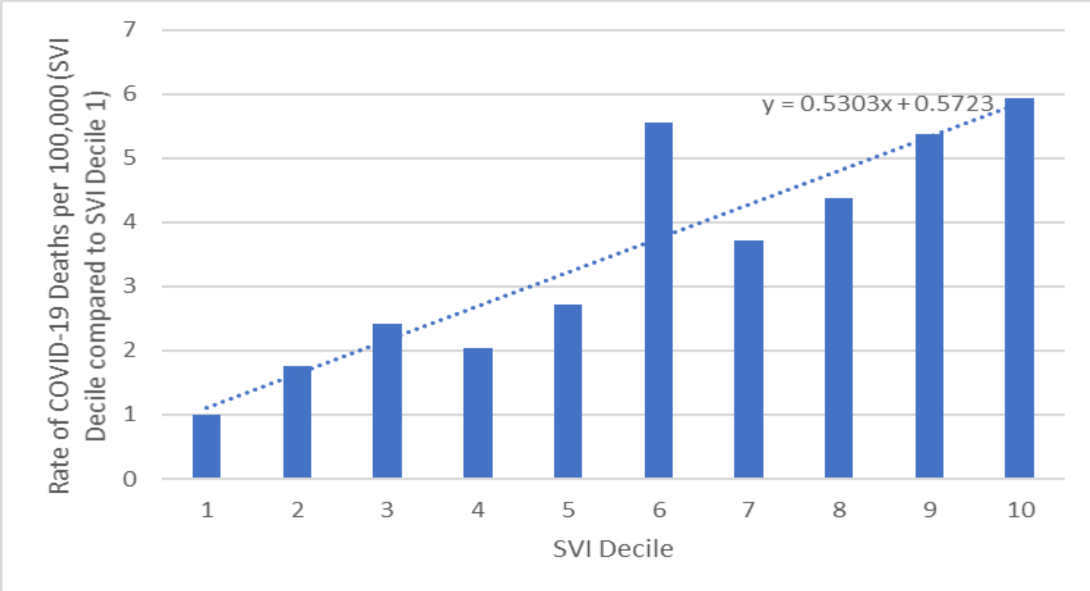

Figure 3. Quartiles of prioritized HCPs in the sample dataset by age rank (0-100) and WI SVI. Color signifies race/ethnicity, where Blue = Asian, Red = Black or African American, Green = Hispanic or Latino, Violet = Multiracial, Orange = Native Hawaiian or other Pacific Islander, Yellow = White, and Teal = Not Disclosed

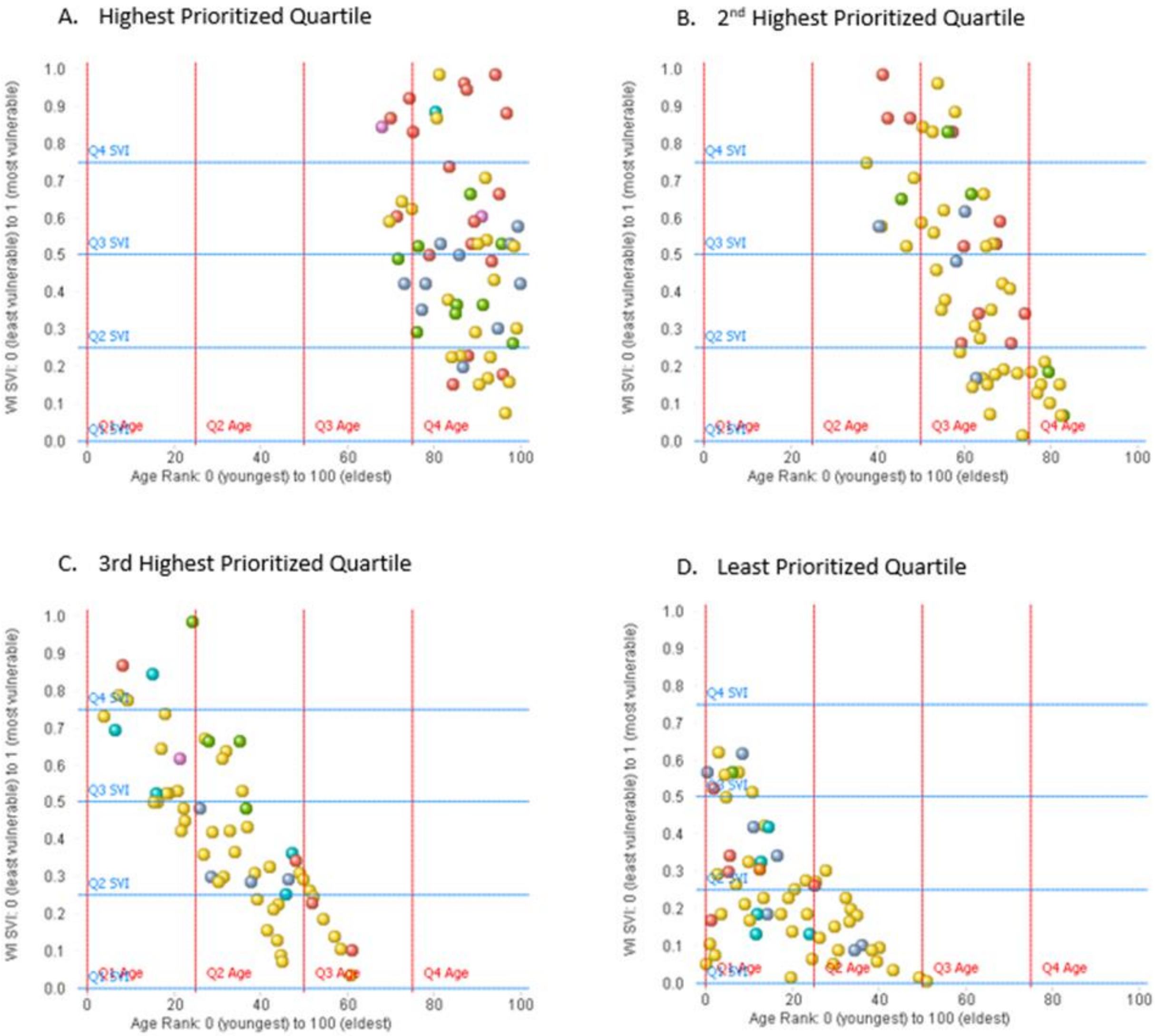

Table 5. Average risk score by Age Category and WI SVI Quartile for sample HCP dataset

Age Category	WI SVI Quartiles			
	1 (Least Vulnerable)	**2**	**3**	**4 (Most Vulnerable)**
15-24	3	5	6	9
25-34	6	10	17	28
35-44	21	40	59	60
45-54	74	117	199	248
55-64	248	444	582	1,012
65-74	-	1,047	1,276	-