EQUITY-BASED OPTIMIZATION FOR COVID-19 VACCINE ALLOCATION

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When vaccine supply is very limited, there is a trade-off between diminishing overall mortality and reducing inequity. However, this trade-off lessens as more vaccine becomes available if vaccine is optimally distributed.

BACKGROUND

The COVID-19 pandemic has highlighted and exacerbated the inequities of the health care system in the United States (US) and other countries in the world. Studies have shown that this is due, in part, to systemic racism and inequities leading to differences in exposure, comorbidities, access to health care, and occupation.

We retrospectively analyze vaccine allocation strategies in Oregon for the first four months of 2021, when vaccine supplies were extremely limited and SARS-CoV-2 was relatively stable. We aim to determine optimal vaccination strategies that minimize overall disease burden (mortality or years of life lost, YLLs) while minimizing inequity in COVID-19 outcomes.

METHODS

We construct a deterministic age- and race-structured mathematical model of SARS-CoV-2 and vaccination and fit it to data from Oregon in January 2021.

We consider enough vaccine to cover 10 or 20% of the population in January 2021.

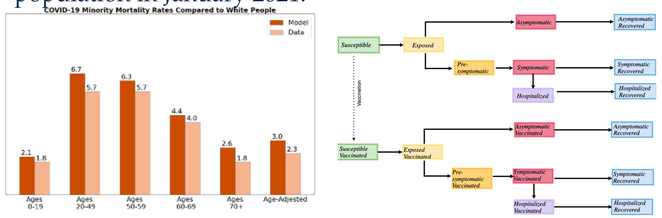


Figure 1. A) Fit to Oregon mortality rates. B) Model diagram

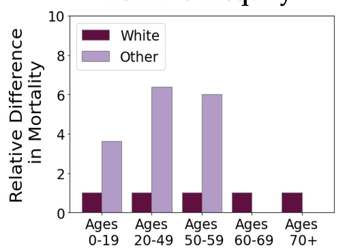
We use optimization to determine the best vaccine allocation strategies to minimize disease burden (mortality or YLL), inequity (Table 1) or a combination of both.

Name	Formula
Relative disparity in mortality	$\sum_{a \epsilon ages} \left\lvert \frac{m_{a,O}}{m_{a,W}} - 1 \right\rvert$
Absolute disparity in mortality	$\sum_{a \epsilon ages} \lvert m_{a,O} - m_{a,W} \rvert$
Index of disparity (mortality)	$\sum_{a \epsilon ages} \frac{1}{2} \cdot \frac{\sum_{R \epsilon races} \lvert m_{a,R} - \bar{m}_a \rvert}{\bar{m}_a} \cdot 100$
Absolute disparity in YLLs	$\sum_{a \epsilon ages} \lvert YLL_{a,O} - YLL_{a,W} \rvert$
Index of disparity (YLLs)	$\sum_{a \epsilon ages} \frac{1}{2} \cdot \frac{\sum_{R \epsilon races} \lvert YLL_{a,R} - \overline{YLL}_a \rvert}{\overline{YLL}_a} \cdot 100$

RESULTS (10% vaccine coverage)

RANDOM VACCINE DISTRIBUTION (base case)

Relative Inequity



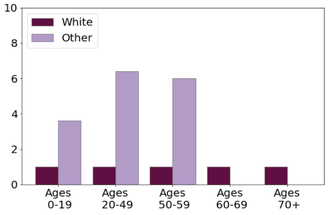
Vaccine Distribution

	Ages: 20-49	Ages: 50-59	Ages: 60-69	Ages: 70+
White	10%	10%	10%	10%
Other	10%	10%	10%	10%

Additional Mortality Averted (with respect to base case%)

Deaths Averted (%)	0-19	20-49	50-59	60-69	70+
White	n/a	0	0	0	0
All Other	n/a	0	0	0	0

MINIMIZING DEATHS

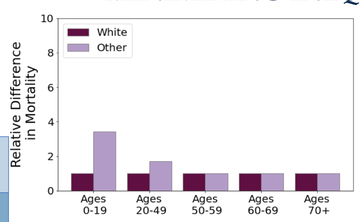


	Ages: 20-49	Ages: 50-59	Ages: 60-69	Ages: 70+
White	0%	0%	0%	74%
Other	0%	0%	100%	100%

Deaths Averted (%)	0-19	20-49	50-59	60-69	70+
White	n/a	0	20	29	86
All Other	n/a	0	17	100	100

- Minimizing mortality: Less mortality in all groups, even in the marginalized ones, at the cost of more inequity, specially in young adults and those aged 50-59.
- Priority given to older adults.

MINIMIZING INEQUITY

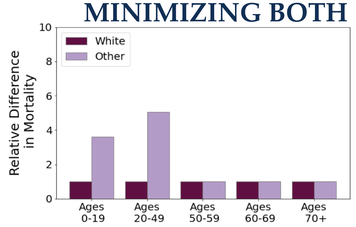


	Ages: 20-49	Ages: 50-59	Ages: 60-69	Ages: 70+
White	0%	0%	0%	0%
Other	70%	80%	69%	45%

Deaths Averted (%)	0-19	20-49	50-59	60-69	70+
White	n/a	0	20	6	2
All Other	n/a	50	83	78	62

- Minimizing inequity: we achieve less inequity, at the cost of more older people dying.
- Priority to vaccinate younger adults in marginalized groups.

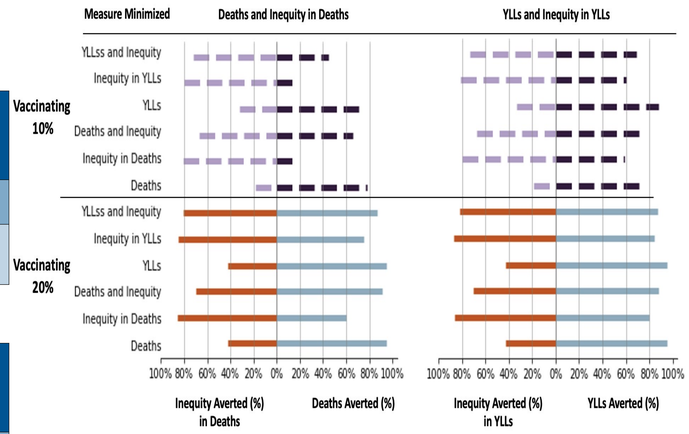
MINIMIZING BOTH



	Ages: 20-49	Ages: 50-59	Ages: 60-69	Ages: 70+
White	0%	0%	0%	47%
Other	17%	81%	71%	74%

Deaths Averted (%)	0-19	20-49	50-59	60-69	70+
White	n/a	0	20	29	67
All Other	n/a	50	83	78	88

- Minimizing both: 7% less deaths averted than in the mortality only scenario.
- Significant gains in equity achieved.



CONCLUSIONS

With low vaccine supply, minimizing deaths was the optimal way of preventing overall deaths, and prevented more deaths in the marginalized communities, even if there was more inequity.

With low vaccine supply, there is a *trade-off* between being more equitable and protecting overall mortality. This is true because COVID-19 related mortality is concentrated in the oldest populations. This would not be true for other diseases like HIV or Monkeypox.

When minimizing deaths and inequity, we achieved higher equity at the expense of a reduction in deaths averted.

When vaccine supply is higher, it is possible to minimize mortality and inequity at the same time.

Of all the metrics compared, a combination of deaths and relative inequity or YYL and absolute inequity seem to be the best optimization metrics to use.

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