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Using absolute risk reduction to guide the equitable distribution of COVID-19 vaccines

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Introduction

Massive economic inequality, poverty and structural racism, in addition to intellectual property laws and regulations, are creating the conditions for gaping inequities in COVID-19 vaccine distribution. Journalists, activists and public health practitioners have characterised the largely preventable public health crisis as vaccine apartheid. At the time of this writing (January 2022), just 9.7% of people in lower-income countries had received at least one shot of the COVID-19 vaccine, compared with 60.6% globally.¹ Vaccine inequities have also been observed within multiple countries such as India and South Africa.^{2,3}

Efforts to bridge the gaps are largely failing. In April 2021, with input from the World Bank and consultants including McKinsey & Company, the WHO and other allied organisations launched the COVID-19 Global Access initiative (COVAX), in a stated attempt to address vaccine inequity by facilitating the global coordination of vaccine production and distribution.⁴ But COVAX is doing little to challenge the intellectual property regime or power of pharmaceutical companies and the World Bank. Wealthier countries are hoarding vaccines by placing advance orders for hundreds of millions of doses at the expense of poorer countries. As a result, many may not be able to vaccinate the majority of their populations until 2024.⁵

Without major structural changes to the global economic order, health inequities related to vaccination are likely to remain a grim reality. In this context, public health researchers, policy-makers and other stakeholders could help generate evidence-based vaccine distribution strategies and identify barriers that prevent these strategies from being enacted.

Effect measures and vaccine distribution

Public health systems can prioritise vulnerable populations for vaccination. Many countries are already prioritising healthcare workers and the elderly, but more specificity may be needed to reduce hospitalisation, severe disease and death. Vaccine distribution programmes and outreach efforts could prioritise subpopulations in geographical areas with high baseline risk during an outbreak, for example, instead of subpopulations in areas with lower baseline risk.

Several key effect measures, including absolute risk reduction (ARR) and the number needed to be treated or number needed to be vaccinated (NNV), are well-suited for this task. ARR and NNV

are more helpful than relative measures such as relative risk reduction (RRR), for assessing the effect of a treatment or a preventative programme like vaccination in populations with differing baseline risks.^{6–10} NNV is estimated from the incidence of a certain event in the unvaccinated population and estimates of vaccine effectiveness (VE): $(NNV=1/ARR=1/incidence\ of\ event\ in\ the\ unvaccinated \times VE)$.

Some researchers have raised concerns that the targets for NNV in prior vaccination programmes are variable, dynamic, context-specific and may not capture the effects of vaccination on transmission and herd immunity.^{11–13} Considering that a substantial proportion of fully vaccinated individuals still can transmit COVID-19 to others, achieving herd immunity remains unlikely.¹⁴

Meanwhile, understanding that the effectiveness of vaccination, estimated by ARR and NNV, can vary in population subgroups with different baseline risks can facilitate policies about vaccine distribution. For instance, studies of influenza and pertussis vaccines in Sweden and Canada have led to differing policy recommendations about vaccine distribution for population subgroups located in geographical areas with varying baseline risks.^{15–16} The Advisory Committee on Immunization Practices of the US Centers for Disease Control and Prevention (CDC) cites absolute vaccine efficacy data in its report on influenza immunisation practices and communicates benefits and harms associated with human papilloma virus.^{17–18}

While randomised controlled trials and population-based assessments do not routinely report ARR or NNV, their main effect measure for vaccine effectiveness is RRR. Some researchers have subsequently calculated ARR and NNV using data from major studies, but none has assessed the metrics across subpopulations.¹⁹

Dynamically reporting key absolute effect measures

To facilitate policies about vaccine distribution, public health researchers could perform continuing analyses that consider ARR and NNV in population subgroups, including across socioeconomic groupings, with differing baseline risks of disease. Researchers could obtain baseline risks from available public data and re-run analyses frequently.

To illustrate, we calculated the ARR and NNV within several states and territories in the USA and India related to our work in public health (table 1).

Table 1 Numbers needed to be vaccinated in geographical areas with different baseline risks

May 2021						
(A) County, state or territory	(B) Active cases per 100 000 population*	(C) Calculated active symptomatic cases per 100 000 (estimated at 50% of cases) (B×50%)†	(D) Calculated active symptomatic cases per 100 000 (expressed as %)=baseline risk (C/100 000)(%)	(E) Calculated risk of symptomatic disease after vaccine with 95% effectiveness (RRR 95%) (D×5%)(%)	(F) Absolute risk reduction (ARR) (D-E)(%)	(G) Number needed to be vaccinated (NNV) (1/F)
De Baca, New Mexico	1124.74	562.37	0.56	0.03	0.53 (0.40 to 0.60)	200 (166 to 252)
McKinley, New Mexico	730.89	365.45	0.37	0.02	0.35 (0.25 to 0.45)	286 (223 to 398)
Catron, New Mexico	80.95	40.48	0.04	0.00	0.04 (0.00 to 0.08)	2500 (1275 to 62 792)
Ladakh territory, India	6250.00	3125.00	3.13	0.16	2.97 (2.60 to 3.32)	34 (30 to 38)
Uttar Pradesh state, India	833.00	416.50	0.42	0.02	0.40 (0.27 to 0.53)	250 (189 to 370)
Kerala state, India	7143.00	3571.50	3.57	0.18	3.39 (3.02 to 3.76)	29 (27 to 33)
September 2021						
(A) County, state or territory	(B) Active cases per 100 000 population*	(C) Calculated active symptomatic cases per 100 000 (estimated at 50% of cases) (B×50%)†	(D) Calculated active symptomatic cases per 100 000 (expressed as %)=baseline risk (C/100 000)(%)	(E) Calculated risk of symptomatic disease after vaccine with 66% effectiveness (RRR 66%) (D×34%)(%)‡	(F) Absolute risk reduction (ARR) (D-E)(%)	(G) Number needed to be vaccinated (NNV) (1/F)
De Baca, New Mexico	409.00	204.50	0.20	0.07	0.13 (0.03 to 0.23)	769 (431 to 3541)
McKinley, New Mexico	517.00	258.50	0.26	0.09	0.17 (0.05 to 0.29)	588 (350 to 1846)
Catron, New Mexico	405.00	202.50	0.20	0.07	0.13 (0.03 to 0.23)	769 (431 to 3541)
Ladakh territory, India	28.00	14.00	0.01	0.00	0.01 (0.00 to 0.01)	10000 (3379 to -10 418)
Uttar Pradesh state, India	14.00	7.00	0.01	0.00	0.01 (0.00 to 0.01)	10000 (3379 to -10 418)
Kerala state, India	1204.00	602.00	0.60	0.20	0.40 (0.23 to 0.58)	250 (174 to 444)

95% CI shown in parentheses. CIs that overlap 0 occur with very low absolute risk reductions and indicate non-significant differences between the intervention and control groups. Such intervals do not necessarily include the point estimates and reflect a range from beneficial to harmful effects of the intervention.⁷

*Sources: Johns Hopkins dashboard, <https://www.arcgis.com/apps/MapSeries/index.html?appid=ad46e587a9134fcd43ff54c16f8c39b> (accessed 23 May 2021 and 5 September 2021); New York Times dashboard, <https://www.nytimes.com/interactive/2020/world/asia/india-coronavirus-cases.html> (accessed 23 May 2021 and 5 September 2021).

†Estimate of percentage of infections that become symptomatic are based on published research and a published systematic review and meta-analysis.²⁸⁻³⁰ Sensitivity analyses based on the range of percentages in published research are available from the authors on request.

‡Reported effectiveness of the most effective vaccines dropped to the range of 66% based mainly on the emergence of the Delta variant.²⁰ RRR, relative risk reduction.

During May 2021 in New Mexico, De Baca County with a large proportion of Latinx low-income residents and McKinley County with a large proportion of Navajo low-income residents would have been prioritised for vaccine distribution compared with Catron County with a mostly white, higher income population. In India, Kerala state and Ladakh territory would have received prioritisation, compared with Uttar Pradesh state. Later, during September 2021, with vaccine effectiveness reduced to 66% due to the Delta variant,²⁰ the ARR and NNVs again varied substantially, linked to variations in baseline risks. McKinley County, New Mexico, would have been prioritised, but the prioritisation of De Baca and Catron counties would not have differed substantially. In India, overall, the ARRs decreased and NNVs increased. Based on available data, Kerala state again would have received prioritisation.

Barriers to adopting these metrics

Despite potential benefits of using these indicators to guide vaccine distribution, such an approach may prove challenging in some countries. For example, in India the federal and some state governments made certain decisions about vaccine distribution based on a framework known as 'eminence-based' medicine.²¹ Some public health agencies withheld data from the public and did not assess baseline risk across socioeconomic groupings.²² In the USA, the CDC tracked vaccination status with demographic data,²³ but it did not use ARR or NNV to guide vaccine distribution policies. Many US states and counties struggled to track COVID-19 cases.²⁴

Calculating and updating ARR and NNV across subpopulations require some investment of time and resources. A region's baseline risk calculation depends on its ability to detect cases and testing capacity. In addition to waiving intellectual property laws and providing technological assistance for vaccine production, wealthier countries could fund data collection in lower-income counties and countries. Understanding the evidence more fully, of course, does not necessarily lead to policy decisions that the evidence suggests, but it may provide some leverage for people to advocate for their own health.

Patients and the public should be provided with transparent information about ARR in addition to RRR for population subgroups, as well as an overview of benefits versus harms. If a vaccine helps reduce transmission or enhances herd immunity, these effects should be quantified and explained clearly to patients and the public. Especially for individuals in population subgroups with higher baseline risks, educational efforts may emphasise the likely greater effectiveness of vaccines than in population subgroups with lower baseline risks.

A similar approach could guide vaccine distribution for subsequent waves, such as that dominated by the Omicron variant, as well as policies about booster vaccinations. Such guidance would depend on the observed baseline risks in different population subgroups, the observed RRR of vaccines against new variants and the varying calculated ARR for different population subgroups.

Guiding an equitable distribution of vaccines

Low-income countries have taken on increased debt and other financial burdens because of intellectual property laws; high prices charged by pharmaceutical companies and vaccine hoarding by wealthier countries, in what has been called vaccine apartheid.²⁵ A strategy emphasising vaccines' differential impacts on reducing absolute risk in population subgroups with varying baseline risks could alleviate some economic and practical burdens of trying to provide vaccines for everyone, especially in poorer regions of

richer countries, or in regions of poorer countries in the Global South.

Public health systems can assess baseline risks to target dynamically 'hot spot' areas for vaccine distribution. While not in any way justifying unequal access to vaccines, this strategy becomes especially important as we face the reality of barriers related to wealth, power, minority status, structural racism and other sources of profound inequality—conditions that create vaccine apartheid, as part of the broader social determination of health.²⁶

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