WHO SAGE ROADMAP FOR PRIORITIZING USES OF COVID-19 VACCINES IN THE CONTEXT OF LIMITED SUPPLY

An approach to inform planning and subsequent recommendations based upon epidemiologic setting and vaccine supply scenarios

Version 1.2 [DRAFT]
29 June 2021

World Health Organization

This Roadmap was developed in November 2020 on the basis of the advice issued by the Strategic Advisory Group of Experts (SAGE) on Immunization, and updated on 29 June 2021.

Contents

Acknowledgements

The *WHO SAGE Roadmap for prioritizing the use of COVID-19 vaccines in the context of limited supply* was prepared by the SAGE Working Group on COVID-19 vaccines. The drafting of the Roadmap was led by Saad B. Omer, Ruth Faden, Sonali Kochhar, David Kaslow and Sarah Pallas with input from the members of the Public Health Objectives Subgroup (Folake Olayinka, Muhammed Afolabi, Celia Alpuche-Aranda, Hyam Bashour, David Durrheim, Peter G. Smith, Yin Zundong, Peter Figueroa and Helen Rees) and Annelies Wilder-Smith, and Joachim Hombach from the WHO Secretariat, with support of Matthew A. Crane from the Johns Hopkins University School of Medicine. Hanna Nohynek leads the SAGE Working Group on COVID-19 vaccines.
The update of the Roadmap was led by Ruth Faden, Nick Grassley, Sonali Kochhar, David Kaslow, Saad B. Omer and Sarah Pallas with input from other members of the Working Group and Shalini Desai, Joachim Hombach, Melanie Marti and Annelies Wilder-Smith from the WHO Secretariat.

Abbreviations

ACT	Access to COVID-19 Tools (ACT) Accelerator
Allocation Framework	Fair allocation mechanism for COVID-19 vaccines through the COVAX Facility
COVAX	The vaccines pillar of the access to COVID-19 tools (ACT) Accelerator
COVID-19	SARS-CoV-2 virus disease 2019
NITAG	National Immunization Technical Advisory Group
Prioritization Roadmap	WHO SAGE roadmap for prioritizing uses of COVID-19 vaccines in the context of limited supply
SAGE	Strategic Advisory Group of Experts on Immunization
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
RITAG	Regional Immunization Technical Advisory Group
Values Framework	WHO SAGE values framework for the allocation and prioritization of COVID-19 vaccination
VOCs	SARS-CoV2- virus variants of concern
YLL	Years of life lost
WHO	World Health Organization

Introduction

To guide countries with their implementation of their respective coronavirus disease 2019 (COVID-19) vaccination programmes, the Strategic Advisory Group of Experts (SAGE) on Immunization of the World Health Organization (WHO) has developed a three-step process to provide guidance for overall programme priorities as well as vaccine-specific recommendations.

Step 1: A Values Framework. The *WHO SAGE values framework for the allocation and prioritization of COVID-19 vaccination (1)*, issued on 14 September 2020, outlines the general principles, objectives and related (unranked) target groups for prioritization of COVID-19 vaccines.

Step 2: Roadmap for prioritizing uses of COVID-19 vaccines (Prioritization Roadmap) (this document). To support countries in planning vaccination programmes, the Roadmap suggests public health strategies and identifies target groups for prioritization of COVID-19 vaccine use (referred to as "priority-use groups") given different levels of vaccine availability and epidemiologic settings. The first version of the Roadmap was published 07 October 2020, and updated on 13 November 2020. This current update is more substantive and reflects data from vaccine clinical studies that have since become available as well as learnings from the early implementation of programmes. The roadmap will continue to be updated, as necessary, to accommodate the dynamic nature of the pandemic, greater availability of vaccines and evolving evidence about vaccine impact.

Step 3: Vaccine-specific recommendations. As conditionally authorized vaccines become available, specific recommendations for the use of these vaccines will be issued. Currently, six vaccines have been emergency use listed by WHO, and interim recommendations on the use of these products have been issued. These recommendations are being updated as additional evidence on effectiveness, safety, and booster needs become available, and as epidemiologic and other contextual conditions evolve (2).

Rationale

Given the urgency and wide-ranging effects of the COVID-19 pandemic, SAGE has developed an approach to help inform national policy deliberations on the range of recommendations that may be appropriate under different epidemiologic and vaccine supply conditions. Despite the support of COVAX and other donor and bilateral procurement mechanisms that have resulted in unprecedented implementation of COVID-19 vaccination programmes, most middle- and lower-income countries still face limited and often unreliable vaccine supply. Hence, there remains a need to prioritize vaccination in a pragmatic and ethical manner. While all currently recommended COVID-19 vaccines have similar and broad indications for use, countries may decide to consider specific product attributes when prioritizing vaccine use in certain populations.

This Roadmap builds on the *WHO SAGE values framework for the allocation and prioritization of COVID-19 vaccination*. The Values Framework listed over 20 population subgroups that, if vaccine use needed to be prioritized because of limited supply, would advance one or more of its principles and objectives. The Values Framework did not rank the subgroups in any order. Specific priority-use group recommendations will require the integration of the ethical principles detailed in the Values Framework with evidence and information about: i) the status of the pandemic in the proposed implementation area (that is, the epidemiologic setting in terms of

the degree of ongoing SARS-CoV-2 transmission and the severity of COVID-19 burden); ii) the amount and timing of vaccine supply and availability, respectively; iii) specific product characteristics of the available vaccine(s); and iv) the benefit–risk assessment for the different population subgroups at the time vaccination is being considered for deployment; as well as other standard criteria used in developing SAGE recommendations (for example, feasibility, acceptability and resource use). These factors, together with the Values Framework, provide a guide to an appropriate public health strategy for vaccine deployment of specific vaccines.

To assist in developing recommendations for use of vaccines against COVID-19, the WHO SAGE Prioritization Roadmap of COVID-19 vaccines suggests priority-use groups for vaccination based on epidemiologic setting and vaccine supply scenarios. These use cases are also set in the context of the overall public health strategy for each epidemiologic setting (Table 1).

This Roadmap is primarily intended to serve as guidance on preparing for vaccine prioritization decisions **within countries**. Although the Values Framework does include the principle of global equity, this Roadmap does not directly address global allocation decisions, which is the remit of the COVAX Facility allocation mechanism for countries participating in the COVAX Facility *(3)*.

In addition, the Roadmap is not proposing coverage targets to be achieved. In 2020, the Roadmap worked with assumptions of initial very limited supply in stages from 0-10%, 11-20%, and 21-50% of population, based on the expected supply of vaccines. More ambitious coverage targets have since been called for, and some countries have indeed reached higher coverage levels. WHO is currently developing a *Global Vaccination Strategy* that will provide considerations to countries on goals and ambitions for COVID-19 vaccination (including coverage targets) and the necessary resource requirements. The Roadmap is intended to aid prioritizing use-cases for within country-set coverage goals and supply. The Roadmap currently provides guidance up to a population coverage level of 50%. Both the Prioritization Roadmap and the Global Vaccination Strategy emphasize the importance of prioritizing initial limited supply of vaccine to optimize impacts across health, socioeconomic, and equity dimensions. Opening vaccine eligibility to all without first achieving higher coverage among age and other highest priority-use groups compromises the impact that initial limited vaccine supply could otherwise secure.

Process of Roadmap development

The Roadmap builds on the population subgroups identified in the *WHO SAGE values framework for the allocation and prioritization of COVID-19 vaccination* as significant for advancing the Framework's principles and objectives. After prioritization exercises by a subgroup of the SAGE Working Group on COVID-19 Vaccines, a draft of the prioritization table was developed and then critiqued by the full Working Group that includes the chairpersons of all six Regional Immunization Technical Advisory Groups (RITAGS) as well several SAGE members. The draft table was then revised and reviewed multiple times. A similar process was used to develop the narrative sections of the Roadmap. Prioritization took account of emerging modelling information exploring the effectiveness and optimal impact of different vaccination strategies and best available epidemiologic information from the scientific literature as well as various surveillance organizations. A penultimate round of review by multiple SAGE members resulted in further substantive changes to the Framework, followed by a final review by the full SAGE committee.

An update was initiated in June 2021 to incorporate new evidence and the evolving landscape of the pandemic. Using methods similar to those used to develop the original Roadmap, data on vaccine efficacy, effectiveness, immunogenicity, safety, as well as new areas, such as SARS-CoV-2 virus variants of concern (VoC), have been added to this update. The updated Roadmap was reviewed by the SAGE COVID-19 working group and RITAG chairs, and endorsed by SAGE.

Guiding considerations

The following considerations guided the development of this Roadmap and its update.

- This Roadmap must remain fully aligned with the *WHO SAGE values framework for the allocation and prioritization of COVID-19 vaccination* that preceded it.
- To be useful in driving discussions at regional and national levels, the Roadmap needs to be kept as clear and concise as possible.
- The Roadmap will be revisited through i) regular review as new information becomes available; and ii) ongoing dialogue with RITAGs and National Immunization Technical Advisory Groups (NITAGs).
- Countries are also referred to the Global Vaccination Strategy in relation to goal setting for vaccination.

Key assumptions

- The Roadmap assumes any vaccine deployed has received emergency use listing or full regulatory approval and has met all the minimal or critical criteria in *WHO Target Product Profiles (TPP) for COVID-19 vaccines* (4). Based on efficacy estimates and effectiveness data, currently available vaccines perform above TPP criteria and somewhat differently in population subgroups, but not to an extent that affects prioritization (for example, people with comorbidities that increase the risk of severe COVID-19 such as HIV-positive status).
- The Roadmap assumes that non-pharmaceutical interventions remain in place to varying degrees as vaccines are introduced and coverage expands.
- Current emerging evidence suggests that at least some vaccines reduce SARS-CoV-2 transmission. Therefore, vaccination of some groups has been prioritized based on those groups' contribution to transmission (5-7).
- The Roadmap does not account for variation in population seropositivity rates or existing degree of naturally acquired protection within countries or communities that may have already experienced a high degree of community transmission.
- Prioritization considerations for development of this Roadmap considered the risk of severe disease to be closely correlated with the risk of death. Similarly, because evidence on chronic morbidity (Post-COVID-19 condition (8)) is still emerging, the impact of vaccines on long-term sequelae from SARS-CoV-2 infection have not been included in this update.
- Data on vaccine efficacy and effectiveness against VOCs continues to evolve. To date, most vaccines continue to exhibit reasonable effectiveness against VOCs, especially after two doses. For some VOCs effectiveness appears to be lower for symptomatic illness not associated with hospitalization and for asymptomatic infection, but is maintained at relatively high levels against severe disease (hospitalization), ICU admissions, and death (9-11).

Epidemiologic setting scenarios

The epidemiologic setting scenarios used here take into consideration the relative benefits and potential risks of vaccination. Moreover, the public health strategy for use of vaccines depends upon the burden of disease and on the local epidemiology, including circulation of VOCs, and in particular the incidence rate of infection in the specific setting at the time

vaccination is being contemplated for deployment. The three proposed broad epidemiologic settings are: (i) Community Transmission, (ii) Sporadic Cases or Clusters of Cases, and (iii) No Cases (Table 1) (12).

Vaccine supply scenarios

As sufficient vaccine supply has not been available to immunize in all countries everyone who could benefit from vaccination, three scenarios of constrained vaccine supply were considered: a Stage I scenario of very limited vaccine availability (ranging from 1–10% of each country's total population) for initial distribution, which most countries have now achieved; a Stage II scenario as vaccine supply increases but availability remains limited, (ranging from 11–20% of each country's total population); and a Stage III scenario as vaccine supply reaches moderate availability (ranging from 21–50% of each country's total population). How each of these three vaccine supply scenarios could be considered in recommendations for prioritized use in specific groups (priority-use groups) is illustrated in Table 1.

The Roadmap recognizes that many countries' prioritization decisions will be tied, in part or in whole, to vaccine distribution through the COVAX Facility. Stages I and II in the Roadmap correspond to the Phase 1 supply of up to 20% of each country's population detailed in the current working version of the WHO *Fair allocation mechanism for COVID-19 vaccines through the COVAX Facility* (3). The Roadmap's Stage III scenario aligns with the Allocation Framework's Phase 2 supply of more than 20% to 50% population coverage.

Overall public health strategies by epidemiologic setting and vaccine supply stage

SAGE recommends overall public health strategies, grounded in the Values Framework, for each of the three epidemiologic scenarios (Table 1). The strategies accommodate the dynamic nature of vaccine supply and epidemiologic conditions in each country.

Community Transmission setting: When vaccine supplies are severely constrained, what it is feasible to achieve with limited vaccine availability justifies an initial focus on direct reduction of morbidity and mortality and maintenance of most critical essential services, while considering reciprocity towards groups that have been placed at disproportionate risks to mitigate consequences of this pandemic (for example, front-line health workers). As vaccine supplies increase, depending on the vaccine characteristics, the strategy expands to reduction in transmission to further reduce disruption of social and economic functions. Special attention is paid to functions that disproportionately impact children (see below) and to the reduction of morbidity and mortality in disadvantaged groups, in keeping with the principles of the SAGE Values Framework.

Sporadic Cases or Clusters of Cases setting: When vaccine supplies are severely constrained, the initial focus remains on direct reduction of morbidity and mortality, and on maintenance of most critical essential services and reciprocity. However, in contrast to the Community Transmission epidemiologic setting, in this setting the initial focus also concentrates on locations with high transmission or anticipated high transmission. Special attention to reducing morbidity and mortality of disadvantaged groups in areas of high or anticipated high transmission is maintained. As vaccine supplies increase, the strategy expands to substantially control transmission and further reduce disruption of social and economic functions.

No Cases setting: This epidemiologic setting applies to countries that have managed to stop transmission through non-pharmaceutical interventions and border controls. When vaccine supplies are severely constrained, the initial focus is on risk mitigation by vaccinating those groups most at risk of severe disease in the event of an outbreak alongside prevention of community transmission from importation of cases, and reciprocity to critical workers, particularly front-line health workers. As vaccine supply increases, the strategy expands to preserve control of transmission and, if possible, to reduce reliance on burdensome non-pharmaceutical interventions.

Priority uses of COVID-19 vaccines

The rationale for the inclusion of each prioritized vaccine use case based upon population subgroup is anchored in the Values Framework principles and objectives. For each priority-use group, the Values Framework objective(s) that would be supported by prioritizing vaccine use in this population are indicated by parenthetical abbreviations after the population description (for example, A1); the legend that links these abbreviations to the objectives is provided below Table 1.

While a detailed explanation of the rationale for each of the priority-use groups is beyond the scope of this document, three examples of rationales are provided in Box 1.

Box 1. Three examples of rationales for priority uses of COVID-19 vaccines

Example 1. Health workers at high to very high risk of becoming infected and transmitting SARS-CoV-2 in the Community Transmission epidemiologic setting

For the Community Transmission epidemiologic setting, health workers at high to very high risk of becoming infected and transmitting SARS-CoV-2 are included in Stage Ia. There are three reasons, linked to the Values Framework, supporting this prioritization. First, protecting these workers protects the availability of a critical essential service in the COVID-19 pandemic response. Also, the indirect health effects of the pandemic beyond COVID-19 are likely to be much worse if such services are compromised or overwhelmed. Second, evidence suggests that health workers are at high risk of acquiring infection and possibly of morbidity and mortality (13). There is also a risk of onward transmission to people who are also at high risk of serious COVID-19 outcomes. Third, prioritization of these workers is also supported by the principle of reciprocity; they play critical roles in the COVID-19 response, working under intense and challenging conditions, putting not only themselves but also potentially their households at higher risk for the sake of others.

There are also pragmatic reasons for prioritizing vaccine use in health workers at high to very high risk of infection. Health workers already interact directly with health systems, which should facilitate effective deployment of a vaccine programme, particularly when two or more doses need to be administered. Launching a vaccine programme with a relatively accessible target population will allow more time for the development of delivery mechanisms to other priority-use groups.

In a second step (Stage Ib), older adults defined by age-based risk specific to country or region are included.

Example 2. Sociodemographic groups at significantly higher risk of severe disease or death

For the Community Transmission epidemiologic setting, sociodemographic groups at significantly higher risk of severe disease or death are included in Stage II. The reasons for this prioritization are grounded in the principles of equal respect and equity.

In keeping with the overall public health strategy that places an initial focus on direct reduction of mortality and morbidity, groups with comorbidities or health states that put them at significantly higher risk of severe disease or death are prioritized to Stage II. However, there are other groups in the population who may be at just as high a risk of these severe outcomes but who are not captured in a prioritization solely by comorbidities. These groups disproportionately include those who are systematically disadvantaged with respect to social standing and economic and political power. In many contexts, disadvantaged groups are more likely to experience a higher burden of infection and consequent COVID-19 because of crowded work or living conditions over which they have no effective control (14-17), as well as a higher prevalence of background states of poor health that increase their risk of severe COVID-19 (18). They may also have less access to appropriate health care necessary for the diagnosis of high-risk conditions such as heart failure or chronic kidney disease (19). Some individuals in these groups would likely qualify for prioritization of vaccine use if their comorbidities were known or ascertainable, but because of inequitable access to health care their conditions often will be undiagnosed and untreated.

Which disadvantaged sociodemographic groups are at significantly higher risk of severe disease or death will vary from country to country. In many contexts, the evidence of elevated risk for COVID-19 severe disease and death will be lacking or less clear than for the risk factors like age or comorbidities. Policymakers may have to decide which disadvantaged groups are likely to be sufficiently burdened by COVID-19 to include in Stage II. While broader efforts must be made to reach out and identify risks among disadvantaged groups, these decisions may have to be based on reasonable assumptions about differential impact inferred from other relevant contexts, including past public health emergencies (20). Table 1 provides examples of groups that, depending on the country context, may fall under this prioritization use category.

Example 3. Social/employment groups at elevated risk of acquiring and transmitting infection because they are unable to effectively physically distance

For the Community Transmission epidemiologic setting, social/employment groups at elevated risk of acquiring and transmitting infection because they are unable to effectively physically distance are included in Stage III. There is considerable overlap in the groups that should be considered in this category and the Stage II sociodemographic groups category just discussed. The relevant difference is that for some disadvantaged groups there may not be good reasons to conclude that they are at significantly elevated risk of severe disease and death (and thus that they do not qualify under Stage II). However, these groups may nevertheless still be at increased risk (if not greatly increased risk) of severe COVID-19 due to the reasons related to inequity discussed above. Groups that have no choice but to work without physical distancing or access to personal protective equipment, or no choice but to live in high-density homes in high-density neighbourhoods fall into this category (21, 22). They are disadvantaged relative to other groups in the population who benefit more from non-pharmaceutical interventions, both in terms of their own risk and in terms of onward transmission to close contacts, others in their community and co-workers. Incarcerated people also fall into this category, although the rationale is somewhat different. Even if the restriction of their liberty is justified, that does not justify leaving unaddressed the elevated risk of infection associated with being incarcerated.

In an ideal world, policymakers could clearly distinguish, based on evidence regarding level of risk, which disadvantaged groups fall under Stage II criteria and which under Stage III criteria. In the real world, these decisions may have to be made with only limited relevant data. Adherence to the principles of equal respect and equity will require a careful assessment to ensure that all relevant sociodemographic groups are given equal consideration for both Stages.

How staging of priority-use groups relates to group size

The staging of priority-use groups is sequential. If there is insufficient vaccine supply to cover the priority-use groups in Stage I, the intention is that all these groups are offered vaccine before groups enumerated in Stage II.

With the exception of Stage Ia and Stage Ib, the priority-use groups within a vaccine supply stage are not ordered for prioritization of vaccine use. The assignment of priority-use groups was based on assumptions about the size of different priority-use groups in high-, middle- and low-income country settings. For some priority-use groups, even estimates of the sizes of different groups were not available. Considerable national variation is expected. In some countries, the amount of vaccine projected for a vaccine supply stage may be insufficient to cover all the

priority-use groups assigned to that stage and countries will have to prioritize vaccine use to groups within stages.

As an example, consider Stage II in the Community Transmission epidemiologic setting. Receiving vaccine supply up to an additional 10% of population coverage in this stage may be insufficient to address all the groups assigned to that stage, even if Stage I supply is sufficient to cover the groups assigned to Stage I. In deciding which groups in Stage II to prioritize vaccine use, countries may wish to consult the Values Framework for guidance. For example, determining which ethical principles are most important to the country at a given time may help identify which groups to prioritize vaccinating, if vaccine supply is insufficient to cover all the groups assigned to Stage II.

Gender considerations

While there is evidence that the risk of severe disease and death is higher in males than in females, particularly in older age groups, this difference in risk is diminished when comorbidities and other factors are taken into account (23, 24). In many contexts, women are disproportionately represented in high-risk occupation groups and they often have direct responsibility for caring for the elderly. Also, in some contexts, women are structurally disadvantaged in terms of access to health care, political and social status, and decision-making authority. Prioritizing men or women for vaccination could exacerbate underlying gender-based inequities. For these reasons, the Roadmap does not use sex or gender to identify prioritized vaccine use cases. The equal respect principle of the Values Framework underscores the importance of ensuring that immunization delivery systems place equal focus on reaching both men and women in every priority-use group.

Pregnant women

Pregnant women warrant particular consideration, because the potential benefits and risks of vaccination apply not only to the health of the women themselves, but also to the health of their offspring. This group has been historically neglected in the testing and deployment of epidemic vaccines including during the current pandemic. Evidence suggests that pregnant women with COVID-19 are at higher risk of developing severe disease compared to non-pregnant women of reproductive age, with increased likelihood of intensive care unit admission and invasive ventilation(25). Pregnant women who are older (age 35 years and above), have a high body mass index, or have an existing comorbidity such as diabetes or hypertension, are at particular risk of serious outcomes from COVID-19. In addition, COVID-19 in pregnancy is associated with adverse outcomes affecting neonates (25, 26). Pregnant women with COVID-19 have an increased risk of preterm birth and of giving birth to neonates requiring neonatal intensive care, compared to pregnant women without COVID-19.

Developmental and reproductive toxicology (DART) studies in pregnant animals have been completed for all vaccines granted WHO Emergency Use Listing to date, and no harmful effects were reported. The availability of data on the safety of COVID-19 vaccination in pregnancy varies by vaccine product. Post-introduction vaccine pharmacovigilance data on two mRNA vaccines thus far have not identified any additional acute safety signals, with a reactogenicity and adverse events profile by age-group similar to that reported in nonpregnant populations (27). Data on safety in pregnancy for other vaccine products continues to accumulate (27-29).

Based on previous experience with other vaccines used during pregnancy, the effectiveness of COVID-19 vaccines in pregnant women is expected to be comparable to that observed for non-pregnant women in similar age groups. Data from small studies have demonstrated that COVID-19 mRNA vaccines are immunogenic in pregnant women and that vaccine-elicited antibodies are

transported in infant cord blood and breast milk, suggesting possible short term, early neonatal as well as maternal protection (28, 29).

In line with the equal respect principle in the Values Framework, pregnant women are positioned in Stage II of all epidemiological scenarios of the Roadmap, to be included as part of the "Groups with comorbidities or health states determined to be at significantly higher risk of severe disease or death". In many contexts, especially in epidemiologic scenarios a and b, these risks are likely to be greater than any theoretical risks posed by vaccination (the available evidence does not suggest any additional risks to date). WHO recommends that countries consult the section on pregnant women in the interim guidance document for specific vaccine products when considering use of a specific vaccine during pregnancy.

Lactating women

Historically, evaluation of benefit and risk in lactating women has also been overlooked in vaccine development and response. There is, as yet, little evidence to draw upon in evaluating whether lactating women are at elevated risk of severe COVID-19. Therefore, they have not been prioritized in the Roadmap because of lactation; however, some lactating women are included in other priority-use groups. Lactating women are as likely to benefit from vaccination as other people their age (28, 29). Limited data for certain products are now available that suggest no risks to the infant from immunization of their lactating mothers, although evidence on the safety of vaccination in lactating women continues to be gathered (30). Data from small studies have demonstrated vaccine-elicited antibodies in breast milk, raising the prospect of some, short term, neonatal protection (28, 31). WHO does not recommend discontinuing breastfeeding because of vaccination.

Children

Children warrant special consideration for at least three reasons. Children are dependent on adults and the wider society for their well-being, severe COVID-19 although rare in children is occasionally observed, and setbacks in well-being during childhood can have severe negative effects that can be lifelong.

Several trials of COVID-19 vaccine candidates in children have been initiated, are ongoing or have been completed. Regulatory authorization for some vaccines has been granted, including with paediatric age-indications, and additional paediatric authorizations may follow. To date, evidence for vaccines for which there are data supports the conclusion that they are safe and efficacious in children (32).

Although children are less likely to suffer from the direct impact of COVID-19 morbidity and mortality when compared to other age groups, children do have a small risk of developing severe illness and complications from COVID-19 (33, 34). Children infected with SARS-CoV-2 are at low risk of developing Multisystem Inflammatory Syndrome in Children (MIS-C), a severe, potentially fatal multi-organ inflammatory condition with persistent fever (35). The long-term effects of acute asymptomatic infections and mild disease in children are yet to be determined (post COVID-19 condition), and need to be studied to more fully evaluate the benefit of vaccinating children. Preliminary evidence suggests that the COVID-19 case fatality ratios (CFR) in children may be higher in low- and middle-income countries compared to high-income countries (36). In addition, infected children of all ages are capable of transmitting SARS-CoV-2 regardless of

symptom status (37-40). The contribution of children under 10 to transmission is uncertain evidence is still evolving and may be context-specific.

Current evidence suggests that children with certain underlying medical conditions and infants (age <1 year) are at increased risk for severe illness from SARS-CoV-2 infection (41-44). In line with the equal respect principle in the Values Framework, children and adolescents with severe chronic comorbidities that place them at significantly higher risk of severe disease are included for vaccine prioritization in Stage II in both the Community Transmission and Sporadic Cases/Clusters of Cases epidemiologic scenarios. This subset of children and adolescents joins the use case for adult groups with significant comorbidities younger than older adults identified for priority use in Stage I (age cut-off determined at the country level). Where there is evidence that the adults in these groups are at higher risk than those 12-18 years-old, adults should be vaccinated first. Whether children and adolescents with severe chronic comorbidities will be eligible for vaccination will depend on the local availability of vaccines that have been issued an indication for use in paediatric populations by regulatory authorities.

The negative impacts experienced by children during this pandemic go well beyond their personal direct risk of COVID-19 and burden of SARS-CoV-2 infection (45, 46). Physical distancing measures designed to decrease or prevent community transmission of SARS-CoV-2 have included withdrawing children from in-person learning at schools or closing schools altogether. The extent of learning loss and its impact on lifetime prospects is expected to be far greater for children living in poverty or in otherwise disadvantaged groups. Beyond poor learning and constrained life prospects from disruption in school provision, students have lost social and developmental benefits afforded by in-person learning. Schools often also provide many additional functions important for child health and well-being such as social interactions, meal provisions, health services including immunizations, and shelter from unstable or unsafe home living environments. These additional benefits are especially important for children living in disadvantaged circumstances. Taken together, while all children are harmed by educational disruptions, these effects hit hardest the most disadvantaged children, who also have less access to distance learning options, widening further existing inequities in child well-being (29). The health of all children, and especially in low-income settings, is also threatened by COVID-19-related disruptions to routine immunization and other child health programmes (47-49).

Child well-being continues to be addressed in the Roadmap through the prioritized vaccine use by other groups that directly contribute to child welfare. Within the Community Transmission epidemiologic scenario, vaccination of health workers engaged in immunization delivery is prioritized in Stage II (limited vaccine availability) to ensure that delivery of routine childhood vaccines is safely maintained. To facilitate the full reopening of in-school education, vaccination of some teachers and other adult staff employed in school settings is also prioritized in Stage II, and as are remaining school staff in Stage III (moderate vaccine availability). However, there is substantial evidence that schools can reopen safely without vaccinating children, particularly in the presence of other risk mitigation strategies (50).

Considering comorbidities in vaccine prioritization

The evidence that specific comorbidities increase the risk of severe COVID-19 is compelling. It has been shown that i) several comorbidities increase the risk of severe COVID-19; ii) the increase in risk varies between specific comorbidities, and thus equity concerns would arise if all comorbidities are given equal weight; iii) in many countries, if everyone with a comorbidity were

prioritized in early vaccine supply scenarios, those eligible for vaccination would well-exceed supply; and iv) the list of relevant comorbidities will be dependent on location and other local factors (23, 24, 51-53).

Based on these considerations, countries should use relevant local and regional data to identify the comorbidities associated with different levels of COVID-19 risks (for example, significant versus moderate risk). One approach is to identify the additional risk associated with each comorbidity. Another approach is to prioritize vaccine use in individuals who have two or more relevant comorbidities (54).

Community engagement, effective communication, and legitimacy

Community engagement and effective communication are essential to the success of COVID-19 vaccine programmes. These elements are grounded in the legitimacy principle of the Values Framework. This principle requires that prioritization decisions be made through transparent processes that are based on shared values, best available scientific evidence, and appropriate representation and input by affected parties. Adhering to the legitimacy principle is a way to promote public trust and acceptance of a COVID-19 vaccine.

When applied in practice, countries may embrace the legitimacy principle through practical strategies which improve the public's perception and understanding of vaccine development and prioritization processes. Examples of such strategies include i) culturally and linguistically accessible communications made freely available regarding COVID-19 vaccination; ii) recruitment of community opinion leaders to improve awareness and understanding of such communications; and iii) Inclusion of diverse and affected stakeholder opinions in decision-making. Efforts towards community engagement and effective communication are additionally important in subpopulations which may be unfamiliar with or distrustful of health-care systems.

As outlined in the Values Framework, there must be no tolerance for personal, financial or political conflict of interest or corruption in the prioritization of groups to have access to COVID-19 vaccines. In all cases, decision-makers must be able to publicly defend their decisions and actions by appealing to reasons that even those who disagree can view as reasonable, and not arbitrary or self-serving. Countries should ensure that individuals are not able to use their social, financial or political privilege to bypass country-level prioritization.

Table 1. Epidemiologic setting and vaccine supply scenarios, and recommendations for priority use cases for vaccines against Covid-19 in the context of limited supply[a,b]

(a) Epidemiologic setting scenario: Community Transmission – defined in Legend 2

Overall public health strategy for this epidemiologic setting: Initial focus on direct reduction of morbidity and mortality and maintenance of most critical essential services; also, reciprocity. Expand for further reduction of mortality/morbidity and contribute to reduction in transmission to further reduce disruption of social and economic functions. **(A1) (A2) (A3) (B1) (B2) (C1) (C2) (D1)** – labels explained in Legend 1	
Vaccine supply scenario	**Priority-use groups**
Stage I (very limited vaccine availability, for 1–10% nat. pop.)	Stage Ia (initial launch): • Health workers at *high to very high risk* of acquiring and transmitting infection as defined in Annex 2. **(A1) (A3) (D1)** Stage Ib: • Older adults defined by age-based risk specific to country/region; specific age cut-off to be decided at the country level. **(A1) (C1)**
Stage II (limited vaccine availability, for 11–20% nat. pop.)	• Older adults not covered in Stage I. (A1) (C1) • Health workers at *low to moderate risk* of acquiring and transmitting infection as defined in Annex 2. (A1) (A3) (D1) • Groups with comorbidities or health states (such as pregnancy) determined to be at *significantly higher risk* of severe disease or death. Efforts should be made to ensure that disadvantaged groups where there is underdiagnosis of comorbidities are equitably included in this category. (A1) (C1) (C2) • Sociodemographic groups at *significantly higher risk* of severe disease or death (depending on country context, examples may include: disadvantaged or persecuted ethnic, racial, gender, and religious groups and sexual minorities; people living with disabilities; people living in extreme poverty, homeless and those living in informal settlements or urban slums; low-income migrant workers; refugees, internally displaced persons, asylum seekers, populations in conflict settings or those affected by humanitarian emergencies, vulnerable migrants in irregular situations; nomadic populations; and hard-to-reach population groups such as those in rural and remote areas). (A1) (B1) (B2) (C1) (C2)

	• Health workers engaged in immunization delivery (routine programmes and COVID-19 vaccination). (A1) (A2) (B2) (C1) (C2) (D1) • High-priority teachers and school staff (depending on country context, examples may include: preschool and primary school teachers because of the critical developmental stage of the children they teach, teachers of children where distance learning is very difficult or impossible). (A2) (A3) (B1) (C1) (C2) • Seafarers and air crews with special attention to seafarers who are stranded at sea and prevented from crossing international borders for crew change due to travel restrictions (55). (A2) (A3) (B1) (C1) (D1)
Stage III (moderate vaccine availability, for 21–50% nat. pop.)	• Remaining teachers and school staff. **(A2) (A3) (B1) (C1) (C2)** • Other essential workers outside health and education sectors (examples: police officers, municipal services, child-care providers, agriculture and food workers, transportation workers, government workers essential to critical functioning of the state not covered by other categories). **(A2) (A3) (D1)** • Personnel needed for vaccine production and other high-risk laboratory staff. **(A1) (A2) (A3) (D1)** • Social/employment groups at *elevated risk* of acquiring and transmitting infection because they are unable to effectively physically distance (depending on country context, examples may include: people living or working in detention facilities, incarcerated people, dormitories, informal settlements or urban slums; low-income people in dense urban neighbourhoods; homeless people; military personnel living in tight quarters; and people working in certain occupations such as mining and meat processing). **(A1) (B1) (B2) (C1) (C2)**

(b) Epidemiologic setting scenario: Sporadic Cases or Clusters of Cases – defined in Legend 2

Overall public health strategy for this epidemiologic setting: Initial focus on direct reduction of morbidity and mortality and maintenance of most critical essential services; also, reciprocity. Expand to contribute to control transmission and minimize disruption of social and economic functions. **(A1) (A2) (A3) (B1) (B2) (C1) (C2) (D1)** – labels explained in Legend 1	
Vaccine supply scenario	**Priority-use groups**
Stage I (very limited vaccine availability, for 1–10% nat. pop.)	• Health workers at *high to very high risk* of acquiring and transmitting infection as defined in Annex 2, **(A1) (A3) (D1)** • Older adults defined by age-based risk specific to country/region – specific age cut-off to be decided at the country level. **(A1) (C1)**
Stage II (limited vaccine availability, for 11–20% nat. pop.)	• Older adults not covered in Stage I. **(A1) (C1)** • Health workers at *low to moderate risk* of acquiring and transmitting infection as defined in Annex 2. **(A1) (A3) (D1)** • Groups with comorbidities or health states (such as pregnancy) determined to be at *significantly higher risk* of severe disease or death. Efforts should be made to ensure that disadvantaged groups where there is underdiagnosis of comorbidities are equitably included in this category. **(A1) (C1) (C2)** • Sociodemographic groups at *significantly higher risk* of severe disease or death (depending on country context, examples may include: disadvantaged or persecuted ethnic, racial, gender, and religious groups and sexual minorities; people living with disabilities; people living in extreme poverty, homeless and those living in informal settlements or urban slums; low-income migrant workers; refugees, internally displaced persons, asylum seekers, populations in conflict settings or those affected by humanitarian emergencies, vulnerable migrants in irregular situations; nomadic populations; and hard-to-reach population groups such as those in rural and remote areas). **(A1) (B1) (B2) (C1) (C2)** • Seafarers and air crews with special attention to seafarers who are stranded at sea and prevented from crossing international borders for crew change due to travel restrictions (55). **(A2) (A3) (B1) (C1) (D1)**
Stage III (moderate vaccine	• Primary and secondary teachers and school staff. **(A2) (A3) (B1) (C1) (C2)**

availability, for 21–50% nat. pop.)	• Other essential workers outside health and education sectors (examples: police officers, municipal services, childcare providers, agriculture and food workers, transportation workers, government workers essential to critical functioning of the state not covered by other categories). **(A2) (A3) (D1)** • Social/employment groups at *elevated risk* of acquiring and transmitting infection because they are unable to effectively physically distance (depending on country context, examples may include: people living or working in detention facilities, incarcerated people, dormitories, informal settlements or urban slums, low income people in dense urban neighbourhoods, homeless people, military personnel living in tight quarters, and people working in certain occupations for example, mining, meat processing). **(A1) (B1) (B2) (C1) (C2)** • Health workers engaged in immunization delivery (routine programmes and COVID-19 vaccination). **(A1) (A2) (B2) (C1) (C2) (D1)** • Age groups at high risk of transmitting infection by age-based risk specific to country/region; specific age cut-off to be decided at the country level. **(A1) (A2)** • Personnel needed for vaccine production and other high-risk laboratory staff. **(A1) (A2) (A3) (D1)**

(c) Epidemiologic setting scenario: No Cases – defined in Legend 2

Overall public health strategy for this epidemiologic setting: Initial focus on risk mitigation to protect those most at risk of severe outcomes in the case of a COVID-19 outbreak alongside prevention of community transmission; also, reciprocity. Expand to preserve control of transmission and reduce reliance on most burdensome non-pharmaceutical interventions. **(A1) (A2) (A3) (B1) (C1) (C2) (D1)** – labels explained in Legend 1	
Vaccine supply scenario	**Priority-use groups**
Stage I (very limited vaccine availability, for 1–10% nat. pop.)	• Health workers at *high to very high risk* of acquiring and transmitting infection as defined in Annex 2. **(A1) (A3) (D1)** • Essential travellers at risk for acquiring infection outside the home country and reintroducing infection upon return to home country (for example, seafarers and air crews with special attention to seafarers who are stranded at sea and prevented from crossing international borders for crew change due to travel restrictions (55),students, business travellers, migrant workers, aid workers). Countries should define essential travellers in a way that constrains the ability of economically and politically powerful individuals to exploit this priority-use group to their advantage. **(A1) (A2) (A3) (B1) (C1) (D1)** • Border protection staff screening for imported cases and workers for outbreak management (for example, isolation and quarantine managers, immunization deployment staff). **(A1) (A2) (D1)** • Older adults defined by age-based risk specific to country/region; specific age cut-off to be decided at the country level. **(A1) (C1)**
Stage II (limited vaccine availability, for 11–20% nat. pop.)	• Older adults not covered in Stage I. **(A1) (C1)** • Health workers at *low to moderate risk* of acquiring and transmitting infection as defined in Annex 2. **(A1) (A3) (D1)** • All travellers at risk for acquiring infection outside the home country and reintroducing infection upon return to home country. **(A1) (A2)** • Groups with comorbidities or health states (such as pregnancy) determined to be at *significantly higher risk* of severe disease or death. Efforts should be made to ensure that disadvantaged groups where there is underdiagnosis of comorbidities are equitably included in this category. **(A1) (C1) (C2)** • Health workers engaged in immunization delivery (routine programmes and COVID-19 vaccination). **(A1) (A2) (B2) (C1) (C2) (D1)**
Stage III (moderate	• Social/employment groups at *elevated risk* of acquiring and transmitting infection because they are unable to effectively physically distance *in areas with high transmission or anticipated high transmission* (depending on country context, examples may include: people living or working in detention facilities, incarcerated

vaccine availability, for 21–50% nat. pop.)	people, dormitories, informal settlements or urban slums, low income people in dense urban neighbourhoods, homeless people, military personnel living in tight quarters, and people working in certain occupations for example, mining, meat processing). **(A1) (B1) (B2) (C1) (C2)** • Age groups at high risk of transmitting infection by age-based risk specific to country/region, specific age cut-off to be decided at the country level. **(A1) (A2)** • Primary and secondary school teachers and staff. **(A2) (A3) (B1) (C1) (C2)** • Other essential workers outside health and education sectors (examples: police officers, municipal services, child-care providers, agriculture and food workers, transportation workers, government workers essential to critical functioning of the state not covered by other categories). **(A2) (A3) (D1)**
National equity considerations: Ensure that vaccine prioritization within countries takes into account the disproportionate burdens of the COVID-19 pandemic on social groups that are systematically disadvantaged. **(C1) (C2)** [a] For individuals in more than one priority-use group, the highest applicable priority-use group determines the order in which they should receive COVID-19 vaccine. [b] Current modelling suggests that (given the many-fold higher mortality rate among older individuals) age-dependent vaccine efficacy would not significantly change the recommendations for priority use cases in older populations for a strategy based on mortality reduction *(56-59)*. If vaccine efficacy in older adults relative to other age groups were so low that individual protection and public health impact became significantly suboptimal, the individuals in older age groups in each scenario would likely be moved to a lower rank.	

Legend 1. Value objectives applied to priority-use groups

A. Well-being	**(A1)** Reduce deaths and disease burden from the COVID-19 pandemic.
	(A2) Reduce societal and economic disruption (other than through reducing deaths and disease burden).
	(A3) Protect the continuing functioning of essential services, including health services.
B. Equal respect	**(B1)** Treat the interests of all individuals and groups with equal consideration as allocation and priority-setting decisions are being made and implemented.
	(B2) Offer a meaningful opportunity to be vaccinated to all individuals and groups who qualify under prioritization criteria.
C. Equity	**(C1)** Ensure that vaccine prioritization within countries takes into account the vulnerabilities, risks and needs of groups who, because of underlying societal, geographic or biomedical factors, are at risk of experiencing greater burdens from the COVID-19 pandemic.

	(C2) Develop the immunization delivery systems and infrastructure required to ensure priority-use populations have access to COVID-19 vaccines, and which ensures equal access to everyone who qualifies under a priority-use group, particularly socially disadvantaged populations.
D. Reciprocity	**(D1)** Protect those who bear significant additional risks and burdens of COVID-19 to safeguard the welfare of others, including health and other essential workers.

Legend 2. WHO transmission categories corresponding to epidemiologic setting scenarios

Transmission category[a]	**Definition**
No Cases	Countries/territories/areas with no confirmed cases.
Sporadic Cases	Countries/territories/areas with one or more cases, imported or locally detected.
Clusters of Cases	Countries/territories/areas experiencing cases, clustered in time, geographic location and/or by common exposures
Community Transmission	Countries/area/territories experiencing larger outbreaks of local transmission defined through an assessment of factors including, but not limited to: • large numbers of cases not linkable to transmission chains; • large numbers of cases from sentinel laboratory surveillance or increasing positive tests through sentinel samples (routine systematic testing o respiratory samples from established laboratories); • multiple unrelated clusters in several areas of the country/territory/area.
Scenario transitions: From lower to higher transmission scenario: change to be reported at any time (in the next weekly update). From higher to lower transmission scenario: observe during a 28-day period before confirming downgrading of transmission.	

[a] Definitions correspond to those used elsewhere in WHO epidemiologic reports, using definitions published in the WHO interim guidance on public health surveillance for COVID-19 (12)

Annex 1. Reduction of deaths versus reduction of years of life lost

Years of life lost (YLL) is a measure that is thought by many to integrate a commitment to maximizing health benefit with a commitment to promoting equity, where equity is understood to include an obligation to ensure that younger people have a fair chance to reach later stages of life. There are good ethics arguments for using YLL in many allocation contexts, including in this particular pandemic (60, 61). However, the particular epidemiology of the current pandemic supports using reducing deaths and hospitalization as a preferred strategy for within-country prioritization. The risk of COVID-19-related mortality is extremely high in older age groups compared to that in younger age groups. For example, in the United States, the mortality risk has been estimated to be 90 times higher among 65–74-year-olds compared to 18–29-year-olds (62). A similar pattern of significantly higher mortality in older age groups has been observed in multiple other countries. The evidence identified to date from modelling analyses suggests that using YLL instead of deaths would not substantially alter the priority ranking of older people relative to younger people when age is the only dimension considered (57, 58). Supplementary unpublished sensitivity analyses prepared for the WHO SAGE Working Group on COVID-19 Vaccines support this finding. As priority rankings would not change, expressing the policy objective in terms of reduction in the number of deaths rather than YLL has programmatic advantages, even if YLL reaches the same conclusions about relative prioritization of vaccine use. Reduction of number of deaths is more easily understood by and communicated to the general public and is likely to be widely endorsed as an important objective at a time when securing public support for and confidence in vaccine programmes is critically important. A prioritization approach relying on YLL could be viewed as disrespectful to older people by failing to address their disproportionately higher risk of death (54).

YLL also does not address the primary equity challenges in prioritization of COVID-19 vaccine use within countries and thus the commitment of the Values Framework to equity does not in this pandemic require use of YLL. In a pandemic with a mortality pattern similar to seasonal influenza where the very young as well as older adults have disproportionately high mortality, or that of the 1918 influenza pandemic where young adults were a high-mortality risk group, equity considerations could well require a focus on YLL. Also, in the current COVID-19 pandemic the equity issues in allocation of vaccine between countries are markedly different from those in within-country prioritization. Standard expected years of life lost, a measure of disease burden often used for cross-national comparative purposes, can help illustrate the commitment of the Values Framework to global equity, as long as global inequities in access to testing and other surveillance technologies do not unfairly skew assessments of this metric.

Annex 2. Definition of health workers

Health workers (63) are all people engaged in work actions whose primary intent is to improve health. This includes health service providers, such as doctors, nurses, midwives, public health professionals, lab-, health- and medical and non-medical technicians, personal care workers, community health workers, healers and practitioners of traditional medicine. It also includes health management and support workers, such as cleaners, drivers, hospital administrators, district health managers and social workers, and other occupational groups in health-related activities. Health workers include not only those who work in acute care facilities but also those employed in long-term care, public health, community-based care, social care and home care and other occupations in the health and social work sectors as defined by the International Standard Industrial Classification of All Economic Activities (ISIC), revision 4, section Q: Human health and social work activities.

The following levels may be useful in assessing the risk of occupational exposure to SARS-CoV-2 for jobs or tasks of health workers, prior to introducing mitigation measures:

a) Low risk - Jobs or work without frequent, close contact with the public or others that do not require contact with people known to be or suspected of being actively infected with the virus responsible for COVID-19. Workers in this group have minimal occupational contact with the public and other co-workers, for example performing administrative duties in non-public areas of healthcare facilities, away from other staff members, telehealth services in individual offices

b) Medium risk - Jobs or tasks with close, frequent contact with the general public or others but that do not require contact with people known to be or suspected of being actively infected with the virus responsible for COVID-19. In areas where COVID-19 cases continue to be reported, this risk level may apply to workers who have frequent and close contact with the people in busy staff work areas within a healthcare facility and work activities where safe physical distance may be difficult to maintain, or tasks that require close and frequent contact between co-workers. In areas without community transmission of COVID-19, this scenario may include frequent contact with people returning from areas with known higher levels of community transmission. Examples include, providing care to the general public who are not known or suspected of having COVID-19, or working at busy staff work areas within a healthcare facility

c) High risk - Jobs or tasks with high potential for close contact with people who are known or suspected of having COVID-19, as well as contact with objects and surfaces possibly contaminated with the virus, e.g. the direct patient care, domestic services or home care for people for people with COVID-19. Jobs and tasks that may fall under this category may include: entering a known or suspected COVID-19 patient's room, providing care for a known or suspected COVID-19 patient not involving aerosol-generating procedures; transportation of people known or suspected to have COVID-19 without separation between the driver and the passenger.

d) Very high risk - jobs and tasks with risk of exposure to aerosols with SARS-CoV-2, the settings where performing aerosol-generating procedures are performed on patients with COVID-19, such as tracheal intubation, non-invasive ventilation, tracheotomy, cardiopulmonary resuscitation, manual ventilation before intubation,

sputum induction, bronchoscopy, spirometry, and autopsy procedures and working with COVID19 patients in crowded, enclosed places without adequate ventilation.

Annex 3. Table of major updates

Section	Rational for update
Rationale	The new version states, that while there now are vaccines licensed and available, the supply remains limited and unreliable in many settings. It further states that, while all currently recommended COVID-19 vaccines have similar and broad indications for use, countries may decide to consider specific product attributes when prioritizing populations.
Rationale	The updated Roadmap is also not proposing coverage targets to be achieved. In 2020, the Roadmap worked with an initial target of 20% population coverage, based on the expected supply of vaccines. The Roadmap currently provides guidance up to a population coverage level of 50%.
Process of the Roadmap development	The update reflects the methods and processes used to arrive at this 2021 version of the Prioritization Roadmap.
Key assumption	Under the key assumption in 2020 it was stated that COVID-19 vaccines will likely have an impact on transmission. In the update it was added that there now is some evidence that supports this statement.
Key assumption	Post-COVID-19 condition was noted, but as evidence is still emerging, the impact of vaccines on long-term sequelae from SARS-CoV-2 infection have not been included in the update.
Pregnant women, lactating women and children	Substantive changes have been made to these sections to reflect the recent evidence.
Epidemiological settings	The need to keep a vaccine reserve has been removed. Pregnant women have been moved to Stage II. Seafarers and air crews have been added to Stage II. Settings and geographic locations of high transmission have been removed.

References

1. WHO Values Framework for the Allocation and Prioritization of COVID-19 Vaccines.
2. COVID-19 vaccines technical documents. World Health Organization. (www.who.int/groups/strategic-advisory-group-of-experts-on-immunization/covid-19-materials, accessed 17 June 2021).
3. Fair allocation mechanism for COVID-19 vaccines through the COVAX Facility. Geneva: World Health Organization; 9 September 2020. (www.who.int/publications/m/item/fair-allocation-mechanism-for-covid-19-vaccines-through-the-covax-facility , accessed 17 June 2021).
4. WHO Target product profiles for COVID-19 vaccines, 9 April 2020. https://www.who.int/blueprint/priority-diseases/key-action/WHO_Target_Product_Profiles_for_COVID-19_web.pdf. 2020.
5. Shah ASV, Gribben C, Bishop J, Hanlon P, Caldwell D, Wood R et al. Effect of vaccination on transmission of COVID-19: an observational study in healthcare workers and their households. medRxiv. 2021.
6. Harris RJ, Hall JA, Zaidi A, Andrews NJ, Dunbar JK, Dabrera G. Impact of vaccination on household transmission of SARS-COV-2 in England. 2021 (https://khub.net/documents/135939561/390853656/Impact+of+vaccination+on+household+transmission+of+SARS-COV-2+in+England.pdf/35bf4bb1-6ade-d3eb-a39e-9c9b25a8122a?t=1619601878136, accessed June 3, 2021).
7. Salo J, Hägg M, Kortelainen M, Leino T, Saxell T, Siikanen M et al. The indirect effect of mRNA-based Covid-19 vaccination on unvaccinated household members. medRxiv. 2021:2021.05.27.21257896. doi: 10.1101/2021.05.27.21257896.
8. The WHO Global Clinical Platform for COVID-19. (www.who.int/teams/health-care-readiness-clinical-unit/covid-19/data-platform/, accessed 22 June 2021).
9. Abu-Raddad LJ, Chemaitelly H, Butt AA, Vaccination NSGfC-. Effectiveness of the BNT162b2 Covid-19 Vaccine against the B.1.1.7 and B.1.351 Variants. N Engl J Med. 2021. doi: 10.1056/NEJMc2104974.
10. Sansone E, Tiraboschi M, Sala E, Albini E, Lombardo M, Castelli F et al. Effectiveness of BNT162b2 vaccine against the B.1.1.7 variant of SARS-CoV-2 among healthcare workers in Brescia, Italy. J Infect. 2021. doi: 10.1016/j.jinf.2021.04.038.
11. Hitchings M, Ranzani O, Scaramuzzini Torres M, Barbosa de Oliveira S, Almiron M, Said R, et al. Effectiveness of CoronaVac in the setting of high SARS-CoV-2 P.1 variant transmission in Brazil: A test-negative case-control study (https://www.medrxiv.org/content/10.1101/2021.04.07.21255081v1.full.pdf, accessed 19 April 2021)2021.
12. Public health surveillance for COVID-19: interim guidance.
13. Nguyen LH, Drew DA, Joshi AD, Guo CG, Ma W, Mehta RS et al. Risk of COVID-19 among frontline healthcare workers and the general community: a prospective cohort study. medRxiv. 2020. doi: 10.1101/2020.04.29.20084111.
14. Lewis NM, Friedrichs M, Wagstaff S, Sage K, LaCross N, Bui D et al. Disparities in COVID-19 Incidence, Hospitalizations, and Testing, by Area-Level Deprivation - Utah, March 3-July 9, 2020. MMWR Morb Mortal Wkly Rep. 2020;69:1369-73. doi: 10.15585/mmwr.mm6938a4.
15. Disparities in the risk of outcomes of COVID-19. London: Public Health England; 11 August 2020. (https://www.gov.uk/government/publications/covid-19-review-of-disparities-in-risks-and-outcomes, accessed 17 June 2021).

16. Lassale C, Gaye B, Hamer M, Gale CR, Batty GD. Ethnic Disparities in Hospitalization for COVID-19: a Community-Based Cohort Study in the UK. medRxiv. 2020. doi: 10.1101/2020.05.19.20106344.
17. Kaul P. India's stark inequalities make social distancing much easier for some than others. The Conversation. 2 April 2020. (https://theconversation.com/indias-stark-inequalities-make-social-distancing-much-easier-for-some-than-others-134864, accessed 17 June 2021).
18. Hatcher SM, Agnew-Brune C, Anderson M, Zambrano LD, Rose CE, Jim MA et al. COVID-19 Among American Indian and Alaska Native Persons - 23 States, January 31-July 3, 2020. MMWR Morb Mortal Wkly Rep. 2020;69:1166-9. doi: 10.15585/mmwr.mm6934e1.
19. Sumaili EK, Cohen EP, Zinga CV, Krzesinski JM, Pakasa NM, Nseka NM. High prevalence of undiagnosed chronic kidney disease among at-risk population in Kinshasa, the Democratic Republic of Congo. BMC Nephrol. 2009;10:18. doi: 10.1186/1471-2369-10-18.
20. Fallah MP, Skrip LA, Gertler S, Yamin D, Galvani AP. Quantifying Poverty as a Driver of Ebola Transmission. PLoS Negl Trop Dis. 2015;9:e0004260. doi: 10.1371/journal.pntd.0004260.
21. The Sustainable Development Goals Report 2020. New York (NY): United Nations; 2020 (https://unstats.un.org/sdgs/report/2020, accessed 17 June 2021).
22. Wasdani KP. Prasad A. The impossibility of social distancing among the urban poor: the case of an Indian slum in times of COVID-19. Local Environ. 3 May 2020; 25(5):414-8. doi:10.1080(13549839.2020.1754375.
23. Docherty AB, Harrison EM, Green CA, Hardwick HE, Pius R, Norman L et al. Features of 20 133 UK patients in hospital with covid-19 using the ISARIC WHO Clinical Characterisation Protocol: prospective observational cohort study. BMJ. 2020;369:m1985.
24. Clark A, Jit M, Warren-Gash C, Guthrie B, Wang HHX, Mercer SW et al. Global, regional, and national estimates of the population at increased risk of severe COVID-19 due to underlying health conditions in 2020: a modelling study. Lancet Glob Health. 2020. doi: 10.1016/S2214-109X(20)30264-3.
25. Allotey J, Stallings E, Bonet M, Yap M, Chatterjee S, Kew T et al. Clinical manifestations, risk factors, and maternal and perinatal outcomes of coronavirus disease 2019 in pregnancy: living systematic review and meta-analysis. BMJ. 2020;370:m3320. doi: 10.1136/bmj.m3320.
26. Woodworth KR, Olsen EO, Neelam V, Lewis EL, Galang RR, Oduyebo T et al. Birth and Infant Outcomes Following Laboratory-Confirmed SARS-CoV-2 Infection in Pregnancy - SET-NET, 16 Jurisdictions, March 29-October 14, 2020. MMWR Morb Mortal Wkly Rep. 2020;69:1635-40. doi: 10.15585/mmwr.mm6944e2.
27. Shimabukuro TT, Kim SY, Myers TR, Moro PL, Oduyebo T, Panagiotakopoulos L et al. Preliminary Findings of mRNA Covid-19 Vaccine Safety in Pregnant Persons. N Engl J Med. 2021. doi: 10.1056/NEJMoa2104983.
28. Gray KJ, Bordt EA, Atyeo C, Deriso E, Akinwunmi B, Young N et al. COVID-19 vaccine response in pregnant and lactating women: a cohort study. Am J Obstet Gynecol. 2021. doi: 10.1016/j.ajog.2021.03.023.
29. Collier AY, McMahan K, Yu J, Tostanoski LH, Aguayo R, Ansel J et al. Immunogenicity of COVID-19 mRNA Vaccines in Pregnant and Lactating Women. JAMA. 2021. doi: 10.1001/jama.2021.7563.

30. Ciapponi A, Bardach A, Mazzoni A, Alconada T, Anderson S, Argento FJ et al. Safety of COVID-19 vaccines, their components or their platforms for pregnant women: A rapid review. medRxiv. 2021. doi: 10.1101/2021.06.03.21258283.
31. Perl SH, Uzan-Yulzari A, Klainer H, Asiskovich L, Youngster M, Rinott E et al. SARS-CoV-2-Specific Antibodies in Breast Milk After COVID-19 Vaccination of Breastfeeding Women. JAMA. 2021;325:2013-4. doi: 10.1001/jama.2021.5782.
32. Frenck RW, Klein NP, Kitchin N, Gurtman A, Absalon J, Lockhart S et al. Safety, Immunogenicity, and Efficacy of the BNT162b2 Covid-19 Vaccine in Adolescents. N Engl J Med. 2021. doi: 10.1056/NEJMoa2107456.
33. Preston LE, Chevinsky JR, Kompaniyets L, Lavery AM, Kimball A, Boehmer TK et al. Characteristics and Disease Severity of US Children and Adolescents Diagnosed With COVID-19. JAMA Netw Open. 2021;4:e215298. doi: 10.1001/jamanetworkopen.2021.5298.
34. Havers FP, Whitaker M, Self JL, Chai SJ, Kirley PD, Alden NB et al. Hospitalization of Adolescents Aged 12-17 Years with Laboratory-Confirmed COVID-19 - COVID-NET, 14 States, March 1, 2020-April 24, 2021. MMWR Morb Mortal Wkly Rep. 2021;70:851-7. doi: 10.15585/mmwr.mm7023e1.
35. Belay ED, Abrams J, Oster ME, Giovanni J, Pierce T, Meng L et al. Trends in Geographic and Temporal Distribution of US Children With Multisystem Inflammatory Syndrome During the COVID-19 Pandemic. JAMA Pediatr. 2021. doi: 10.1001/jamapediatrics.2021.0630.
36. Kitano T, Kitano M, Krueger C, Jamal H, Al Rawahi H, Lee-Krueger R et al. The differential impact of pediatric COVID-19 between high-income countries and low- and middle-income countries: A systematic review of fatality and ICU admission in children worldwide. PLoS One. 2021;16:e0246326. doi: 10.1371/journal.pone.0246326.
37. Brandal LT, Ofitserova TS, Meijerink H, Rykkvin R, Lund HM, Hungnes O et al. Minimal transmission of SARS-CoV-2 from paediatric COVID-19 cases in primary schools, Norway, August to November 2020. Euro Surveill. 2021;26. doi: 10.2807/1560-7917.ES.2020.26.1.2002011.
38. Heavey L, Casey G, Kelly C, Kelly D, McDarby G. No evidence of secondary transmission of COVID-19 from children attending school in Ireland, 2020. Euro Surveill. 2020;25. doi: 10.2807/1560-7917.ES.2020.25.21.2000903.
39. Ehrhardt J, Ekinci A, Krehl H, Meincke M, Finci I, Klein J et al. Transmission of SARS-CoV-2 in children aged 0 to 19 years in childcare facilities and schools after their reopening in May 2020, Baden-Württemberg, Germany. Euro Surveill. 2020;25. doi: 10.2807/1560-7917.ES.2020.25.36.2001587.
40. Ismail SA, Saliba V, Lopez Bernal J, Ramsay ME, Ladhani SN. SARS-CoV-2 infection and transmission in educational settings: a prospective, cross-sectional analysis of infection clusters and outbreaks in England. Lancet Infect Dis. 2021;21:344-53. doi: 10.1016/S1473-3099(20)30882-3.
41. European Centre for Disease Prevention and Control. Interim public health considerations for COVID-19 vaccination of adolescents in the EU/EEA. 1 June 2021. Stockholm: ECDC; 2021.
42. Kompaniyets L, Agathis NT, Nelson JM, Preston LE, Ko JY, Belay B et al. Underlying Medical Conditions Associated With Severe COVID-19 Illness Among Children. JAMA Netw Open. 2021;4:e2111182. doi: 10.1001/jamanetworkopen.2021.11182.
43. Abrams JY, Oster ME, Godfred-Cato SE, Bryant B, Datta SD, Campbell AP et al. Factors linked to severe outcomes in multisystem inflammatory syndrome in children (MIS-C) in

the USA: a retrospective surveillance study. Lancet Child Adolesc Health. 2021;5:323-31. doi: 10.1016/S2352-4642(21)00050-X.

44. Feldstein LR, Tenforde MW, Friedman KG, Newhams M, Rose EB, Dapul H et al. Characteristics and Outcomes of US Children and Adolescents With Multisystem Inflammatory Syndrome in Children (MIS-C) Compared With Severe Acute COVID-19. JAMA. 2021;325:1074-87. doi: 10.1001/jama.2021.2091.
45. Dong Y, Mo X, Hu Y, Qi X, Jiang F, Jiang Z et al. Epidemiology of COVID-19 Among Children in China. Pediatrics. 2020;145. doi: 10.1542/peds.2020-0702.
46. Kim L, Whitaker M, O'Halloran A, Kambhampati A, Chai SJ, Reingold A et al. Hospitalization Rates and Characteristics of Children Aged <18 Years Hospitalized with Laboratory-Confirmed COVID-19 - COVID-NET, 14 States, March 1-July 25, 2020. MMWR Morb Mortal Wkly Rep. 2020;69:1081-8. doi: 10.15585/mmwr.mm6932e3.
47. Santoli JM, Lindley MC, DeSilva MB, Kharbanda EO, Daley MF, Galloway L et al. Effects of the COVID-19 Pandemic on Routine Pediatric Vaccine Ordering and Administration - United States, 2020. MMWR Morb Mortal Wkly Rep. 2020;69:591-3. doi: 10.15585/mmwr.mm6919e2.
48. McDonald HI, Tessier E, White JM, Woodruff M, Knowles C, Bates C et al. Early impact of the coronavirus disease (COVID-19) pandemic and physical distancing measures on routine childhood vaccinations in England, January to April 2020. Euro Surveill. 2020;25. doi: 10.2807/1560-7917.ES.2020.25.19.2000848.
49. At least 80 million children under one at risk of diseases such as diphtheria, measles and polio as COVID-19 disrupts routine vaccination efforts, warn Gavi, WHO and UNICEF. Geneva: World Health Organization; 22 May 2020 (www.who.int/news-room/detail/22-05-2020-at-least-80-million-children-under-one-at-risk-of-diseases-such-as-diphtheria-measles-and-polio-as-covid-19-disrupts-routine-vaccination-efforts-warn-gavi-who-and-unicef , accessed 17 June 2021).
50. WHO, UNICEF, UNESCO. Considerations for school-related public health measures in the context of COVID-19: annex to considerations in adjusting public health and social measures in the context of COVID-19, 14 September 2020. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/334294.
51. Petrilli CM, Jones SA, Yang J, Rajagopalan H, O'Donnell L, Chernyak Y et al. Factors associated with hospital admission and critical illness among 5279 people with coronavirus disease 2019 in New York City: prospective cohort study. BMJ. 2020;369:m1966. doi: 10.1136/bmj.m1966.
52. Graff K, Smith C, Silveira L, Jung S, Curran-Hays S, Jarjour J et al. Risk Factors for Severe COVID-19 in Children. Pediatr Infect Dis J. 2021;40:e137-e45. doi: 10.1097/INF.0000000000003043.
53. Clift AK, Coupland CAC, Keogh RH, Diaz-Ordaz K, Williamson E, Harrison EM et al. Living risk prediction algorithm (QCOVID) for risk of hospital admission and mortality from coronavirus 19 in adults: national derivation and validation cohort study. BMJ. 2020;371:m3731. doi: 10.1136/bmj.m3731.
54. National Academies of Sciences, Engineering, and Medicine. Framework for Equitable Allocation of COVID-19 Vaccine. Washington (DC): The National Academies Press; 2020. doi:https://doi.org/10.17226/25917.
55. Joint Statement on prioritization of COVID-19 vaccination for seafarers and aircrew. 25 March 2021. World Health Organization. (www.who.int/news/item/25-03-2021-joint-statement-on-prioritization-of-covid-19-vaccination-for-seafarers-and-aircrew, accessed 17 June 2021).

56. Slayton RB. Modeling allocation strategies for the initial SARS-CoV-2 vaccine supply. Atlanta (GA): United States Centers for Disease Control and Prevention; 26 August 2020 (https://www.cdc.gov/vaccines/acip/meetings/downloads/slides-2020-08/COVID-06-Slayton.pdf , accessed 17 June 2021).

57. Moore S, Hill EM, Dyson L, Tildesley MJ, Keeling MJ. Modelling optimal vaccination strategy for SARS-CoV-2 in the UK. PLoS Comput Biol. 2021;17:e1008849. doi: 10.1371/journal.pcbi.1008849.

58. Hogan AB, Winskill P, Watson OJ, Walker PGT, Whittaker C, Baguelin M et al. Within-country age-based prioritisation, global allocation, and public health impact of a vaccine against SARS-CoV-2: A mathematical modelling analysis. Vaccine. 2021;39:2995-3006. doi: 10.1016/j.vaccine.2021.04.002.

59. Bubar KM, Reinholt K, Kissler SM, Lipsitch M, Cobey S, Grad YH et al. Model-informed COVID-19 vaccine prioritization strategies by age and serostatus. Science. 2021. doi: 10.1126/science.abe6959.

60. Devleesschauwer B, McDonald SA, Speybroeck N, Wyper GMA. Valuing the years of life lost due to COVID-19: the differences and pitfalls. Int J Public Health. 2020;65:719-20. doi: 10.1007/s00038-020-01430-2.

61. Emanuel EJ, Persad G, Kern A, Buchanan A, Fabre C, Halliday D et al. An ethical framework for global vaccine allocation. Science. 2020;369:1309-12. doi: 10.1126/science.abe2803.

62. COVID-19 hospitalization and death by age. Atlanta (GA): United States Centers for Disease Control and Prevention; 18 Feb 2021 (https://www.cdc.gov/coronavirus/2019-ncov/covid-data/investigations-discovery/hospitalization-death-by-age.html, accessed 17 June 2021).

63. COVID-19: Occupational health and safety for health workers. World Health Organization.(www.who.int/publications/i/item/WHO-2019-nCoV-HCW_advice-2021.1, accessed 17 June 2021).