

Key aspects regarding the introduction and prioritisation of COVID-19 vaccination in the EU/EEA and the UK

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Summary

This document provides an overview of the key aspects related to the initial phases following the introduction of one or more COVID-19 vaccines in the European Union and European Economic Area (EU/EEA) and the United Kingdom (UK). The aim is to support but not define EU policy on COVID-19 vaccination.

The key components for a successful national and EU-level COVID-19 vaccine deployment are:

- a robust COVID-19 disease surveillance system;
- post-marketing studies on effectiveness and impact;
- active and passive monitoring of adverse events following immunisation;
- robust and timely vaccination coverage data;
- evidence-based decision-making;
- legal and regulatory frameworks for vaccines deployment;
- vaccine delivery infrastructure and supply chain management;
- monitoring of vaccine acceptability and behavioural research;
- communication plans;
- ethical and equitable access to vaccination.

These components are those usually adopted when a new vaccine is available on the market and integrated into national vaccination schedules.

COVID-19, caused by the virus SARS-CoV-2, is a new disease, and no vaccine is yet available for it, posing great challenges to the early development of national vaccination strategies. Patterns of exposure to SARS-CoV-2, as well as the incidence, burden and geographical distribution of COVID-19, will influence choices about vaccine deployment. There is currently a lack of certainty and knowledge about the characteristics of COVID-19 vaccines that could become available in the EU/EEA and the UK, as well as remaining gaps in the scientific knowledge of the virus and the disease. Vaccination plans and strategies will therefore need to be adapted as more information becomes available.

Once vaccines against COVID-19 are available, their supply is likely to be limited, at least initially. Supply capacity, both initially and over time, will thus determine vaccine usage and delivery prioritisation. Deployment will need to be adjusted accordingly to promptly optimise vaccine allocation and ensure vaccine availability to those most in need.

The following non-mutually exclusive approaches for vaccine deployment can be considered when building vaccination strategies, taking into account different levels of vaccine supply and stages of the pandemic:

- focusing on selected groups (e.g. individuals at risk of severe COVID-19, essential workers, vulnerable groups);
- vaccinating according to age strata (e.g. all individuals above a certain age);

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- targeting groups with an increased risk of exposure and onward transmission of SARS-CoV-2 (e.g. exposure in professional settings, younger adults);
- prioritising geographical regions with high incidence of COVID-19;
- deploying the vaccine to control active outbreaks;
- performing adaptive approaches to be modulated according to circumstances;
- conducting a universal vaccination strategy.

Given the anticipated initial shortage, countries will need to identify priority groups for vaccination. A broader characterisation of these groups will need to further categorise them into different priority tiers. The identification of the priority groups, and of the tiers within them, will depend on several factors, including the disease's epidemiology at the time of vaccine deployment, the evidence of risk of severe disease and of exposure to COVID-19, the preservation of essential societal services and equity principles, among others. In the process of developing an iterative approach for vaccine deployment with varying supply, mathematical modelling may aid public health experts in identifying priority groups for vaccination and in assessing different scenarios and the impact of alternative vaccination strategies. Lessons learned from the 2009 H1N1 influenza pandemic should also be considered.

Target audience

Public health authorities, national policymakers, regulatory authorities, civil society organisations, professional and scientific societies, national immunisation technical advisory groups (NITAGs) and others involved in the decision-making process for the introduction of COVID-19 vaccines at the national level (e.g. paediatricians, epidemiologists, specialists in infectious diseases, and primary care physicians) in the EU/EEA and the UK.

Background

Epidemiological situation

A novel coronavirus (SARS-CoV-2) was identified following the initial report to WHO on 31 December 2019 from the Wuhan Municipal Health Commission, China, of a cluster of cases of pneumonia in Wuhan, Hubei Province. After confirming human-to-human transmission and a rapid increase and spread of cases of disease caused by SARS-CoV-2 infection (COVID-19), WHO declared COVID-19 a pandemic on 11 March 2020 [1].

Since 31 December 2019 and as of 22 October 2020, and in accordance with the applied case definitions and testing strategies in the affected countries, more than 40 000 000 cases of COVID-19 have been reported worldwide, including over one million deaths [2].

All EU/EEA countries and the United Kingdom (UK) have reported COVID-19 cases, but the spread of the outbreak and the number of infections vary between and within countries. As of 19 October 2020, 4 909 402 cases and 201 151 deaths have been reported in the EU/EEA and the UK.

Immunity following natural infection

The scientific evidence regarding protective immunity following natural COVID-19 infection is currently limited, and the full extent of interaction between host and virus is also unknown. Since the immunological correlate for protection is not yet fully established, it is difficult to estimate what an observed vaccine-induced immune response means. Moreover, there is currently limited information on the duration of immunity following natural infection. A few reported cases of re-infection have been observed, although they have largely been identified through sporadic observations rather than systematic studies [3]. It is considered possible that a previous infection confers protection for around six months [4], although this may also vary across age groups and between severe, mild and asymptomatic cases. Immune response to SARS-CoV-2 includes both cell-mediated immunity and antibody production. It is currently unknown what the relative contributions are of antibody response and T-cell response in infected individuals towards conferring immunity [5]. Standardised tests with high sensitivity and specificity for assessing COVID-19-specific antibodies (IgM and IgG) are now widely available. Population-based sero-epidemiological studies across EU/EEA and the UK show that most countries have low levels of seropositivity in the general population overall. In some areas however, the seroprevalence of antibodies to COVID-19 can reach over 40% [5].

Identified risk factors for severe disease

COVID-19 pathogenesis is not yet fully understood, although severe cases appear to be linked to a paroxysmal immune response to SARS-CoV-2, leading to multi-organ failure. The risk for severe COVID-19 disease, hospitalisation and death due to COVID-19 increases with age. These risks are generally higher for males than females for reasons that are not yet fully understood. Underlying health conditions such as hypertension, diabetes, cardiovascular disease, chronic respiratory disease, obesity and immunocompromised status have frequently been observed among patients hospitalised with COVID-19, patients admitted to the ICU with COVID-19, and patients dying from COVID-19. However, some of these conditions are not uncommon in ageing European adult

populations, so careful assessment of their causal role in severe outcomes of COVID-19 should be made by constantly reviewing available evidence [6].

Vaccination against COVID-19

A functioning vaccine will be essential to containing the pandemic, in addition to the current non-pharmaceutical interventions (such as physical distancing) and antivirals. The development of vaccines against COVID-19 commenced early in the pandemic and involves many actors. As of 19 October 2020, there is no approved COVID-19 vaccine for use in the EU/EEA and the UK. However, several candidate vaccines are undergoing human trials, with nine vaccine candidates having entered phase II/III or phase III clinical trials globally [7]. It is currently unknown when potential COVID-19 vaccines will be authorized for use in the EU/EEA and the UK. According to the European Medicines Agency (EMA), in a best-case scenario the agency would receive clinical data on the most advanced vaccines towards the end of 2020. It is expected that once COVID-19 vaccines are authorised and available the doses will initially be limited, so there will be a need to prioritise those target groups that should be vaccinated first.

Framework for national and EU-level COVID-19 vaccination deployment

Although immunisation programmes and systems are intrinsically heterogeneous across the EU/EEA, a successful roll-out of COVID-19 vaccination campaigns will be dependent on a coordinated and concerted effort that is in line with global recommendations. A policy approach that recognises the cross-border nature of viral transmission and seeks to minimise disparities in equity and access across countries and regions as much as possible will be paramount to the acceptance and success of vaccination efforts.

The public health goals of a vaccination programme will largely depend on the epidemiological situation and on the characteristics of the vaccines that will be available. For example, specific target groups for a vaccine that mainly prevents severe disease will potentially differ from those prioritised for a vaccine that also functions in reducing disease susceptibility (and thereby affects disease transmission). As the availability of COVID-19 vaccines is likely to be scarce at first, the identification of priority groups whose vaccination will most benefit those individuals and/or society in these early stages is also imperative. Nonetheless, regardless of the national and/or regional context in which vaccination plans are rolled out, a set of key fundamental components will need to be considered by governments and public health authorities in preparation for future vaccines. Such components should include the following elements, which are the key building blocks of a solid COVID-19 vaccination strategy:

Robust COVID-19 disease surveillance systems to generate data for action

Surveillance is the foundation of public health practice. Surveillance systems include routine reporting, sentinel surveillance, and community-based reporting. Data from ongoing surveillance should be linked with other data sources, such as immunisation information systems, to provide information for vaccination programme planning, implementation, evaluation, and modification.

Capacity and capability to perform post-marketing studies on the impact, effectiveness and safety of the vaccines being deployed

Such a system is critical in order to sustainably monitor vaccines' and an immunisation programme's impact, safety, effectiveness and disease burden on the ground, and to more rapidly and accurately inform public health policy decisions regarding vaccinations. The data generated will also provide timely evidence on the efficacy and safety of COVID-19 vaccines to support regulatory decision-making, and will be useful for communicating to the public about vaccine safety and effectiveness.

Active and passive adverse events following immunization (AEFI) monitoring

All EU/EEA Member States and the UK have established the routine reporting of adverse events following immunisation. Such reports are submitted to National Public Health Institutes, which then forward them to National Regulatory Agencies. All national reports are automatically forwarded to the European Union Drug Regulating Authorities Pharmacovigilance (Eudravigilance) management and analysis system operated by the European Medicines Agency (EMA). In the event of a vaccine safety signal association studies must be carried out, preferably in line with the EU's Pharmacovigilance legislation. When new or updated vaccines are deployed in EU/EEA Member States and the UK's immunisation programmes, it is common practice to institute active surveillance in at least the first countries that initiate the new programmes. Such surveillance can involve sentinel hospitals, sentinel vaccination units or systems using mobile phone apps. For each EU authorised vaccine, requirements for active surveillance will be stipulated in risk management plans developed by EMA in conjunction with the market authorisation holder. It is advantageous if background incidence rates exist for all these adverse events of special interest (AESIs) in a number of EU/EEA countries and UK. Agreed case definitions are essential in order to conduct background incidence studies, and if there is a need for association studies in the event of a safety signal. Such

case definitions for COVID-19 vaccination are currently under development by the Coalition for Epidemic Preparedness Innovations (CEPI) [8] together with the Brighton Collaboration [9].

Robust and timely vaccination coverage data

Stratified monitoring of coverage data (i.e. date administered, what dose and what vaccine product) at the level of each citizen will be essential to ensuring the delivery of programmes that can provide life-long protection should the virus continue to circulate in coming years, as well as in the assessment of population-based uptake. This requires establishing manual or electronic registration systems for vaccinations. Information on population-based uptake can also facilitate studies addressing vaccine safety and effectiveness. Monitoring COVID-19 vaccines' uptake will also provide information about the performance and efficiency of the vaccination programme and its capability of reaching most of the population. In addition, it will help inform on how equitable (in terms of access to vaccines) and how acceptable the programme is to target populations. Data collected at the finest geographical level and in specific subgroups will allow for the identification of areas with low coverage and pockets of susceptible individuals (or specific groups that may pose a risk for the wider community, e.g. healthcare workers). Such data will allow for the tailoring of specific interventions. In the event that uptake does not meet expected levels, additional strategies or promotional efforts may be needed in order to reach specific groups.

Evidence-based decision-making on vaccination policies and strategies

The evidence may be gathered from clinical and epidemiological studies that could help better identify those at a higher risk of severe COVID-19 and those driving the transmission. Updated systematic reviews may allow further synthesis of current available evidence and the performance of meta-analyses. Using available data, mathematical modelling can provide key evidence for efficient and effective COVID-19 vaccine deployment in the event of limited supply. Evidence-based decision-making models (such as GRADE) could also be used to support vaccination policies and prioritisation strategies of vaccination against COVID-19 in a transparent and rigorous way.

Legal and regulatory aspects linked to vaccines deployment

While legal and regulatory provisions for the authorisation and use of vaccines in the EU are part of a well-established legal framework, specific clauses and conditional authorisations may be granted in pandemic situations. In addition, past pandemic situations have brought to the fore the importance of having effective and transparent systems aimed to address potential liability issues (e.g. related to the product) or compensation schemes (e.g. in case of serious adverse events following immunization (AEFI) detected during the roll-out) in place. As of 22 October 2020, the European Commission has signed Advance Purchase Agreements with two vaccine manufacturers (AstraZeneca and Sanofi-GSK) [10,11]. Further negotiations for Advance Purchase Agreements are ongoing between the Commission and other companies [7].

Vaccine delivery options and supply chain management

The ability to distribute and administer the vaccine will influence decisions about the target groups. The logistics required for the scale that a COVID-19 vaccination programme could have are likely to be very different from routine vaccination programmes. In addition, physical distancing will need to be maintained during the process of vaccination, which will place further demands on locations for vaccine distribution. The delivery aspects will have an impact on the feasibility and efficiency of the programme. Delivery options, including school-based programmes, well-baby clinics, general practitioners' practices, pharmacies, hospitals, long-term care facilities, social care facilities, mobile clinics and dedicated mass vaccination clinics will need to be considered and might be suitable only to a segment of the target groups. The number of doses required for short- and long-term protection, including the need for booster doses, will also impact the selection and feasibility of delivery options. Documentation of vaccinated individuals should be ensured in all types of delivery settings. Supply chain management will need to be adapted to national decisions on chosen delivery settings. It is unlikely that staffing levels required for routine vaccination programmes will be sufficient for the delivery of a mass vaccination programme. Dedicated competent human resources should therefore be prepared and trained for a mass vaccination campaign. Different job profiles will be required for campaign planning, logistics, vaccine administration, communication and management.

Behavioural research

The uptake of the vaccines will be influenced by the acceptability of the benefit/safety profile in light of the risk related to COVID-19, and may be different in various segments of the population and across target groups. Early investment in behavioural research will be critical to help anticipate perceptions and any possible issues around the uptake of the vaccines. Results from this research can help to inform the development of tailored strategies to support governments and public health programmes in achieving the required levels of coverage to ensure adequate levels of protection. Attitudinal and behavioural insights/issues already known with regards to routine vaccination programmes are likely to interplay in the dynamics of acceptance of COVID-19 vaccines. In addition, safety issues linked to one of the vaccines widely used during the H1N1 influenza pandemic affected several countries in the EU, and are likely to bear on collective memory and influence individual decisions on whether to vaccinate or not.

Communication plans

In principle, communications plans should already be in place as part of a more holistic communication plan and should be ready for activation in case of need. Developing communication plans is critical for building and

maintaining trust in vaccines and demand for vaccination. They are also critical in order to prepare for the possibility of vaccine safety events and crises as well as ensuring an immediate and efficient communication response. Communication strategies need to be prepared to explain the objectives of the vaccination campaign for different audiences, including the public, healthcare workers, policymakers and other stakeholders, in order to aid acceptability of the vaccine/s and to tackle vaccine hesitancy. Reactive planning is needed for safety scares and public concerns during these campaigns. Plans should be developed as part of the vaccination pandemic plan. Messages and responses will need to be aligned, coordinated and consistent across countries and regions in order to avoid fuelling unfounded mistrust or leaving legitimate questions unanswered. Communication responses must be swift, tailored to the setting, and leverage the relevant stakeholders that can act as effective communication ambassadors.

Ethical considerations and equal access to vaccination

In a situation with limited access to COVID-19 vaccines and the prioritisation of population groups to be targeted, it will become imperative to consider the ethical aspects, equity and solidarity underlying these decisions. Such discussions should ideally take place as part of the formulation of the vaccination strategy, and at local, national, EU and international levels. Given the expected scale of deployment for COVID-19, it will be critical to full deployment that vaccines are available at large scale and low cost. Various entities have developed ethics frameworks in order to guide discussion and inform decisions about the equitable allocation and prioritisation of COVID-19 vaccines [12-14].

Options to consider in developing a COVID-19 vaccination strategy – a conceptual framework

The fact that there is currently no COVID-19 vaccine approved for use in the EU indicates the likely need for current policy to be adjusted once a vaccine with known characteristics is ready to be filed for licensing. In addition, further knowledge about the virus, the duration of immunity, viral spread in the population and associated morbidity and mortality will help refine the objectives of vaccination strategies. The vaccination strategy against COVID-19 will ultimately be guided by the available vaccines and the outcomes against which each vaccine will provide protection.

Notwithstanding the existing limitations and gaps in the current knowledge, the approaches set out below for the introduction of COVID-19 vaccines can be considered by countries. These options do not represent mutually exclusive vaccination strategies, but rather conceptual approaches that could be implemented in parallel or sequentially.

Focusing on specific groups (e.g. essential service employees, risk groups, socially vulnerable groups)

Vaccination could be given to specific groups in the population based on their key societal role during the COVID-19 pandemic (e.g. healthcare workers, first responders, social care workers), on their individual risk of developing severe COVID-19 (e.g. individuals with underlying conditions), and on belonging to specific vulnerable groups (e.g. socially vulnerable groups). Pursuing this approach would contribute to well-functioning healthcare and to protecting those most at risk and the most vulnerable, given adequate vaccine safety and effectiveness in all these groups.

Targeting different age groups

Based on incidence of COVID-19 across different age groups, age itself is to be considered a risk factor for severe COVID-19. The aim of pursuing a vaccination programme targeting older adults is to reach the age group with the highest burden of COVID-19 and to protect the majority of the individuals most at risk in the population. However, before pursuing this approach, acceptable levels of vaccine safety and efficacy need to be demonstrated among older adults. At this stage, this information is not known. Synergies with, and impact on, other vaccinations against respiratory infections in older adults (e.g. influenza, pneumococcus) should also be considered. Targeting by age group could optimise the vaccine deployment strategy.

Aiming at efficient reduction of disease transmission at the population level

Based on modelling and data from investigations of COVID-19 outbreaks (including active case finding, sero-epidemiological studies, social contact patterns data), groups that are identified as highly exposed to SARS-CoV-2 (e.g. younger adults, specific occupations) can be targeted for vaccination to protect them and efficiently minimise the viral circulation in the population. Pursuing this option could significantly and cost-effectively reduce the spread of COVID-19 in the community enabling the society to return to functioning normally. However, the identification of these groups may not be possible, while groups at risk for severe COVID-19, and death from COVID-19, may not immediately benefit from this approach, unless prioritised in parallel.

Targeting high incidence and densely populated areas

Based on COVID-19 surveillance and geographical data, vaccination can initially target areas and subnational regions in which the highest viral activity is detected, in particular densely populated areas. By pursuing this

approach, areas with high disease incidence and population density are targeted first, as COVID-19 incidence seems to vary significantly across different geographical settings over time.

Deploying vaccines in outbreak settings

Priority can be given to vaccination activities within active clusters of COVID-19 outbreaks. Different vaccination approaches (e.g. mass vaccination, ring vaccination) can be considered in order to maximise cost-effectiveness of the intervention in the outbreak setting. The choice of this approach should be carefully weighed against or in addition to alternative options following a specific evaluation of the COVID-19 epidemiology and vaccine supply in the country.

Implementing an adaptive approach based on the evidence emerging during the development of the pandemic

Countries could decide to adaptively prioritise approaches and target groups based on changes in patterns of different indicators. These indicators should ideally be monitored via real-time surveillance during the COVID-19 pandemic. For pursuing this approach, high-quality surveillance and adequate modelling capacities are necessary pre-requisites. This approach, if appropriately carried out, would be the most effective and flexible approach allowing for adaptations to sudden changes in vaccine supply or in COVID-19 epidemiology.

Planning a universal vaccination strategy for subsequent phases following COVID-19 vaccines' introduction

This will depend on the availability of sufficient doses of vaccines and on whether the vaccines can be safely administered to everyone (seronegative and seropositive individuals). Universal vaccination may be reached through a gradual approach following sequential prioritisation steps (by using e.g. tiers) based on some of the principles outlined above.

Considerations for defining target groups for vaccination and prioritisation

Depending on the characteristics of the vaccine and on the objectives of the vaccination strategy, potential target groups should be identified and decided upon. These target groups can be characterised by age groups, underlying medical conditions, place of residence or day-time activity, or occupation and workplace (Annex 1). As previously mentioned, the ability of people in selected target groups to mount a protective immune response following vaccination, and the lack of any major safety concern or contraindication needs also to be taken into account. It is likely that some population segments and potential target groups cannot be assessed by the vaccine trials. Therefore, decisions on inclusion of some target groups may need to be taken before others, as evidence becomes available.

In a pandemic, essential service employees (e.g. healthcare workers, first responders, social care workers) are usually one of the first target groups considered for vaccination. Their role is pivotal for maintaining a functioning healthcare system, providing assistance to those affected by COVID-19 and to those who are medically and socially vulnerable in the different phases of the pandemic and in particular when healthcare is under pressure.

Additionally, groups in the population that are more likely to be infected with SARS-CoV-2, and groups that are more likely to suffer from severe COVID-19 (e.g. older adults, especially those living in crowded settings, and individuals of any age with comorbidities) could also be selected as primary targets of the vaccination [15].

Prioritisation involves selecting target groups that will be offered the vaccine first or who will be offered the vaccine in a situation of limited resources [16-19]. Possible target groups for vaccination programmes can include groups such as those at risk for severe outcomes, essential service workers and socially vulnerable populations. Subgroups within these different target groups could be prioritised; for example, in the broad target group of essential service workers, frontline healthcare workers could be included in the priority group for initial vaccination.

When COVID-19 vaccines and other resources become more widely available, subsequent groups can be offered vaccination until it can be distributed to all target groups [20].

Evidence needed for defining target groups and prioritisation decisions

The scientific evidence base for prioritisation relies on various sources (See Table 1). Ongoing and future clinical studies and trials will provide the first insights into the efficacy and safety of any vaccines. The first phase 3 clinical trials are expected to report in coming months. Data from surveillance and specific studies will help accurately determine the epidemiological situation (incidence and trends) and the groups at high risk of severe outcomes (including admission to hospital, intensive care and deaths) in order to prioritise the programmes. Key epidemiological characteristics include geographical distribution of the disease, age-specific group disease indicators, description of clinical risk factors and sociological characteristics (for the identification of socially vulnerable individuals). Information about COVID-19 transmission in different contexts, from surveillance, contact tracing, scientific studies and modelling, is also necessary for characterising those groups more exposed to infection (e.g. healthcare workers, frontline workers, social care workers, individuals working in contact with the general public and young adults).

Table 1. Elements and sources of evidence needed for prioritisation decisions

	Element of evidence	Source of evidence	
Virus	Is the virus mutating with impact on transmissibility, severity or immune profile of the disease?	Sequence-based surveillance	
	Where is the virus circulating and what are the trends?	Surveillance and modelling	
	What is the expected incidence of the disease in the population?	Surveillance and modelling	
Immunity	Correlates of protection	Clinical serology studies	
	Seropositivity in population and in specific settings	Sero-epidemiologic studies	
	Duration of immunity	Cohort studies with serology	
Vaccine	Efficacy and safety by age group	Phase 3 randomised clinical trials	
	Effectiveness and safety	Vaccine-effectiveness studies in hospital and out-patient settings; vaccine-effectiveness studies in clinical outcome databases linked with electronic immunisation registries; post-authorisation routine monitoring of safety; active adverse event following immunisation surveillance in sentinel hospitals; active adverse event following immunisation surveillance using app techniques	
	Vaccination regimen (number of doses needed to mount a protective immune response)	Phase 2 & 3 randomised clinical trials	
	Route of administration	Pre-clinical and Phase 1-3 studies	
	Cost	Procurement negotiations	
	Acceptability	Population surveys	
	Date of availability	Manufacturer	
	Indications and contraindications	Regulatory authority	
	Target population	Size of target population	National statistics office
	Risk groups	Who is at risk of severe disease?	Surveillance data and studies
Who is at high risk of infection?		Surveillance data and studies	
Who transmits the disease?		Surveillance data and studies	
Size of risk groups		Demographic data and population surveys	
Vulnerable groups	Which segments of population and settings are vulnerable to outbreaks?	Surveillance data and studies	
	Which population groups are hard to reach?	Social and anthropological studies	
	Which population groups have special communication needs?	Communication studies and monitoring	
Essential services	Define essential services other than healthcare	Pandemic/crisis response committee decision	
	Define number of employees in essential services including HCWs	National statistics office, employers/ EUROstat	

Role of modelling and main parameters for inclusion

Models in assessing different scenarios and impact of immunisation programmes

By drawing on the available data regarding COVID-19 epidemiology, expected population immunity, and social contact patterns in observed in different non-pharmaceutical interventions in Member States, mathematical modelling can be used to make projections of COVID-19 occurrence and of the potential impact of various vaccination strategies [21]. Modelling can also be used to describe different scenarios and uncertainties around these projections [22]. Mathematical modelling is therefore a fundamental tool to guide the prioritisation of future COVID-19 vaccines, notably by identifying optimal (i.e. the most efficient) scenarios for vaccine deployment among target groups. Alternative scenarios can also be characterised based on different epidemic features (i.e. spread and trends) and/or different options of vaccination strategies. Moreover, information about the proportion of susceptible individuals and of individuals at risk in the population can be used to enable mathematical models to estimate the indirect effects of the vaccine on the unvaccinated population, provided that evidence of vaccine efficacy against infection and onward transmission and of adequate duration of protection following vaccination.

An integration of COVID-19 real-time surveillance with modelling data would be ideal for an adaptive approach to the deployment of the vaccine. Modelling could also be used to estimate numbers needed to vaccinate (NNV) for different settings and scenarios as well as for cost-effectiveness of each competing prioritisation strategy.

Main parameters for inclusion

For mathematical modelling to effectively guide decisions around deployment of COVID-19 vaccine(s), prior knowledge is important on the following:

- Primary objectives of vaccination (e.g. protection of priority groups; reduction of viral circulation in the whole population; geographical containment; outbreak response to sporadic clusters, disease elimination);
- Disease-specific parameters (e.g. age-specific transmission rates, age/risk-specific mortality rates, age/risk-specific burden of disease, age/risk-specific hospitalisation rates, latency period, infectious period);
- Epidemic parameters (e.g. COVID-19 geographical and community spread, epidemic trends, COVID-19 spread in healthcare settings; based on COVID-19 incidence, hospitalisation, mortality and age/risk-specific sero-epidemiological data);
- Vaccine-specific parameters (e.g. vaccine efficacy and safety in different age/risk groups, vaccine protection daily rate, duration of protection, number of doses);
- Population parameters (e.g. numbers of individuals in each age group for each country/region, number and proportion of individuals in each target group);
- Programmatic parameters (e.g. vaccine availability, vaccination coverage of target groups, drop-out rates).

Lessons learned from earlier pandemic vaccination campaigns

In an early assessment of EU-wide pandemic vaccine strategies conducted after the 2009 influenza A (H1N1) influenza pandemic [23], the Commission's Directorate-General for Health and Food Safety concluded with the following challenges and suggestions:

- A better national coordination and cooperation within Member States, among the Member States and the EU is necessary, and coordination and cooperation with EMA, ECDC and WHO should be strengthened. Further, an improvement on defining vaccination strategy goals is necessary, as will be ensuring the coordination of timing and content of messaging related to the vaccination campaign.
- Achieving higher vaccine coverage among healthcare professionals was viewed as essential to maintaining healthcare services in a pandemic, with low coverage for this group an obstacle to reaching both target/risk groups and the general public.
- A need for enhancing rapid public research capacity in support of vaccination was emphasised.
- Future procurement contracts, whether done nationally or at the EU level, should be flexible and include conditions under which the specified amount can be changed, and include conditions for returning excess vaccines.
- Research on best practice for communication on vaccination campaigns and tracking the use and effectiveness of social media is needed.

The above-mentioned lessons learned are useful to consider when going forward with national planning for COVID-19 vaccination.

All EU/EEA countries and the UK have developed pandemic preparedness plans, in which pandemic influenza vaccination programmes are considered a core component [24]. COVID-19 is a different disease that affects various age groups and segments of the population in ways that differ from pandemic influenza. In the absence of a vaccine, there is also a need for further strategic decisions when adapting existing preparedness plans, including the development of new components that reflect the realities posed by COVID-19.

Conclusions

Determining COVID-19 vaccination strategies involves taking several complex factors into consideration. The multi-faceted nature of the described aspects underpinning immunisation policies must be factored in to ensure that EU/EEA Member States and the UK can build robust approaches to COVID-19 vaccination, both in the short and longer term, once vaccines become available.

Supply limitations, at least in the initial stages of deployment, will be a key factor affecting decision-making regarding prioritisation. While a common and concerted EU policy approach in setting up vaccination strategies is warranted and encouraged to ensure that no region or nation is left behind, adaptability will be needed. Countries should deploy vaccines against COVID-19 with an iterative approach based on vaccine supply, trends of transmission, observed epidemiology of COVID-19, prevalence of the selected target groups in the population, and principles of equity, among others. Flexibility to adapt strategies will be essential, particularly as new evidence is consistently generated and should be used to inform approaches.

This document should be considered as one part of a process laying down the foundations of a common framework for the deployment of safe and effective COVID-19 vaccines in the EU/EEA and the UK. While the primary responsibility for the design and delivery of COVID-19 vaccination programmes will continue to lie with the Member States, an EU-wide approach will be crucial in the interest of solidarity, equity, accessibility and ultimately halting the threat to citizens' health posed by COVID-19.

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References

1. World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. WHO; March 2020. Available at: <https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020>
2. European Centre for Disease Prevention and Control (ECDC). COVID-19 Pandemic. Stockholm: ECDC; 2020. Available at: <https://www.ecdc.europa.eu/en/novel-coronavirus-china>
3. European Centre for Disease Prevention and Control (ECDC). Reinfection with SARS-CoV: considerations for public health response. Stockholm: ECDC; 2020. Available at: <https://www.ecdc.europa.eu/sites/default/files/documents/Re-infection-and-viral-shedding-threat-assessment-brief.pdf>
4. Ripperger TJ, Uhrlaub JL, et al. Orthogonal SARS-CoV-2 Serological Assays Enable Surveillance of Low Prevalence Communities and Reveal Durable Humoral Immunity. *Immunity*. 2020. Available at: <https://doi.org/10.1016/j.immuni.2020.10.004>
5. European Centre for Disease Prevention and Control (ECDC). Immune responses and immunity to SARS-CoV-2. Stockholm: ECDC; 2020. Available at: <https://www.ecdc.europa.eu/en/covid-19/latest-evidence/immune-responses>
6. European Centre for Disease Prevention and Control (ECDC). Coronavirus disease 2019 (COVID-19) in the EU/EEA and the UK – ninth update, 23 April 2020. Stockholm: ECDC; 2020. Available at: <https://www.ecdc.europa.eu/sites/default/files/documents/covid-19-rapid-risk-assessment-coronavirus-disease-2019-ninth-update-23-april-2020.pdf>
7. European Centre for Disease Prevention and Control. Increased transmission of COVID-19 in the EU/EEA and the UK – 24 September 2020 . Stockholm: ECDC; 2020. Available at: <https://www.ecdc.europa.eu/sites/default/files/documents/covid-19-risk-assessment-increased-transmission-12th-update-september-2020.pdf>
8. Coalition for Epidemic Preparedness Innovations (CEPI). Available at: <https://cepi.net/>
9. Brighton Collaboration. Available at: <https://brightoncollaboration.us/>
10. European Commission. Coronavirus: the Commission signs first contract with AstraZeneca. Press Release, Brussels, 27 August 2020. Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1524
11. European Commission. Coronavirus: the Commission signs second contract to ensure access to a potential vaccine. Press Release, Brussels 18 September 2020. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1680
12. National Academies of Sciences Engineering Medicine. Discussion Draft of the Preliminary Framework for Equitable Allocation of COVID-19 Vaccine. Washington, DC; 2020. Available at: <https://www.nap.edu/catalog/25914/discussion-draft-of-the-preliminary-framework-for-equitable-allocation-of-covid-19-vaccine>
13. Toner E BA, Krubiner C, et al. Interim Framework for COVID-19 Vaccine Allocation and Distribution in the United States. Baltimore, MD: Johns Hopkins Center for Health Security; 2020. Available at: https://www.centerforhealthsecurity.org/our-work/pubs_archive/pubs-pdfs/2020/200819-vaccine-allocation.pdf
14. World Health Organization. WHO SAGE values framework for the allocation and prioritization of COVID-19 vaccination. 14 September 2020. Available at: https://apps.who.int/iris/bitstream/handle/10665/334299/WHO-2019-nCoV-SAGE_Framework-Allocation_and_prioritization-2020.1-eng.pdf
15. Williamson EJ, Walker AJ, Bhaskaran K, Bacon S, Bates C, Morton CE, et al. Factors associated with COVID-19-related death using OpenSAFELY. *Nature*. 2020 08;584(7821):430-6.
16. Dorratoltaj N, Marathe A, Lewis BL, Swarup S, Eubank SG, Abbas KM. Epidemiological and economic impact of pandemic influenza in Chicago: Priorities for vaccine interventions. *PLoS Comput Biol*. 2017 Jun;13(6):e1005521.
17. Saito MM, Imoto S, Yamaguchi R, Tsubokura M, Kami M, Nakada H, et al. Enhancement of collective immunity in Tokyo metropolitan area by selective vaccination against an emerging influenza pandemic. *PLoS One*. 2013;8(9):e72866.
18. Shim E. Prioritization of delayed vaccination for pandemic influenza. *Math Biosci Eng*. 2011 Jan;8(1):95-112.
19. Straetemans M, Buchholz U, Reiter S, Haas W, Krause G. Prioritization strategies for pandemic influenza vaccine in 27 countries of the European Union and the Global Health Security Action Group: a review. *BMC Public Health*. 2007 Sep 7;7:236.
20. Chowell G, Viboud C, Wang X, Bertozzi S, Miller M. Adaptive vaccination strategies to mitigate pandemic influenza: Mexico as a case study. *PLoS Curr*. 2009 Aug 17;1:Rrn1004.
21. Kim S, Lee J, Jung E. Mathematical model of transmission dynamics and optimal control strategies for 2009 A/H1N1 influenza in the Republic of Korea. *J Theor Biol*. 2017 Jan 7;412:74-85.
22. Lee BY, Wiringa AE. The 2009 H1N1 influenza pandemic: a case study of how modeling can assist all stages of vaccine decision-making. *Hum Vaccin*. 2011 Jan 1;7(1):115-9.

23. Stern EK YS, Amlôt R, Blake A, Dacey G, Lightfoot N et al. Assessment Report on EU-wide Pandemic Vaccine Strategies: European Commission, 25 August 2010.
24. Droogers M, Ciotti M, Kreidl P, Melidou A, Penttinen P, Sellwood C, et al. European Pandemic Influenza Preparedness Planning: A Review of National Plans, July 2016. *Disaster Med Public Health Prep.* 2019 Jun;13(3):582-92.

Annex 1. Potential target groups for COVID-19 vaccination, to be adapted according to emerging evidence

Target groups	Characteristics	Basis for defining priority	Comment
Persons at risk of severe outcomes	People with underlying medical conditions; the elderly; infants	Surveillance and epidemiological studies; Modelling	
Healthy adults and children	Children; pregnant women; working-age adults without underlying medical conditions	Ecological studies to assess their role in transmission of the virus; studies assessing trans placental transfer of antibodies; surveillance and (sero)-epidemiological studies; modelling	Prioritisation of specific age groups at higher risk of contracting/transmitting the disease; The baseline immunity of this population should be checked
Healthcare workers	Primary care services; outpatient and inpatient facilities; long-term care facilities; clinical laboratories; pharmacies; emergency services/paramedics; social institutions (e.g for adolescents); public health staff	Pandemic/crisis response committee decision; surveillance and epidemiological studies	Prioritisation of subgroups of healthcare workers may be considered
Contact of cases	Those in contact with index case and at risk of secondary infection	Based on scientific evidence on the immunity confirmed and the timing for protective immunity; modelling	
People living in an area with an ongoing outbreak	Areas with high disease incidence	Surveillance data and studies; modelling	
Socially vulnerable groups	Migrants and refugees; the homeless; minority ethnic or language groups; mobile populations; elderly living alone; disabled people; those whose access to healthcare system is reduced	Surveillance data and studies; social and anthropological studies; communication studies and monitoring	
Essential service providers	Social workers; staff needed to maintain basic economic activities; police, fire fighters, funeral services; utility staff (water, electricity); staff involved in food productions and distribution; critical government workers; defence forces; others to be defined	Pandemic/crisis response committee decision	
Settings at risk of outbreaks	Hospitals; long-term care facilities; other health care settings; remote and isolated communities correctional facilities; schools and day care centres	Surveillance data and studies; modelling	Any person in the setting regardless of its occupation or residential status