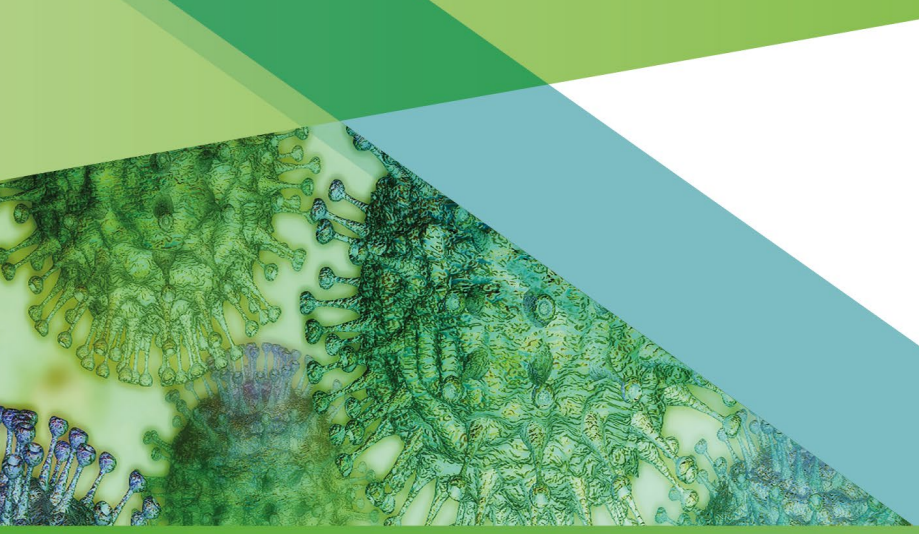


Long-term qualitative scenarios and considerations of their implications for preparedness and response to the COVID-19 pandemic in the EU/EEA

August 2022

Key messages

- There are a wide range of potential trajectories for the progression of the COVID-19 pandemic in the coming months and years. This document sets out a number of scenarios that are intended to be plausible, internally consistent, and coherent descriptions of possible futures.
- The scenarios consider the epidemiological context that can generally anticipated in the EU/EEA from the summer of 2022 onwards. The timeframe for the scenarios is from 2022 to 2032. In publishing this document, ECDC does not ascribe a probability, nor suggest a higher likelihood of occurrence, for any of the scenarios described, which are not quantitative forecasts. The scenarios are based on the key variables of growth rate, disease severity and immune protection from severe outcomes.
- The qualitative scenarios are not mutually exclusive; over the course of the next decade it is entirely likely that there could be a transition from one scenario to another, due to changes in the virus, the level of immunity in the population or variations in societal response. The coming years will require extreme vigilance should new, more severe or more transmissible variants of SARS-CoV-2 emerge.
- The scenarios and the associated public health response priorities outlined in this document provide a potential framework for defining overall strategic objectives and actions for managing COVID-19 according to a range of possible trajectories in the future.
- Such strategic objectives need to be agreed upon so that operational discussions on the implications for a wide range of public health activities can take place according to a common understanding.
- The public health activities outlined in this document that need to be considered in preparing for potential future scenarios include, but are but not limited to, surveillance, risk communication, pandemic preparedness, early warning, vaccination, medical countermeasures, NPI measures and IPC measures.

Background

The European Commission Communication, published in April 2022, put forward an approach for the management of the pandemic in the months to come, supporting a move from emergency to a more sustainable mode [1]. This reflected the fact that many EU/EEA countries currently have or are approaching high levels of population immunity against severe disease (through vaccination and/or natural infection) and, consequently, have observed reduced severity of outcomes with the currently circulating Omicron variant of concern (VOC).

The Commission Communication also set out an analysis on qualitative long-term scenarios, developed by ECDC, that demonstrated a wide range of possible outcomes, based on the assumption that SARS-CoV-2 is here to stay

Suggested citation: European Centre for Disease Prevention and Control. Long-term qualitative scenarios and considerations of their implications for preparedness and response to the COVID-19 pandemic in the EU/EEA. August 2022. ECDC: Stockholm; 2022.

and will probably represent a long-term challenge to public health and healthcare systems. ECDC's document elaborates on those longer-term scenarios.

There are a wide range of potential trajectories for the progression of the COVID-19 pandemic in the coming months and years. The trajectory of the pandemic will ultimately be determined by a large number of parameters including, but not limited to, characteristics of emerging and circulating variants of SARS-CoV-2, effectiveness and waning protection from vaccination and/or natural infection, human behaviour, demographics and public health and political responses.

As the COVID-19 pandemic has continually demonstrated, delayed or insufficient action can be costly. Qualitative scenarios can be used to fill the gap between the need to rapidly implement evidence-informed policy decisions and the availability of sufficient scientific evidence.

Part 1 of this document presents qualitative scenarios that have been developed to focus on possible trajectories of the pandemic for an approximate ten-year period, from the present time onwards. These scenarios are intended to support decision-making until further information becomes available. The scenarios were briefly described in a European Commission Communication[1] and this document aims to provide further details.

Part 2 outlines public health priorities that are relevant across all of the scenarios, focusing on the shorter-term, as it is during the next few years that recovery from the COVID-19 pandemic and preparedness for the long-term management of COVID-19 needs to take place.

1. Qualitative pandemic scenarios

The scenarios presented in Table 1 are intended to be plausible, internally consistent, and coherent descriptions of possible futures [2]. The scenarios consider the epidemiological context generally anticipated in the EU/EEA from 2022 onwards. The timeframe for the scenarios is from 2022 to 2032. These have been developed by a multi-disciplinary team at ECDC and previously presented to the ECDC Advisory Forum.

At the time of writing, there are still many uncertainties and knowledge gaps, which ECDC has appraised through expert consultation [3]. While many factors may affect the COVID-19 pandemic, the scenarios developed consider different combinations of the primary variables presented below.

1. Viral properties

- Viral evolution
- Growth rate
- Disease severity (intrinsic)
- Seasonality.

2. Immunology

- Immune protection from severe outcomes
- Duration of protection.

3. Societal factors

- Societal tolerance for non-pharmaceutical interventions (NPI) and infection prevention and control (IPC) measures
- Societal tolerance for the residual risks of COVID-19
- Vaccination acceptance
- Healthcare system capacities.

4. Medical interventions

- Vaccines
- Antiviral medications
- Diagnostics.

[1] European Commission Communication: https://health.ec.europa.eu/publications/covid-19-sustaining-eu-preparedness-and-response_en

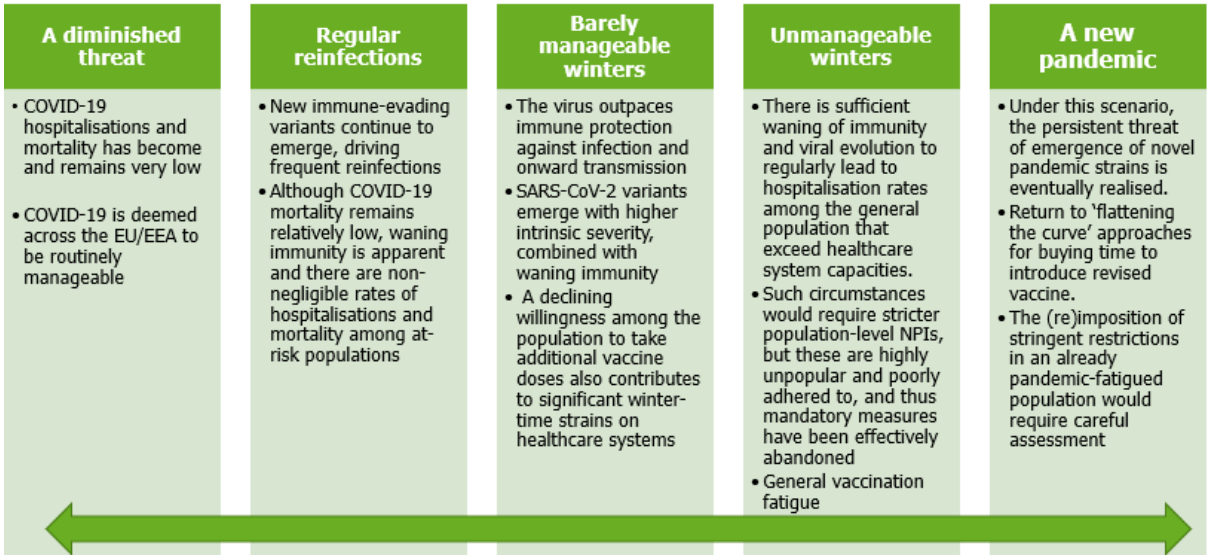
Table 1. Description of qualitative long-term scenarios

Scenario	Description	Key scenario assumptions
A diminished threat	In this scenario, the vast majority of the global population has been previously infected with SARS-CoV-2 and/or received COVID-19 vaccinations. Consequently, the observed severity of COVID-19 outcomes has been driven down to very low levels. While SARS-CoV-2 continues to circulate globally and new variants are periodically detected, the cross-protective immunity accrued through 2020, 2021 and 2022 means that while reinfections are fairly common, the impact of new variants on hospitalisations and mortality has become and remains very low. In this scenario, COVID-19 is deemed across the EU/EEA to be routinely manageable. There remains a persistent risk of a SARS-CoV-2 variants of concern emerging that reverses the dynamics of this scenario and leads to higher levels of hospitalisation and mortality.	**Viral properties** - No new variants with significant immune escape properties emerge. **Immunology** - Natural and vaccine-induced immunity against severe disease is very high globally; protection against reinfections is only partial. - Immunity from severe outcomes appears to be long-lived and rates of severe outcomes are very rare among healthy individuals. **Societal factors** - COVID-19 is not considered to be a major societal threat and the majority of the population has learned to live with the occasional SARS-CoV-2 reinfection. **Medical interventions** - Newer-generation vaccines that work across SARS-CoV-2 strains appear to be feasible and are expected to limit transmission in the future. - Antiviral medicines are effective at reducing severe disease.
Regular reinfections	In this scenario as in 'A diminished threat', a large proportion of the global population has acquired natural or vaccine-induced immunity, which provide a significant reduction of risk for severe outcomes. However, in this scenario, vaccine-induced and natural immunity are less efficient in preventing infection or transmission, and new immune-evading variants continue to emerge, driving frequent reinfections. Although COVID-19 mortality remains relatively low, waning immunity is apparent and there are non-negligible rates of hospitalisations and mortality among at-risk populations. However, since most severe cases are reported in people with known risk factors, healthcare systems can cope with this burden. Vaccines targeting the most recent variants are made available on an annual basis and are recommended for at-risk groups (e.g. immunocompromised, older adults and others with underlying comorbidities) in order to reduce pressure on healthcare systems, but vaccine uptake rates continuously decline. EU/EEA countries have generally abandoned the population-level NPIs that were implemented in 2020 and 2021. Emphasis is placed upon voluntary measures when interacting with risk groups.	**Viral properties** - Transmission levels remain high globally, with seasonal fluctuations. - Immune evasion variants periodically appear. **Immunology** - Natural and vaccine-induced immunity is very high globally but does not protect against reinfections. - Immunity from severe outcomes appears to be long-lived (e.g. multiple years) and rates of severe outcomes are low, but enough waning immunity exists to threaten the health of at-risk people. **Societal factors** - Declining uptake rates for vaccine boosters and little political or population acceptance for the re-introduction of NPIs, due to a collective sense that reinfections are inevitable but mostly harmless. - At-risk populations are generally more amenable to follow-up vaccinations and to adopting voluntary protective measures during periods of high transmission. **Medical interventions** - The high rate of reinfections and the emergence of new variants has proven to be difficult to counter with proposed variant-adapted SARS-CoV-2 vaccines. • Vulnerable populations are often the focus of annual vaccination campaigns.
Long, barely manageable winters	As in the second scenario 'Regular reinfections', the virus continues to circulate at considerable levels and reinfections are common, occurring at a rate of one or more per year for a healthy person. However, in this scenario the repeated emergence of more transmissible and immune evasive variants allows the virus to outpace vaccines and our immune system's protection against infection and onward transmission. In this scenario SARS-CoV-2 transmission intensity follows a seasonal pattern with the highest transmission in the EU/EEA between December and February. Thus, the highest SARS-CoV-2 spread coincides with that of other seasonal diseases (rhinovirus, RSV, influenza, other human coronaviruses). While the observed severity of SARS-CoV-2 is strongly reduced since the virus first	**Viral properties** - Immune evasion variants appear. - A winter seasonal transmission pattern has become apparent. **Immunology** - Combination of variants with immune evasion and some degree of waning immunity leads to severe outcomes among some at-risk groups. **Societal factors** - The regular reintroduction of a select range of targeted measures is generally accepted but there is a very visible opposition to more stringent population-level NPIs. There is a minor but steady reduction in public acceptance of additional vaccine doses.

Scenario	Description	Key scenario assumptions
	emerged, in some years SARS-CoV-2 variants emerge with higher intrinsic severity and this, combined with waning immunity and a declining willingness among the population to accept additional vaccine doses, leads to significant winter-time strains on healthcare systems. There remains considerable debate about whether and to what extent population-level NPIs should be re-implemented.	- Vulnerable populations are generally amenable to receiving additional vaccinations and adopting voluntary protective measures. **Medical interventions** - Annual vaccination campaigns target the at-risk population and, periodically, the immunological naïve, including young children. - While antiviral medicines work well when provided early in the course of disease, during seasonal surges the capacity to ensure early administration of antivirals to at-risk populations is stretched to the limit.
Long, unmanageable winters	As in the above scenario, the virus continues to circulate at considerable levels and reinfections occur frequently and with a seasonal pattern. The repeated emergence of more transmissible and immune evasive variants allows the virus to outpace vaccines as well as immunological protection against infection and onward transmission. In contrast to the above scenario, despite the fact that the perceived individual-level risk is low for most people, in winter months, the pool of susceptible people has built up more quickly. Hospital burdens increasingly become unmanageable. While much of this burden is among at-risk people, there is sufficient waning of immunity and viral evolution to regularly lead to hospitalisation rates among the general population that exceed healthcare system capacities. Such circumstances would in theory necessitate the re-implementation of stricter NPIs, but they will have to be targeted, as population-level NPIs have become highly unpopular and are poorly adhered to. In addition, attention is paid to promoting voluntary protective measures, and to annual vaccination campaigns targeting the general population, even if there appear to be diminishing returns from such campaigns.	**Viral properties** - Frequent emergence of more transmissible, immune-evasive variants - A winter seasonal transmission pattern has become apparent. **Immunology** - The combination of waning immunity and immune-evasive variants leads to high rates of severe outcomes among at-risk groups and moderate rates of severe outcomes among the general population. **Societal factors** - Adherence to unspecific population-level NPIs is low, but higher for targeted and time-bound NPI and IPC measures during periods of high transmission. - Vaccination fatigue across all groups, accompanied by a widespread sentiment that if vaccines worked the virus would no longer be so problematic. **Medical interventions** - Annual vaccination campaigns target the full population but rarely exceed 45% coverage. - While antiviral medicines work well when provided early in the course of disease, during seasonal surges the capacity to ensure early administration of antivirals to at-risk populations is stretched to the limit.
A new pandemic	Under this scenario, the persistent threat of novel pandemic strains emerging is eventually realised. A new variant of concern (or a different pandemic virus) begins to circulate and establish itself in exposed populations, with indications suggesting a significant impact on public health. The experience of COVID-19 has demonstrated the impact that enhanced public health measures can have if enacted rapidly. Hence in the initial phases, introducing restrictive and precautionary infection control and social distancing measures may be warranted. This will have the dual benefit of reducing initial spread and minimising immediate burden on healthcare systems, while also buying time to gain a better understanding of the scale of the potential public health threat. It will also help with the commencement of vaccine roll-out and extend the time window for effective development and deployment of strain-specific vaccines and other new interventions. If this scenario were to occur in the near future, the greatest challenge would arguably be to reengage with the public to aid compliance with restrictions during the period of uncertainty following initial emergence. The (re)imposition of stringent restrictions in an already pandemic-fatigued population would require careful assessment and different policy approaches may be needed to obtain public trust and support.	**Viral properties** - A new virus has emerged with a high intrinsic severity and the ability to transmit rapidly **Immunology** - The global population is immunologically naïve to this pandemic virus. **Societal factors** - Fatigue from the COVID-19 pandemic and low levels of resilience as societies are still not fully recovered from COVID-19. **Medical interventions** - Rapid upscaling of vaccine programmes will be a priority. - The advances in vaccination technologies exhibited during the COVID-19 pandemic create hope that within 4–6 months, strain-specific vaccines will become available. - As with the COVID-19 pandemic, it is expected to take many years to produce enough vaccine supplies for the entire global population.

It is important to note that the scenarios presented in Table 1 represent a range of plausible future possibilities. The range of scenarios represents a continuum, from least to most severe outcomes (Figure 1). In addition, it is important to note that the scenarios presented here are not necessarily mutually exclusive. It is entirely possible that for a period of time, one scenario will manifest itself, but this does not preclude a transition into another scenario. This underscores the importance of continued vigilance, based on effective surveillance, in order to inform timely and proportionate EU/EEA preparedness and response. However, while preparedness needs to be in place to address the most severe scenarios, there are also specific types of public health responses that should be in place for each of these scenarios – these are elaborated in Section 2.

Figure 1. Continuum of plausible pandemic scenarios



2. Public health actions required across pandemic scenarios

As noted above, the pandemic scenarios presented in this document may at any point transition to a more or less severe scenario. Continued public health vigilance, and preparedness to implement specific types of measures across the scenarios will be paramount to ensure that the scenarios have the least possible health and societal impacts in the EU/EEA. A summary of some of the key public health activities that may be relevant for each scenario is summarised in Table 2 below.

Table 2. Implications and public health actions required, depending on the different scenarios

Scenario name	Diminished threat	Regular reinfections	Long, barely manageable winters	Long, unmanageable winters	A new pandemic
Scenario number	1	2	3	4	5
Viral properties: public health consequences /action	• Routine sampling and sequencing ongoing to support assurance of strain stability. • Integrated respiratory surveillance at community and hospital levels.	• Continual variant monitoring focusing on rapidly developing or atypical clusters and patients exhibiting unusual epidemiological/clinical presentation as likely sources of emergence (symptoms, severity, duration etc.) • Requirement for appropriate levels of testing implementing community wide COVID-19-specific surveillance (self-testing).	• Seasonal scale-up of variant monitoring and rapid strain characterisation. • Increased testing and sequencing requirements may go beyond 'peacetime' requirements. • Ensure seasonal rapid antigen testing capacity is in place to support routine self-testing during peaks.	• Expansive variant monitoring and rapid strain characterisation established as routine. • Testing capacity adjusted to address seasonal peaks, with potential increased reliance on self-testing and quarantine during peaks due to limits on community testing capacity.	• Expansive variant monitoring and rapid strain characterisation (genotypic and phenotypic assessment). • Increased testing and sequencing requirements, adjusted to available capacity. • Possible limits in testing availability if existing tests display reduced specificity/sensitivity to emerging strains.
Immunology: public health consequences /action	• COVID-19 vaccines introduced into routine vaccination programmes, schedules based on estimated duration of protection against severe disease. Focus on individuals at risk and those eligible but not yet vaccinated with a primary course and booster dose(s). • Challenge to maintain vaccine uptake in the absence of significant health burden.	• Routine COVID-19 vaccination programmes may be supplemented with targeted booster campaigns for at-risk groups where there is evidence of waning protection against severe disease. • Challenge to maintain vaccine uptake.	• Consider seasonal strain-specific vaccination deployment targeting at-risk groups, and their contacts. Attendant need for vaccine teams (human resources, supplies, etc) and special vaccination sites and delivery options during time-limited periods. • Supported campaigns for vaccine uptake in key groups, including healthcare workers and staff in long-term care facilities (LTCFs), for both direct and indirect protection.	• Emphasise public health value in deploying seasonal strain-specific vaccination for all. • Concerted vaccination campaign to encourage general population uptake, emphasising importance of vaccination for at-risk groups. • Utilise community-wide vaccination centres to support rapid vaccine uptake.	• Massive global research effort to develop strain-specific vaccines. • Reliance on NPIs and other 'social' measures as the primary mitigation approach in absence of effective vaccines.
Social factors: public health consequences /action	• Basic hygiene measures promoted, but specific COVID-19 mitigation/intervention measures largely absent in most settings (including towards/within vulnerable groups). • Healthcare systems prioritise non-COVID care.	• Messaging focused on voluntary isolation if symptomatic (individual responsibility). • Possible targeted 'light' mitigations (NPIs, etc.) for vulnerable groups and settings with escalating infection rates (e.g. use of masks in LTCFs, hospitals). • Hospitalised/severe COVID-19 cases integrated into normal hospital case management.	• Seasonal NPI implementation during periods of high transmission/infection including: self-monitoring, self-testing and self-isolation for all with symptoms during 'COVID season'. • Increase adherence to NPI mitigation and interventions for vulnerable groups and settings (social distancing, use of masks in LTCFs, hospitals).	• Seasonal NPI implementation during periods of high transmission/infection, including: self-monitoring, self-testing and self-isolation for all with symptoms during 'COVID season'. • Required adherence to NPI for vulnerable groups and settings (shielding, self-isolation, use of masks).	Multi-layered response based on risk-based approach that optimises NPIs to maximise public health impact, minimises societal burden, and maintains adherence. Options may include: • enhanced contact tracing, quarantine and isolation of close contacts; • increased testing requirements, including assisted and self-testing (increased diagnostic testing capacity);

Scenario name	Diminished threat	Regular reinfections	Long, barely manageable winters	Long, unmanageable winters	A new pandemic
Scenario number	1	2	3	4	5
			• The need for proportionate NPIs in other settings may need to be assessed (e.g. use of masks, social distancing). • Implement specific COVID-19 hospital management plans, with possible reprioritisation of care to address COVID-19 patient needs within existing capacity during peak season.	• Remote working/ on-line environments may be considered. • The need for proportionate NPIs in other settings will need to be assessed (e.g. use of masks, social distancing, limits on community gatherings, vaccine certification). • Possible infection/symptom monitoring in community settings (schools and workplaces, etc.) to remain open. • Community engagement and communication strategies key to support compliance in sceptical/fatigued populations. • Options for expanded inpatient/ICU hospital capacity during peaks (beds, healthcare workers, etc.) to manage COVID cases.	• NPIs in community settings including use of masks, social distancing, capacity limits etc. (schools/workplaces etc.); • viability of non-essential services. (shops, restaurants etc.); • extended use of remote working/on-line environments;. • clear communication strategies are the key to emphasising community responsibility to minimise impact; • contingencies for surge-capacity in healthcare systems (including healthcare workers) in place for months.
Medical interventions: public health consequences /action	• Broadly effective vaccines, and absence of immune escape variants reduce the need for strain specific vaccine programmes/boosters, but still require broad-level of vaccine uptake to be maintained among at-risk groups in order to retain protection against severe disease at population level. • AV stocks and usage supported under normal treatment guidelines.	• Antiviral usage employed according to standard prescribing practices to reduce severe disease.	• Increase AV usage as numbers of cases increase with possible need for prioritised prescription during in-patient surges.	• Increase AV usage as numbers of cases increase with possible need for prioritised prescription during in-patient surges.	• Reliance on social measures in the short term until strain-specific vaccines become available. • Vaccine roll-out defined by assessment of approaches to minimise health burden. • Early assessment of effectiveness of existing medical interventions and treatments to mitigate (severe) disease.

2.1 Public health objectives beyond the acute and transition phases of the pandemic

There are numerous public health actions that will require priority in the coming years. On 26 April 2022, the European Commission published a Communication on sustaining EU preparedness and response [1]. This is complemented by an ECDC-authored perspectives paper, outlining public health considerations for transitioning beyond the acute phase of the COVID-19 pandemic [4].

To summarise these documents in brief, there is still a strong need to remain vigilant in the longer-term scenarios described in this paper. The European Commission highlighted the following areas as priorities for Member State attention:

- Step up **vaccination and boosting**, taking into account the simultaneous circulation of COVID-19 and other respiratory viruses, such as seasonal influenza.
- Set up integrated **surveillance systems** that are no longer based on the identification and reporting of all COVID-19 cases, but on obtaining reliable and representative estimates.
- Continue targeted **testing and sequencing** of sufficient samples to accurately estimate variant circulation and detect new variants.
- Invest in the **recovery of healthcare systems** and assess the wider health impacts of the pandemic, including on mental health and delays in treatments and care.
- Apply EU coordinated **rules to ensure free and safe travel,** both within the EU and beyond.
- Support the development of the **next generation of vaccines and therapeutics**.
- Intensify collaboration against **mis- and disinformation** on COVID-19 vaccines and NPIs.
- Continue to **deploy global solidarity and improve global governance**.

Further details on selected cross-cutting activities that would collectively help to achieve these objectives are presented below.

2.1.1 Refining surveillance

Appropriate and sustainable surveillance will be essential for tailoring and evaluating responses in all scenarios, and detecting the early signs of transition from one scenario to another. The current sentinel ILI/ARI and SARI surveillance systems should be significantly strengthened to increase their geographical coverage, sensitivity, and representativeness [5]. Systems will need to include sufficient coverage of sequencing to detect variant emergence and trends and will need to be integrated with the overall respiratory virus monitoring strategy. Failure to do so will hamper the possibility to effectively monitor the levels of virus circulation in the community and protect the most vulnerable. Furthermore, in the absence of such systems, we will be at constant risk of missing emerging virus variants or detecting them with significant delay. Such systems will allow for the rapid detection of seasonal increases at manageable testing levels, while avoiding artefacts that can result from ascertainment bias.

2.1.2 Sequence capacity and sharing

It is in the global interest to ensure that all countries have sequence capacity to monitor virus evolution. It is also important that countries are incentivised and not disincentivised (e.g. by travel and trade restrictions) to exchange information as promptly as possible on any new SARS-CoV-2 variants, novel viruses or health threats generally. Measures are vital to ensure that information sharing from scientific or public health communities on new variants is widely supported and that the response to the pandemic is globally coordinated.

2.1.3 Enhancing preparedness and response

While much has been learned about the role and effectiveness of response measures during the last two years, there are still gaps in our understanding about what and when specific measures are optimally applied in the face of changes in the epidemiology of COVID-19.

Priority actions to address these gaps include:

- Careful assessments of the effectiveness, cost-effectiveness, and social acceptability of the range of NPIs implemented during the COVID-19 pandemic. This will inform future decision-making if time-limited introduction of NPIs is required in the future in response to enhanced viral circulation or outbreaks.
- It is critical to identify thresholds and develop protocols for outbreak identification and management, including contact tracing, with an emphasis on congregate and healthcare settings.
- Rapid identification and assessment of key epidemiological parameters (including severity, transmissibility, immune escape) is vital, particularly through the conduct of 'first few' studies, for each new variant of interest or variant of concern. This includes:
  - operational study protocols to quickly assess secondary attack rates and growth rates, and R_t and R_0 are needed to provide reliable risk assessments;
  - the ability to rapidly assess severity, including follow-up by age group, previous infection, and vaccination status of cases identified, each time a new variant emerges;
  - readiness to quickly assess immune escape and waning protection against infection and severe disease, including by age group, previous infection, and vaccination status.

2.1.4 Protection of vulnerable groups

Owing to vaccine protection and immunity from natural infection the majority of the population is currently expected to be protected from severe COVID-19. However, there will still be parts of the population that remain vulnerable to unfavourable outcomes (and repeatedly so over time, with each new variant), such as older adults, people with underlying conditions, the immunocompromised, the unvaccinated/partially vaccinated and those whose protection from vaccines or natural infection has waned. Efforts should focus on the protection of these people with both pharmaceutical (e.g. vaccine boosters, when necessary, and early access to antiviral treatments) and non-pharmaceutical interventions.

2.1.5 Prevention of healthcare-associated COVID-19

COVID-19 can be transmitted within healthcare settings, often with devastating outcomes because it affects people who are already vulnerable to severe disease and death. Optimisation of infection prevention and control practices in both acute and long-term care settings is the key to mitigating the effects of COVID-19 in terms of morbidity, mortality and healthcare burden. If variant-adapted vaccines demonstrate a greater effect against infection and transmission, their administration to healthcare workers and LTCF personnel may be considered to provide both direct and indirect protection.

2.1.6 Healthcare system management and resilience

COVID-19 has had a heavy toll on healthcare systems and the staff within them. In each of the scenarios presented it is envisaged that COVID-19 will continue to give rise to hospital admissions, albeit at manageable levels in the first two scenarios. Healthcare systems need to be capable of dealing with the accumulated backlog of non-COVID-19 patients requiring management, and to be prepared for scenarios that will place them under further pressure. This will require:

- ongoing refinement of preparedness planning in laboratory and healthcare systems to ensure that staff and resources are able to meet increasing demand;
- increased focus on the resilience and adaptability of these systems in terms of financial and human resources and allocated goods for healthcare delivery, including the direct negative impact of a decreasing workforce due to staff infections (irrespective of whether these are acquired outside or within the healthcare system);
- an increased understanding of levels of excess mortality and morbidity during the pandemic, which may also relate to backlogs in non-COVID care.

2.1.7 Behavioural and societal aspects

Two years into the pandemic, there is still insufficient understanding of the behavioural, cultural and societal drivers that have an impact on population acceptance and adherence to public health interventions (including NPIs and vaccine uptake), or on how these can change over time. The emergence of a new variant, and the resultant potential need to refine intervention approaches exacerbates this uncertainty. Therefore there is a need to improve the capacity to conduct behavioural insights research on vaccine acceptance and various NPIs.

- It can be expected that unless there is a major change in the (perceived) risk, severity or susceptibility to severe outcomes, the willingness to adhere to any reintroduced unspecific population-level NPI measures or even routine COVID-19 booster doses will decline in the general population over time (possibly less so in vulnerable groups and healthcare workers).
- It is unclear how the acute phase of the COVID-19 pandemic will lead to sustained lifestyle changes in society (e.g. from teleworking, seasonal use of NPIs such as masks, as observed in other parts of the world, adapting buildings to make them COVID-secure, etc.)
- The question of protecting the most vulnerable in society through the adoption of targeted mass vaccination programmes will need to be investigated, both in terms of effectiveness and cost-effectiveness, following the same processes and methods as are applied for non-pandemic diseases.
- Continuing management of mis- and dis-information should be maintained.

2.1.8 Ensuring proportional responses

There is a need for broad political/societal agreement on the appropriate forms, level, and targeting of response measures within any given scenario. At the milder end of the spectrum of scenarios, there are potentially substantial, negative societal consequences to reintroduced stringent disease control measures and travel bans, both directly in terms of impact on population health and livelihoods, and socially and politically if large proportions of the population do not accept them. At the severe end of the spectrum, sufficiently targeted and proportionate measures will be required to minimise the disruption to society while protecting those most at risk of severe outcomes. Furthermore, there is a need for continual re-assessment of the risks from new variants balanced against waning immunity. This will require measures to be proportional to the risk - neither too stringent, nor too relaxed.

2.1.9 Vaccine 'agility'

As long as SARS-CoV-2 is circulating widely on a global basis, we may expect new variants to arise. New VOCs may emerge at any time, with unpredictable characteristics, further affecting the duration of protection from

current vaccine formulations. However, cell-mediated immunity from current vaccines, which is important for protection against severe disease, has shown good cross-protection against different VOCs and seems broadly preserved so far, although the duration of such preserved protection cannot be known until it has been possible to follow up for a longer period.

It is important to be clear about the objectives of future vaccination and booster campaigns in the general population and vulnerable groups (e.g. reduce severe disease, hospitalisations and deaths to an acceptable level, protect vulnerable groups, reduce the overall burden of disease as much as possible, reduce viral circulation), and to balance these against the costs, opportunity costs, benefit and risks associated with repeated vaccinations. Depending on the objectives and the priorities, and also on the actual added benefit that can be obtained from additional doses, different needs for COVID-19 vaccine development and deployment may arise.

It appears likely that there will be a regular need to develop and manufacture updated vaccines at scale, whether for primary vaccination courses or boosters. At present, the mRNA technology is the platform that can deliver updated versions of approved vaccines most rapidly, although the time required to develop variant-adapted formulations at sufficient scale could be too long to have an impact on new waves of VOCs. The capacity to develop and deploy updated vaccines in a timely manner could be required for decades as the virus enters an endemic phase, especially given the unpredictability of variant emergence.

Efficiency improvements are required for the full vaccine development cycle, from processes for selecting updated vaccine targets through to manufacturing. This should be done through a governance mechanism that also prioritises equity for strain selection and includes consideration of alternative vaccine strategies such as developing and deploying multivalent vaccines or targeting conserved SARS-CoV-2 virus antigens that may offer more stable and broader protection against future variants.

Long-term vaccination strategies should align with public health priorities for managing COVID-19 burden as the situation (and population immunity) evolves, addressing immunity gaps and protecting those most at-risk. Use of vaccines will also need to be balanced against use of other pharmaceutical and non-pharmaceutical interventions, as the added benefit derived from vaccines may increase if other measures are not adopted (or do not need to be adopted).

The speed at which vaccines can be produced, distributed and administered to citizens is also vital, given the development of scenarios that envision the need for a rapid response. This will require substantial global investment to develop surge capacities, with resources to additionally monitor and respond to acceptance and concordance challenges for recurrent COVID-19 vaccination in all population groups, but particularly in the most vulnerable and at-risk population groups [7].

2.1.10 Determine the role of antiviral treatments

Novel antiviral therapeutics that are easily administered for the prevention of severe disease have the potential to significantly contribute to decreased healthcare burden. It is necessary to define the indications of antiviral agents and, if approved for use, ensure their availability at least for those who are most vulnerable to severe COVID-19 and unfavourable outcomes. The potential development of antiviral resistance that can compromise the effect of antiviral agents needs to be monitored.

2.1.11 Global health

COVID-19 has intensified existing discussions surrounding global health equity and demonstrates very clearly that no country is safe until all countries are safe. Strategic decisions are required concerning enhanced investments in global health infrastructure and bolstering the availability of COVID-19 vaccines, antivirals, personal protection equipment, medical equipment such as ventilators, and testing reagents on a global scale. Furthermore, there is a need to support countries globally in conducting epidemiological investigations into new variants of concern.

Our understanding of possible pathways for virus evolution also needs to be improved. During the COVID-19 pandemic there were multiple instances of COVID-19 outbreaks among a range of mammalian species, and there is a risk that the novel VOCs could emerge through reverse zoonoses, followed by zoonoses. Therefore, the animal-human interface is a topic deserving of more attention at global level.

2.1.12 Lessons learned and after-action reviews

The COVID-19 pandemic has had a myriad of long-ranging impacts on public health and the world at-large. It is imperative that innovations and good practices that emerged during the pandemic are safeguarded. Lessons learned must be acted upon so as to improve public health preparedness and response to future large-scale outbreaks and pandemics. An evidence-based approach should inform decision-making during the transition phase. Structured after-action reviews and lessons learned exercises should be an important activity area during the pandemic transition phase and there should be sufficient high-level buy-in to ensure that the results of these exercises are acted upon [8].

3. Long-term strategic considerations

In the longer-term, through sufficient planning, preparedness, and foresight, the EU/EEA can be better equipped to sustainably handle the additional long-term challenge that COVID-19 has created, in addition to other pre-existing and continuing infectious disease threats. In this respect, pandemic preparedness in the EU/EEA needs to be enhanced and coordination of responses between Member States optimised.

To achieve this, firstly, the overall strategic objectives and actions for future management of COVID-19 must be agreed upon so that there is a common playing field. Secondly, operational discussions are required on the implications for a wide range of public health activities, including surveillance, risk communication, pandemic preparedness, early warning, vaccination, medical countermeasures, NPI measures and IPC measures.

Finally, moving forward, it is imperative that public health agencies have the best possible information, to ensure that recommended mitigation measures are commensurate with assessed levels of risk.

Conclusion

Given the number of uncertainties surrounding possible trajectories for the COVID-19 pandemic, particularly in light of the continued high levels of viral transmission globally, and the possibility that new variants of concern may arise, it seems clear that SARS-CoV-2 is here to stay. As such, public health systems, clinical services and society in general will need to adapt to the fluctuating levels of threat that this virus is likely to present in the coming years.

The scenarios presented here are based on a range of plausible trajectories, and have been developed to support and inform decision-making concerning the type of long-term investments and arrangements required to manage the next phases of the COVID-19 pandemic. Common to all scenarios is the perpetual risk posed by new SARS-CoV-2 variants. A key message is that even when or where current scenarios appear to be less severe, adequate surveillance and monitoring systems need to be in place to detect changes in the level of threat posed by SARS-CoV-2, and preparedness must be strengthened in order to mount an effective and proportionate response to rapidly deteriorating situations. The wide range of possible outcomes presented in this document serves as a reminder that there is much work yet to be done to strengthen global and EU health security against COVID-19 and future pandemics.

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