Sustainable strategies against the COVID-19 pandemic in Germany in winter 2021/2022

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Available e.g. via TU Berlin Repository: http://dx.doi.org/10.14279/depositonce-12635
Date of this version: 11/11/2021

Suggested citation: Priesemann, V. et al, Sustainable strategies against the COVID-19 pandemic in Germany in winter 2021/2022, position paper of 11/11/2021.

Summary

Since July 2021, the Delta variant of SARS-coronavirus-2 (SARS-CoV-2) has also been dominant in Germany. It is significantly more contagious than the previously known variants. This means a high risk of infection for the unvaccinated. In addition, without a third vaccination ("booster"), protection against the virus decreases continuously over time. After five months, protection against infection drops from a factor of around 10 to a factor of 2-3. As a result, not only the unvaccinated currently contribute to the spread of the virus, but also that part of the population that has been vaccinated for some time. Together with seasonality, this results in a rapid increase in incidence.

This makes the current situation very critical. The exponentially increasing incidences are directly linked to the occupancy of the intensive care units. In order to counteract a permanent overload of the intensive care units, vaccination and the improvement of vaccination protection by means of a third vaccination are particularly effective in the long term. Vaccinations have two protective effects: They protect the vaccinated person from severe disease and protect those around them from transmission. Thus, with each improvement in vaccine protection, both the spread and the likelihood of a severe course are reduced. Boosting and closing vaccination gaps is therefore extremely helpful. Currently, vaccines are available in sufficient quantities. New vaccines coming on the market, which are among the "classic" protein vaccines, could further support this, especially in people who are critical of the previous vaccines. Especially among those vaccinated first, i.e., those at increased risk of a severe course due to advanced age and underlying disease, protection is now significantly lower, and thus the burden on hospitals from this group will increase again.

Rapid third vaccination of this fairly large group, as well as all those who have contacts with vulnerable individuals, significantly reduces the expected burden on the health care system.

However, a significant reduction in the dynamics of infection will only be achieved with the help of truly nationwide booster vaccination. However, this will require a significant acceleration in the pace of booster vaccination: Since about 7% of the population has been second-vaccinated per week since the end of May, the same vaccination pace for third-vaccination 5-6 months later would now be possible and reasonable. Simulations show that a booster campaign at this vaccination rate will begin to have an impact after only one month.

Until a sufficient proportion of the population is boosted and vaccinated, the current situation also requires clear and effective measures to bridge the gap if ICUs are not to be severely overloaded. Here, the well-known hygiene measures, as well as consistently enforced and comprehensive rules and testing concepts in the work and leisure sectors, are important and helpful. Increased testing as a sole measure will probably not be sufficient to break the incipient winter wave. We describe the effectiveness of possible measures in detail in the text. However, these are only stop-gap measures, as they do not directly address the problem of too high a rate of spread, but instead leave it to "natural immunization" through infection. However, "natural immunization" progresses much more slowly than vaccination could, and is also associated with a significant disease burden. In this respect, rapid and comprehensive vaccination and boosting appears to be the most effective method to break the current wave soon and to control the pandemic in the long term.

Introduction

Winter is just around the corner. Compared to last year, we are in a better position in one major respect: We have very effective vaccines available, and the majority of adults are vaccinated or recovering. Nevertheless, the number of cases is currently rising sharply again. What is the reason for this? What does this mean for the coming months? And how can we deal with it? We now know much more about the virus and how it spreads. Nevertheless, there are a number of misconceptions and myths. We would therefore like to clear up some of the misconceptions below and summarize the current state of knowledge. Based on this, we will discuss possible scenarios and then discuss some selected tools to get well through the winter.

Fact base

Incidence

To date, only a small proportion of the population in Germany has been infected with SARS-CoV-2. To estimate how the pandemic will develop, it is important to know how many people have had COVID-19. About 5.5% of the population had confirmed SARS-CoV-2 infection. If undetected cases are taken into account, about 10-15% of the population had direct contact with the virus.[1] [2] At the same time, this means that people in their own circle of family and friends probably know only a few people who were infected, had a severe course or died. This sometimes gives the impression that the pandemic is far away. But this is exactly what is to be expected: the probability of dying from COVID-19 after an infection is about 1% in Germany. This 1% is also the probability for a 60-year-old person to die of COVID-19 after an infection. So if a person has 100 friends and acquaintances, that typically includes 10 infected people, and in the expected value 0.1, so usually no people die. However, many have heard from friends that someone in their family or circle of friends has died. If one assumes that the "friends of friends" are 10,000 people, then one expects 10 deaths in this group. Had the pandemic not been so severely mitigated last winter by significant contact restrictions and precautions, there would have been significantly more deaths, similar to the situation in England.

Immunization of the population and "herd immunity". At the beginning of the pandemic, we assumed that the R-value would fall below one when about 70% of the population was immune. This is sometimes referred to as the "herd immunity threshold." Why is that not the case now after all? The reason is that the Delta variant now prevalent is much more contagious than the original variant at the start of the pandemic, and that even those who have been vaccinated or recovered - albeit less frequently - can still become infected and pass on the virus. Thus, significantly more people must be immune (whether through

[1] Gornyk et al, Deutsches Ärzteblatt 2021, https://www.aerzteblatt.de/pdf.asp?id=221932:
The number of undetected infections in the first wave was about 3-6 times higher than the number of confirmed infections. In the following months, the testing strategy was significantly expanded. Since summer 2020, the proportion of undetected infections has therefore been significantly lower: On average, it is currently assumed that ⅓ to ½ of infections remain undetected; at high incidence, this so-called dark figure is somewhat higher, and at low incidence, it tends to be lower.
[2] Robert Koch Institute, Epidemiologisches Bulletin from the 16/09/2021, https://www.rki.de/DE/Content/Infekt/EpidBull/Archiv/2021/Ausgaben/37_21.pdf?__blob=publicationFile

vaccination or after infection) to keep incidence low even without maintaining additional measures.
This situation has far-reaching consequences. First, it affects the unvaccinated. This is because most of this group will inevitably become infected. If 20-30% of the population continue to be unprotected, there will be a correspondingly large number of severe courses and deaths in this group. In addition, the health care system remains permanently burdened (and, depending on the time course, overburdened) because of COVID-19, so that the care of all other patients is also limited. At the latest, when hospitals are significantly overloaded, further restrictions will become necessary - with the well-known consequences for our society.

Protection after infection has so far contributed only slightly to herd immunity in Germany. The heavy waves of infections during the last approx. 1.5 years have placed a considerable burden on hospitals and have led to significant regional excess mortality during this time - although only 10-15% of the population has been infected (see above). This shows that so-called "natural immunization" of the population - i.e., immunization as a result of SARS-CoV-2 infection - would not have been a realistic option for achieving herd immunity. In contrast, we can immunize 5% of the population per week with vaccination. For the majority of those people who permanently choose not to be vaccinated, infection will inevitably occur, with the known age-associated risks of severe courses, complications, and death. Overuse of the health care system thus depends to a considerable extent on the number of people who are vaccinated and the time period over which previously unvaccinated people - and especially unvaccinated people over the age of 60 - become infected.

Incidence and new admissions to intensive care units continue to be very closely correlated. Currently, approximately 0.8-0.9% of all individuals who test positive will require intensive care. This factor changes only slowly over time and can be estimated well from the data. This makes the incidence a useful early warning indicator, even if one does not know the fraction of undetected cases or the vaccination rate with complete accuracy.

Limited capacity in intensive care units

High incidence will overwhelm intensive care units. Despite vaccination progress, there are still more than 3 million people over the age of 60 and more than 11 million between 18 and 59 who are not vaccinated. A small proportion of these have recovered. However, immunity wanes over time in both vaccinated and recovered people. As a result, there is a high number of people for whom SARS-CoV-2 infection is dangerous. For example, in the event of infection, an unprotected person aged 60 has a 2-3% chance of requiring treatment in an intensive care unit. A person 20 years younger has nearly 10 times less risk. If all previously unprotected people were to become infected this winter, we would have at least 3 times more people in ICUs than we did all of last winter. At the same time, due to staff being permanently overworked, leaving the clinics or reducing their working hours, the reserve capacity in the ICUs is much lower this winter than last winter. Due to staff shortages and reporting corrections, there are about 4000 fewer beds available than last year. So if the current surge is not slowed, ICUs will be overloaded for weeks and many other necessary surgeries and treatments will have to be postponed.

Intensive care units have little spare capacity. Even at "normal times," i.e., even without COVID-19, ICUs are at capacity. In Germany, a typical ICU has a median of 12 beds. Therefore, an occupancy of more than 90% is to be considered critical, because 90% occupancy means that typically only one operable bed is still free. At a minimum, this buffer is needed so that unforeseeable and urgent cases, such as accident victims and people with acute heart attacks or strokes, can be cared for immediately. If a hospital has to turn down an emergency because of capacity, it can mean delays in acute care and a long transport. Regional congestion exacerbates the problem.

In 2020, there were shortages in intensive care units. It was reported that in 2020, only 3% of ICU beds were occupied by COVID-19 patients on an annual average. However, this average is misleading. While there were hardly any cases requiring intensive care in January, February, and May until October, and only southern Bavaria and Baden-Württemberg were affected in March and April, occupancy rates increased dramatically everywhere from November onward. Thus, spreading the extreme burden of the months of November and December mathematically over the entire year 2020 is of little help in assessing what is currently happening. In the current very dynamic infection situation, a very large number of patients are at risk of being infected in a short period of time.
The nursing shortage determines the bottleneck in the intensive care units, not a shortage of beds. A bed in an intensive care unit can only be operated if trained specialist staff are available. The shortage of staff on the wards is the real bottleneck and cannot be compensated quickly and easily. Intensive care training is costly and lengthy. In addition, a significant proportion of staff are burned out by the constant workload. In this respect, counting "vacant" beds is not purposeful. It is primarily a question of how many patients can be cared for in the long term without overburdening the staff.

Influenza, RSV and other pathogens bring additional burden. In the winter of 2020/2021, there were few infections with influenza or with other respiratory pathogens that can potentially cause severe illness, due to measures taken against the spread of SARS-CoV-2. At the peak of the last strong influenza wave in 2018, about 3,000 patients were in intensive care at the same time. If this were to happen again in the winter of 2021/2022, it would add to the current sharp increase in the number of COVID-19 cases.
For premature infants, babies and young children, infection with respiratory syncytial virus (RSV) and other pathogens from the group of paramyxoviruses and picornaviruses relatively often leads to symptomatic and also more severe courses, necessitating oxygen or even intensive care. Since RSV and other infections of infants and children did not occur last year, many children are now catching up with initial infections.[3] This is already currently causing a very significant burden on pediatric health care systems, while the effect of COVID-19 here is smaller.
The hygiene measures that protect against the spread of SARS-CoV-2 are even more effective at reducing the spread of influenza, RSV, and other viruses, and may also reduce or even completely prevent these waves in the coming winter - as was the case globally in 2020/2021. An initial infection with RSV - unlike influenza thanks to vaccination - cannot be prevented in principle, but only delayed. This is precisely where the hygiene measures come in.

[3] Buda et al, ARE-Wochenbericht from calendar week 43 2021, https://influenza.rki.de/Wochenberichte/2021_2022/2021-43.pdf

Spread

The dual benefit of vaccination. Vaccinations against COVID-19 not only protect the vaccinated person from infection and severe illness. They also reduce transmission of the virus from vaccinated persons to their contacts because vaccinated persons are less likely to become infected and are typically infectious for a shorter period of time. It is important for the entire transmission chain, and for preventing overuse of the health care system, to consider both protective effects.

Protection against infection is very good, but diminishes over time. Initially, protection by vaccination is about 90%, which means that a vaccinated person is about 10 times less likely to infect themselves. Even if the vaccinated person becomes infected, the risk of transmitting the virus to another person is further reduced. Overall, this gives recently vaccinated people about 20 times less chance of transmitting the virus than unvaccinated people. That is a lot. After about 5 months, the protection provided by the vaccination is still 50% to 70%, so the probability of becoming infected is only reduced by about a factor of 2-3. (The exact values depend on vaccine, age, virus variant, and other aspects). The decline in vaccination protection is one of the reasons why the number of cases is currently rising. Protection against a severe course also declines with increasing interval to vaccination, albeit at a higher level (initially around 98% with Comirnaty, 90% after 5 months, so it declines from a protection factor of 50 to a protection factor of 10).[4] This protection can be significantly increased by a third vaccination. Natural infections after vaccination can also improve protection. Recovered individuals are likely to have similarly good protection against infection as vaccinated individuals. Vaccination of persons who have already experienced SARS-CoV-2 infection can further increase protection, so that it then significantly exceeds protection in fully vaccinated persons.

Unvaccinated individuals, as well as those with declining immune protection, contribute to the pandemic. No vaccination provides 100% protection, including that against COVID-19. This is just as no medicine works with 100% certainty, or - using an everyday example to illustrate this - the airbag in a car does not protect 100% against injury in the event of an accident. It is possible for a vaccinated person to become infected, although less likely than for an unvaccinated person. The number of breakthrough infections is often interpreted as a failure of vaccination. However, this does not take into account that the group of vaccinated persons is significantly larger than the group of unvaccinated persons. The protective effect of vaccination is still considerable. According to the Robert Koch Institute, protection against hospital admission in calendar weeks 40-43 2021 is approximately 89% (age 18-59 years) and approximately 85% (age ≥60 years), respectively, and protection against treatment in intensive care units is approximately 94% (age 18-59 years) and approximately 90% (age ≥60 years), respectively.[5] On average, when an unvaccinated person becomes infected, it results in a hospital burden that is about 3-10 times higher than when a person becomes infected despite being vaccinated. You can also see this in the current incidence rates presented separately by vaccination status. This is

[4] Barda et al, The Lancet 2021, https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)02249-2/fulltext and Tartof et al, The Lancet 2021, https://doi.org/10.1016/S0140-6736(21)02183-8

[5] Robert Koch Institute, Wöchentlicher Lagebericht from the 04/11/2021, https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Situationsberichte/Wochenbericht/Wochenbericht_2021-11-04.pdf?__blob=publicationFile
These numbers hold specifically for these calendar weeks.

why hospitals sometimes talk about a pandemic of the unvaccinated. You see this effect in all age groups.
At the same time, the younger half of the population would not overload ICUs on their own, since the probability of becoming seriously ill also increases by a factor of 3-10 for every 20 years of age. So for the hospital burden, 20 years of age difference is similar to the difference between vaccinated and unvaccinated. Could we conclude that it doesn't matter if younger people get infected? Apart from the ethical aspect that children under 12 years of age do not yet have a good opportunity to protect themselves, a second aspect is very important: vaccination plays a decisive role for the spread, and thus for the incidence in all age groups.

Stabilizing case numbers is even more difficult at high incidence than at low incidence. Some people intuitively think that we can have more contacts (or "freedoms") if we accept that hospitals are full. The common argument is that in order to protect some people, we should not accept such burdensome restrictions. But there is a misunderstanding here as long as there is a threat of overwhelmed hospitals. If the number of cases is allowed to rise until the hospitals are overloaded, the R-value must be stabilized at 1 at that point at the latest. Stabilization needs just as many precautions at high case numbers as at low case numbers, as long as "natural immunization" contributes very little. The point then is that the effective R-value must be 1, meaning that each person has only enough contacts to infect a maximum of one person, should that person be unknowingly infected.

SARS-CoV-2 will, in all likelihood, become endemic. So, sooner or later, basically every person will come into contact with the virus. The decision each person makes is whether or not to protect themselves by vaccination beforehand. Due to the fact that not enough people have been protected so far, it is not yet possible to completely lift the precautionary measures without significantly overloading the hospitals.
So will vaccination have to be repeated every fall in the future? We don't know yet. It depends on how long the protection against a severe course lasts and whether there is a risk of too many people getting sick at the same time.

Scenarios

Many tools are now available for pandemic control, which will be discussed in detail below. In the following, some possible scenarios are developed from these, showing examples of possible combinations of instruments and the resulting consequences.

Scenario "Business as usual!"
Assumptions: Incidence continues to rise with an R-value of 1.2 and slows down only very slowly due to further voluntary restrictions and increased caution by individuals. There are no measures other than in October 2021 in Germany. Vaccination and "boosting" by third dose vaccination is progressing at the current rate of just under 1.5% vaccinated per week.
Consequences: Weekly incidence increases to many hundreds per 100,000. Vaccination or booster rates are +10% higher after 7 weeks. Overall "natural immunization" reaches about +10% after seven weeks (variable, depending on incidence). This improved immunity (+20%) in the population is reduced by a waning immune response in the other parts of the

population. Thus, overall immunity is somewhat improved. Whether it is sufficient to significantly reduce infection dynamics will vary by region. In regions that already have 80% vaccinated, it may be enough. Nevertheless, hospitals are overwhelmed primarily because of the vulnerable and unprotected. There are likely to be delays and bottlenecks in hospital care and emergency care locally. At that point, at the latest, we need to think about changing our strategy.
In short: Not deciding is also a "strategy" and would probably lead to an overwhelming of the health care system.

Scenario: "The capacity limit of the health care system"
Assumptions: The capacity limit of the health care system is used as a benchmark for action. That is, in addition to hygiene measures and 2G/3G[6], there are other restrictions, possibly locally adjusted, if the health care system is overwhelmed. If some relief occurs, these measures are relaxed again.
Consequences: Weekly incidence continues to rise until the additional measures take effect, but can eventually be stabilized and possibly reduced. The incidence is typically a few hundred infected persons per 100,000. There is some booster and vaccination progress, and about 1% natural immunization per week. If the boosting and vaccinating is brisk, it may be sufficient after a few weeks to relax measures somewhat (regionally). Hospitals are clearly and long-term burdened and bottlenecks may occur locally. The exact development depends heavily on the implementation of the measures. If the premise is to significantly tighten measures only at the limit of the health care system, then regulation is difficult because there is no room for maneuver.
In short: Vaccination or booster progress, in particular, determines the necessary measures. Until immunization is sufficiently high, boosted measures and testing strategies can stabilize incidence. However, the burden on the health care system is considerable and will remain high for some time due to the large number of unprotected persons, the long hospitalization times of younger patients in particular, and the slow decline in incidence.

Scenario: "Vaccination and booster offensive”
Basis: As the effect of the vaccination against a severe course and against infection decreases with time, especially vulnerable persons who were vaccinated early are currently no longer so well protected. A booster vaccination increases protection against severe course and contagion by another factor of about 10. This is considerable. In Israel, about 50% of people have been boostered. That was enough to break the wave there. In Germany, a similar effect could probably be achieved. So the faster you boost, the sooner the wave can be broken. The current vaccination speed is far from sufficient for this. If it were possible to boost around 7% of the population per week, 50% of people would be much better protected before Christmas. As long as there are not enough vaccination opportunities, the STIKO recommends clear prioritization. To accelerate vaccination, very low-threshold vaccination offers, mobile vaccination teams, vaccination at company doctors, and possibly vaccination offers in stores or pharmacies, accompanied by clear communication also via local influencers, would help. To reach 50% quickly, the six-month limit on boosters would need to be interpreted less strictly. In parallel to boosting, the population that has not yet been vaccinated can also be reached at a low threshold.

[6] 2G=”geimpft oder genesen”=”vaccinated or recovered” means that access to events or locations requires immunity against COVID-19 from vaccination or past infection. 3G=”geimpft, genesen, oder getestet”=”vaccinated, recovered, or tested” extends the access to people who have recently been tested negative for COVID-19.

Impact: Boosting 50% of the population can make a significant contribution to breaking the wave in all probability. The effect will be seen successively in the incidence and also the admissions to the intensive care units. Immune protection will then be high enough to get through the winter with basic measures.
In short: Boosting is a very effective measure to break the current wave.

Notes

In the scenarios, vaccinating and boosting in particular show a lasting effect. Other measures serve to bridge the gap. It should be noted here:

- The known hygiene measures achieve a good effect when done correctly, but do not appear sufficient on their own at this time.
- 2G and 3G restrictions alone will not be enough if they are not supported by other measures. The reasons include private visits and household contacts, which are not covered by 2G/3G. In Austria, it is being discussed to largely prevent private visits for unvaccinated persons above a certain incidence; in simulations, this shows very good effects. We cannot judge whether this is politically expedient and/or enforceable by the state.
- Regular massive testing would have to be on the order of one test per person per week and would have to include contact tracing and quarantine to significantly reduce spread. However, this is so logistically complex and costly that implementation does not seem realistic. Targeted use in suspected cases, before meetings with vulnerable individuals, in large groups, or in groups with high transmission (students without vaccine protection) can protect these individuals.
- If there is a need to reduce an acute overwhelming of the health care system, an "emergency circuit breaker" may be necessary and helpful (see below). It is important to plan it early and implement it as strongly as possible so that the payoff is disproportionately high. In principle, it can also be applied to preemptively reduce the burden on the health care system. A half-hearted emergency circuit breaker misses its mark.

Pandemic toolkit for the coming winter

The most effective tool we have against the virus is vaccination. The more people who get vaccinated or booster vaccinated, the less the virus will spread and the less the intensive care units will be burdened. Thus, fewer other measures and restrictions would be needed. However, if the vaccination gap is large, measures are inevitable to avoid overwhelming the healthcare system. We therefore explain below an overview of measures and make their mechanisms and effectiveness understandable. Most of the measures are well known, and we do not claim to be exhaustive.
We emphasize that these mechanisms and their effectiveness depend heavily on how well they are (or can be) implemented. Whether a particular mandatory measure is justified must ultimately be determined in a democratic balancing of interests. All measures that restrict or prohibit are simultaneously protective of others and give those individuals the freedom to protect themselves and the health care system.

Vaccinating and boosting

Vaccinating and boosting is a very powerful tool for preventing severe courses. Three groups are particularly important for booster vaccination:

1. Individuals with immune deficiencies. In these individuals, vaccination has sometimes not triggered immunity, so protection must be built up in the first place through a timely booster vaccination.
2. Elderly people, or people with certain risk factors. According to findings from Israel,[7] the biological age, not strictly the calendar age, is decisive for the risk of becoming seriously ill from a breakthrough infection. That is, people with certain pre-existing conditions can in some cases become severely ill with COVID-19 even despite having received two vaccinations. Since this same vulnerable group was also the first to be vaccinated in the spring 2021 vaccination campaign, booster vaccination is particularly helpful for them in the current situation.
3. Health care workers and caregivers. Booster vaccination in this group can significantly reduce the spread of the virus and thus transmission to those for whom there is a duty of care, and thus is important for protecting vulnerable individuals.

A large study from Israel[8] compared individuals with and without the third dose vaccination, and showed that the number of hospitalizations is reduced by a factor of just over 10 again after the third vaccination (92% effect) - in principle in each group. The total number of hospitalizations avoided is particularly high in the elderly and in people with multiple risk factors[9]: people with risk factors have well over a tenfold greater risk of needing hospitalization compared to those without; as the number of risk factors increases, this risk increases significantly. This clearly shows that boosting the elderly part of the population as well as people with risk factors can make a very strong contribution to relieving the burden on hospitals. In Germany, however, the effect could be somewhat smaller than in Israel, because in Germany the interval between the first and second vaccination is longer. Nevertheless, a very strong effect can be assumed.

Booster vaccination is a very powerful tool for pandemic containment. Booster vaccination not only restores the protection that was present shortly after the second vaccination, but significantly surpasses it. Therefore, individuals are better protected after booster vaccination and are likely to be protected longer. Protection against infection and transmission of the virus is also better by a factor of 10 in the booster vaccination group than in the twice-vaccinated group. Israel, with a booster of 50% of the population, very quickly and significantly pushed back the wave there in August. So a consistent booster campaign can very likely slow down a wave in Germany as well, if enough people are reached quickly. However, last summer we vaccinated a maximum of 1% of the population per day (Oct/Nov 2021: 0.2% per day). So it would take at least 7 weeks to reach 50%. It will take correspondingly longer for hospitals to be relieved. In order to maximize the impact of the boosters, it is very important to first refresh the vulnerable groups mentioned above and to return to a high immunization coverage rate overall.

Global solidarity. Despite the high benefits of booster vaccinations, it remains especially important to provide good access to vaccine doses to countries that do not yet have high

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[7] Barda et al, The Lancet 2021, https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)02249-2/fulltext

[8] Barda et al, The Lancet 2021, https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)02249-2/fulltext

[9] These include pre-existing conditions such as asthma and cancer, as well as factors such as pregnancy and obesity.

vaccination coverage. The World Health Organization's COVAX program is available for solidarity-based purchase of additional vaccine doses. But even beyond that, there is much to be done to bring about a more equitable global distribution of vaccines and other resources.[10]

Higher vaccination rates can be achieved through low-threshold vaccination offers and good communication. In addition to booster vaccination, it should not be forgotten that increasing the vaccination rate among those who have not yet been vaccinated is of great importance - especially among the older half of the population. It is becoming clear that further growth in vaccination rates is now very slow. At the current vaccination rate, it is questionable whether it can even compensate for the decline in protection against infection that occurs with the interval between vaccinations. Contributing to the current low vaccination rate have been differences in vaccination readiness among the population as well as aspects of vaccination campaign implementation. A core aspect is to ensure easy and low-threshold access to vaccination also in the long term, together with a convincing information strategy that takes into account the diversity of the population. Increased discussions with the general practitioner can clarify open questions. Mobile vaccination teams, multilingual information in various information channels and cooperation with local institutions and influencers, such as religious communities, sports clubs and primary care, are an essential part of this strategy. Clear communication is essential and trust in government and science helpful.

In the long term, universal mandatory vaccination is not necessarily effective. Given concerns about overwhelmed hospitals, it is understandable that calls for mandatory vaccination are growing louder. For a general vaccination requirement to be effective, few exceptions must be allowed, severe penalties must be imposed, and enforcement must work across the board. If this is not the case, then in the current polarized situation, there is a risk that a general vaccination requirement will deter hesitant people, and will not reach convinced vaccination opponents - because they would then rather pay the fine than be vaccinated. It is therefore unclear what effect a general vaccination obligation would have. A duty to vaccinate those who care for vulnerable groups must be viewed in a different light.

Mandatory vaccination in the workplace. What already exists today in certain institutions is the rule that only vaccinated or recovered persons are allowed to work there. This is the case, for example, in occupations that require close physical proximity to other people. This is especially true when it comes to vulnerable groups, such as in the healthcare and nursing sectors. This requirement is not to be equated with an obligation to vaccinate. Even if employers are allowed to terminate employees who do not want to be vaccinated (and cannot be employed elsewhere), they are not allowed to require them to be vaccinated. This is a small but important distinction. This poses significant challenges for workplace cohesion and community cohesion.

[10] Kienzler and Prainsack, Stiftung Entwicklung und Frieden 2021, https://www.sef-bonn.org/fileadmin/SEF-Dateiliste/04_Publikationen/GG-Spotlight/2021/ggs_2021-02_de.pdf

Testing

PCR testing. PCR testing remains the most sensitive and specific test for SARS-CoV-2. For example, a PCR test should be performed if the patient is symptomatic, regardless of previous vaccination or infection, or if the patient has had contact with a confirmed COVID-19 case. Because of its high sensitivity, PCR testing can identify infections as a preventive measure prior to encounters. How effective the use of testing is in prevention depends on implementation. For PCR testing no more than 24 hours old, it can be expected to detect roughly 90% of infectious individuals in practice (depending on the time since sample collection). Rapid antigen tests are somewhat less sensitive. They detect about 50-75% of individuals detected by a PCR test, and among them especially those with high viral loads. In particular, self-administered rapid tests have the advantage of costing little and being more readily available.

Rapid antigen tests are useful but do not provide complete certainty. Rapid antigen tests cannot reliably detect all infections. In particular, at the beginning of an infection, if the test is performed incorrectly, or if the infection is asymptomatic, the risk increases that a person will get a negative test result when in fact there is an infection (false negative). The user should therefore never be lulled into a false sense of security. Nevertheless, rapid tests, when used correctly, can detect on average about half of the infected individuals[11] that a PCR test would also detect. For highly infectious and newly symptomatic individuals, the detection rate by rapid tests is probably even higher. Rapid tests are therefore suitable as a low-threshold safety measure to detect infections, especially in suspected cases.
If, in theory, every person were to take about one rapid test per week in the current situation, the pandemic could be contained. This is also shown by the example of Slovakia, where mass testing has achieved a prevalence reduction of 80%.[12] In addition, it would of course be necessary that a potentially positive result is promptly verified by PCR testing and that contact tracing, isolation and quarantine are carried out quickly and reliably. However, contact tracing is not feasible by the public health service at high incidence. And a false negative result risks neglecting necessary hygiene measures such as wearing a mask. Also, about half of the population seems to rarely or never test. One of the reasons is socioeconomic consequences: Those who fear severe disadvantages at work or in their private lives have an incentive not to get tested. To increase the willingness to test, socioeconomic risks must be reduced, for example, through consistent employee protection or financial compensation.

Costs and benefits of a testing strategy. The cost-benefit ratio of testing depends on the cost of a test and the number of cases detected per test used. With a weekly incidence of about 100 per 100,000, a maximum of one in 1,000 tests is expected to be true-positive. These values are in line with empirical evidence.[13] If the cost per test is used, the cost for each positive case detected can be calculated. The advantage of testing in schools and workplaces is that you reach large parts of the population. Of the positive rapid tests in

[11] Osterman et al, Medical Microbiology and Immunology 2021, https://www.springermedizin.de/covid-19/diagnostik-in-der-infektiologie/evaluation-of-two-rapid-antigen-tests-to-detect-sars-cov-2-in-a-/18773354
[12] Pavelka et al, Science 2021, https://www.science.org/doi/full/10.1126/science.abf9648
[13] Frankfurter Allgemeine Zeitung from the 02/11/2021, https://zeitung.faz.net/faz/rhein-main/2021-11-02/wenige-positive-tests-an-schulen/683549.html?GEPC=s3

schools, just over 60% were confirmed by PCR testing.[14] Overall, this indicates that testing strategies in schools and workplaces can be helpful for transitional phases, especially when incidence is high. Here, well-conducted self-tests also help thanks to their good availability.

The impact of non-pharmaceutical interventions

2G and 3G events: The goal of 2G and 3G is to reduce the risk of infection at face-to-face meetings and gatherings. There are three effects to distinguish here.

- Both approaches, 2G and 3G, have the advantage of reducing the number of infected people coming to an event. The incidence[15] at the event is thus reduced. In vaccinated persons, incidence is currently (Oct/Nov 2021) about 4 times lower than in unvaccinated persons; this reduces incidence at a 2G or 3G event (depending on vaccination rate). A rapid test can detect ½ to ¾ of infectious individuals. Thus, if testing is done well (test finds ¾ of infectious persons), there is not much difference between 2G and 3G in terms of infectious persons.
- 2G has the advantage over 3G that if an infectious person participates, fewer people will be infected, since vaccinated or recovered participants are 3-10 times less likely to become infected. However, the effect of 3G compared to 2G is not a factor of 3-10, but depends on the proportion of unprotected people at the event. If we assume that ⅓ of the people are unprotected, then the expected number of infections is reduced by about a factor of two with 2G compared to 3G. However, here too, it is mainly unprotected persons who become infected and who then also have less protection against a severe course.[16]
- Less severe courses: Among infected persons, a vaccinated person has a significantly lower probability of having a severe COVID-19 course than an unprotected person. Thus, 2G further reduces the number of persons who have a severe course. The exact effect size is not easy to estimate. This is because the groups of vaccinated and unvaccinated people naturally meet outside events - and the virus can be transmitted to the unprotected people there.

Three aspects also need to be considered: (1) Whether 2G or 3G, for measures to work, they must be implemented consistently. (2) If persons who are neither vaccinated nor recovered are excluded from 2G events, then these unprotected persons may meet in a different context and have an increased risk of infection there. (3) Furthermore, it matters in how many areas of life 2G, 3G, or just no restrictions apply to estimate the overall impact. 3G in the workplace would have the advantage of regularly testing unprotected individuals from a wide range of population groups.
If masks are not used at a 2G event *or* if events are larger, the advantage of 2G over 3G in terms of transmission of infection may be offset.

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[14] Frankfurter Allgemeine Zeitung from the 02/11/2021, https://zeitung.faz.net/faz/rhein-main/2021-11-02/wenige-positive-tests-an-schulen/683549.html?GEPC=s3

[15] Explicitly: the probability that a vaccinated person will test positive

[16] Assumption: ⅔ of individuals are recovered or vaccinated. For the calculation, we assume that the incidence is the same for recovered/vaccinated versus unprotected+test.
Then the following reduction in the expected number of infections is expected for 2G versus 3G:
Assumption factor 3 reduction: ⅔ * ⅓ + ⅓ =5/9 = 0.55 → slightly half as many infections for 2G instead of 3G.
Assumption factor 4 reduction: ⅔ * 1/4 + ⅓ =3/6 = 0.5 → half as many infections with 2G versus 3G.
Assumption factor 10 reduction: ⅔*1/10 + ⅓ =12/30 = 0.4 → slightly half as many infections with 2G instead of 3G.

2G or 3G with mandatory testing for all participants. In addition to 2G or 3G, a test can in principle also be required of vaccinated and recovered participants. This further reduces the likelihood of an outbreak compared to 2G or 3G alone, as even fewer infectious people attend an event. For 2G, the reduction factor is the same as the effectiveness of the selected test for vaccinated individuals (see section on testing). In the case of testing all (3G+test), an effective impact factor is somewhat lower compared to 3G, since only the vaccinated and recovered persons are additionally tested, and here the probability of a positive test result is lower. However, the cost and effort of testing must be considered, as well as the effect on vaccination readiness.

Event size is important. For events with little mixing (such as fixed seating or very good ventilation), the number of infected people increases linearly with event size. For heavy mixing, the number of infected people increases on average quadratically with the number of guests. Heavy mixing means that everyone is in contact with each other or that infection can spread evenly to everyone via aerosols and poor ventilation. Thus, doubling the size of the event can result in a fourfold increase in expected infections.[17]

Indoor spaces with high densities of people. High probabilities of infection exist primarily in indoor spaces with high densities of people. And this applies not only to indoor restaurants or clubs, for example, but also to receiving guests in private homes, as well as to meetings and gatherings at work. Less problematic are large halls, where people are distributed over the available space and ventilation is good. It is important that such potential infection contexts be mitigated as much as possible. The measures to do this are well known: Reduce people densities, ventilate well, test beforehand, and wear masks.
In simulations[18], we find that self-testing before 40% of all encounters (followed, of course, by self-isolation if the test is positive) would at least stabilize the current infection dynamics if everyone, including the vaccinated, participated in the process. For example, all employers could actively distribute self-tests in sufficient numbers on a weekly basis; some employers already do this on their own initiative. Relying only on vaccination (without boosters) for high densities of people indoors, however, is unfortunately not enough for this winter.

Schools, childcare and educational institutions. All prevention and containment measures help avoid childcare and school closures. To adequately reduce the spread of the virus even in open schools, good ventilation, targeted use of air purifiers, incidence-based mandatory masking in all types of schools during class time, hygiene measures, testing, and cohorting are effective. Among tests, PCR tests are more sensitive in practice, detecting about twice as many infected children. Pool testing in the form of the lollipop method is helpful in enabling PCR testing across the board. It can also be shown that regular testing at schools and subsequent quarantine of infected students and their families greatly helps to control the spread of the pandemic not only at schools but throughout the population.

Emergency circuit breaker: Bundled measures are much more effective in reducing the number of cases quickly and significantly.

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[17] This is because two probabilities or rates are doubled, (1) the probability of an infectious person attending the event is doubled, and (2) a doubling of the people who (could) become infected at the event. This is true when there is a high degree of mixing, i.e., when everyone has direct contact with each other and/or the aerosols spread throughout the room in such a way that everyone is reached.
[18] Müller et al, MODUS-COVID Bericht from the 22/10/2021, https://doi.org/10.14279/depositonce-12510

If, despite vaccination, a significant restriction of contacts becomes necessary to relieve the burden on the health care system, then a short, intensive "emergency circuit breaker" is very effective. The better one bundles all measures, the shorter it can be and the less collateral damage it will cause. If you achieve an R-value of 0.7 in this way, the number of cases is halved every week. Thus, within just two weeks, the incidence can be reduced by a factor of 4. In the weeks to come, this reduces the workload in the intensive care units. However, if the R-value reaches only 0.9, then the same reduction takes almost 2 months. Thus, if such an intervention were to become necessary, a bundling of all measures would be infinitely more effective than one measure alone. This includes (i) home office and close-meshed testing at work, (ii) reduction of group size in kindergartens, schools and at work alike, (iii) closure/reduction of stores, restaurants, services and events, and in general (iv) significant reduction of contacts at work, in public and in private.

For maximum effectiveness, these measures would have to be concerted and carried out simultaneously. Effectiveness can be enhanced by testing (self-administered tests, workplace tests, etc., depending on the area). Such a concerted intervention could significantly save time and temporarily relieve the burden on health care. Further, the psychological and economic burden of such a brief emergency lockdown appears much less than that of lighter but disproportionately longer restrictions. The lockdown-light in the winter of 2020/2021, unlike an emergency circuit breaker, was neither effective nor purposeful.

Because of the high negative health and educational consequences for children and adolescents, as well as the increased burdens on parents (and especially mothers), school closures should be considered only as an ultima ratio in this context, unless they were necessary to relieve the burden on the pediatric health care system.

It is unclear whether an emergency circuit breaker will be necessary. But it would still be helpful to develop a clear plan now, announce it early, and preemptively mitigate potential collateral damage. It is therefore also important to have such measures constitutionally and ethically reviewed in advance, and to have a clear communication strategy. If intervention becomes necessary, then it should not be limited to closing schools and care facilities, as the burden is heavy, and as it is much less effective on its own than together with the measures listed above. A short but intense "emergency shutdown" of contacts in all areas for a short period of time (two weeks) is much more effective and relieves the system of much longer than two weeks due to the severe reduction.

Masks play an essential role in reducing contagion. First, masks protect other people: Foreign protection is extremely high because the large droplets remain in the mask and the small aerosols are greatly reduced. In addition, the masks break the exhalation jet and diffusively disperse the aerosols in the room. Therefore, it is unlikely to directly inhale the exhaled air of a person wearing a mask. It is quite different if the person is not wearing a mask. With the Delta variant, the risk of infection in the breathing jet of an infected person is very high; one can become infected after only a few minutes when breathing in the breathing jet. Masks also result in significant self-protection. Person-to-person transmission in close proximity when both are wearing an FFP2 mask is massively reduced compared to a situation without a mask (at least a factor of 10; if the mask fits very well, infection becomes extremely unlikely).

Infectious aerosols can accumulate in the volume of a room. Ventilation or air filtration reduces the risk of infection by a factor of 4. If you wear a mask, you protect yourself by a factor of 10-100. To illustrate: If you assume that the probability of infection is 100% without ventilation and masks, then the probability is reduced to about 25% with ventilation. If you wear a mask, the probability is very low.

Health system

As explained above, it is a very likely scenario that hospitals and especially intensive care units will again reach their capacity limits this winter. In order to deal with such a situation as best as possible, certain preparations should be made in advance. After all, when resources are in short supply, they must be used as fairly and efficiently as possible.

Advanced Care Planning (ACP) implemented across the board relieves the burden on the healthcare system as well as on patients and their relatives. ACP is intended to enable people to consider their future medical care and to plan it in such a way that it meets their own expectations, wishes and values (e.g. by means of a living will). Ideas about care in the last phase of life vary widely; while some people want invasive treatment "until the last breath", others reject certain measures, such as intensive care.
From the patient's perspective, it is therefore advisable in any case, even during a pandemic, to state clearly whether admission to an intensive care unit or invasive ventilation is desired at all. This seems all the more urgent the more foreseeable it becomes that bottlenecks in care may arise. In such a situation, the quality of care is likely to suffer, and decisions may no longer be patient-centered, but must take into account supra-individual decision-making criteria in an emergency.[19]

The end of the pandemic

Should we continue to expect even more contagious virus variants?
The Delta variant of SARS-CoV-2 is a very highly optimized variant of the virus that combines several mutations in such a way that it has become very contagious. It can also escape vaccination protection better than the original variant because of its ability to spread more rapidly in the body. The question is whether the virus can continue to change, causing us new problems.
A virus must always keep its genome stable enough to maintain all the functions it needs to replicate; i.e., the possibility of variations is limited. The fact that SARS-CoV-2 variants carrying similar changes always prevail clearly shows that the variation ability of the virus is limited, and it is not possible to endlessly evolve new variants.
A new viral variant will only prevail if it has an advantage, i.e., either spreads faster or is better able to evade the immune response. Being more severely ill is not per se an advantage for a virus, but rather a disadvantage. This is because those who are more severely ill are less mobile and thus less likely to infect others. However, it is very possible that variants will evolve in the future that better evade an immune response.

Do we need a booster vaccination every year?

[19] Deutsche Interdisziplinäre Vereinigung für Intensiv- und Notfallmedizin, S1-Leitlinie from the 17/04/2020, https://www.awmf.org/uploads/tx_szleitlinien/040-013l_S1_Zuteilung-intensivmedizinscher-Ressourcen-COVID-19-Pandemie-Klinisch-ethische_Empfehlungen_2020-07_2-verlaengert2.pdf

We cannot yet predict whether all people or certain groups of people will need regular booster vaccination in the future. For that, we need data on repeated infections. This data is not available at the moment, but it is expected that we will have more knowledge on this after this winter.

When will the pandemic be over?
This is not a trivial question. One must distinguish at least three dimensions here: (1) a medical/virological/epidemiological dimension, (2) a mental and habitual dimension, and (3) a political/legal dimension. The first dimension speaks clearly: the pandemic is not over. It appears that the pandemic situation will eventually disappear, but the existence of the virus will not end and COVID-19 will evolve into one among other infectious diseases. There will then continue to be a need for a dense monitoring network, a series of follow-up vaccinations, and corresponding research. This points to the second dimension. Currently, there is a decreasing attention in everyday actions towards the virus. Relaxation of behavioral standards and greater resistance to the disease almost automatically leads to habitualization of more carefree behavior, which is understandable and also desirable. At the same time, this situation makes it more difficult to maintain or even reinforce measures. It is against this inertia of social routines that monitoring of the crisis must now prevail. The wish that the pandemic is largely over is, thus, contrasted with the need to keep attention at a high level. In the third dimension, this inevitably leads to conflicting goals and inconsistent communication. People seem to be tired of being confronted with further action, which at the same time increases the need for action. This circle points to the fact that the pandemic is not over yet.
In terms of the future, it must be expected that the pandemic will have come to an end when the measures against the pandemic (introduction of local or area-specific protective measures, continued vaccinations) have become so routinized that they pass below the attention threshold. Routines serve to make decisions as semantically invisible as possible.
Incidentally, this also applies to increasing vaccination readiness, in which simple access is likely to play at least as large a role as information campaigns and professionalized communication strategies, such as we know from the beginning of AIDS education, for example.
It is currently impossible to predict when a complete end to non-voluntary measures will be conceivable. To even discuss this into the winter is completely unrealistic, but it must be the goal for the time after winter. How much this will depend on a successful increase in vaccination preparedness and the logistical planning of further vaccination waves should have become clear.

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