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Adaptive strategies to contain the COVID 19 epidemic

Summary

Successful containment of the COVID 19 pandemic requires both an understanding of the dynamics of its spread and a well thought-out strategy. This paper has emerged from the scientific exchange on the basic properties of propagation dynamics between modeling groups at different institutions. This exchange was conducted by scientists using different modeling approaches. Despite the different methods, we have come to concordant results about the propagation dynamics and the consequences for a way out of the crisis. Because of this strong consensus, we have decided to present the current status here.

In our paper, we summarize our current knowledge about the dynamics of the spread and present various long-term scenarios for epidemic containment. While the dynamics of the epidemic are determined by the reproduction rate R, the scenarios clearly differ in the targeted number of new infections per day N. Consideration from the perspective of theoretical epidemiology favors an adaptive strategy: expansion of testing and tracing capacities together with adaptive management of contact restrictions. The aim of this adaptive strategy is to reduce the number of cases to such an extent that the remaining cases can be traced and controlled, thus allowing us to return to normal social life.

We would like to emphasize that our expertise and perspectives are those of theoretical epidemiology, i.e. our estimates are based on models that use data from the past to make predictions about the development of the epidemic in the future under certain assumptions, e.g. regarding the reproduction rate. All estimates primarily relate to the dynamics of the spread of the epidemic and the medium-term capacity of the health care system. We expressly cannot and do not wish to weigh up the costs and benefits. We hope that our summary will contribute to finding a viable strategy in an interdisciplinary exchange that is supported by society as a whole.

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2 Helmholtz Initiative "Systemic Epidemiological Analysis of the COVID 19 Epidemic": https://www.helmholtz.de/aktuell/coronavirus-sars-cov-2/statement of the helmholtz-initiative-systemic-epidemiological-analysis-of-covid-19-epidemia/

Longtext

Now that the first wave of COVID-19 infections is decreasing thanks to the clear precautions taken by everyone, a strategy for the coming weeks is being widely discussed. As scientists, we have exchanged views on the basic characteristics of SARS-CoV-2 propagation and have summarized the key features here. The various mathematical models and approaches of the individual teams were developed independently and differ from each other. Despite this diversity, they have produced very similar results. Therefore, we have decided to summarize the key results here. These can thus help society and politicians make decisions about COVID-19 containment strategies. We explicitly do not propose individual measures; according to the social discourse, this should be reserved for policymakers, even beyond the dynamics of propagation. If measures are addressed in the following, they should be understood as exemplary to illustrate the effect of a category of measures.

Basic parameters of the propagation dynamics: R and N

- **In the current phase of the pandemic, two epidemiological parameters play a key role in the containment of COVID-19:** the effective reproduction rate R and the number of new infections per day N. While N quantifies the level of new infections, R indicates the trend. The reproduction rate R thus determines how the number of new infections N will develop in the future. In return, R can be measured from the confirmed case numbers with a certain time lag.

- **A reproduction rate of R = 1 represents the important threshold between exponential growth and exponential decline of new infections N.** R quantifies how many people on average are infected by an infectious person. If R is close to 1, even small reductions in the probability of infection or contact behavior can contribute to a decrease in new infections instead of an increase. In contrast, every small increase in R above 1 triggers new exponential growth.

- **The number of confirmed new infections per day N is a very important indicator.** It allows predictions to be made as to how many people will need hospital treatment after a certain period of time, how many will die, and how many are potentially infectious.

- The estimated **number of unreported incidents** is the number of unobserved COVID-19 cases. If one knew the number of undetected cases, one could conclude from the observed number of infected people how many have already been infected with SARS-CoV-2 and possibly developed immunity. This estimated number of undetected cases determines how high the basic immunity in the population already is and how many infections might further spread undetected.

Consistent estimation of basic indicators

- **Since the end of March, the reproduction rate R in Germany has been below the important value of 1**, which we have arrived at on the basis of different approaches and models. In addition, our results are consistent with those of other research groups. Finding consistent results despite different approaches strengthens the evidence of the results for the reproduction rate R. Recent data suggest that R is approaching the value of 1 again, which according to the models may be an effect of the Easter holidays.

- **The clear decline in new infections N that we are currently observing is the combined effect of the policy measures gradually introduced in March and of individual precautions**: (1) the ban on large gatherings; (2) the restriction of public life along with the closure of educational institutions and many shops; (3) contact restrictions, which were implemented by a large part of the population even before the official ban on contact. Personal commitment and widespread acceptance among the population have contributed significantly to this result.

- **The effects of contact restriction measures cannot yet be assessed individually.** Some of the measures were introduced as a bundle or in quick succession. Moreover, their effects are time-delayed.
  Therefore, we must first carefully and cautiously observe how the individual measures or their relaxation influence the spread.

- **The value of R at a given time can only be estimated with reasonable certainty after a delay of 2 to 3 weeks.** There are several reasons for this delay, including: incubation time, time to testing, evaluation and publication of the test results, and the time needed to accumulate evidence from the observed data.

- **Because of this delay, the effects of the measures eased since 20 April will only become apparent in the reported case numbers N in the second week of May**. This considerable delay between change in measures (change in the likelihood of infection) and visible effect (change in reported cases N) must be taken into account when assessing the effectiveness of each set of measures.

- **Different classes of measures to control the spread can be distinguished:** (i) General contact restrictions ranging from "social distancing" to travel restrictions aim at reducing contact or mixing.
  (ii) Hygiene measures, masks etc. aim at reducing the probability of infection. (iii) Precautionary quarantine measures aim at a targeted interruption of infection chains. The combined effect of these measures influences the reproduction rate R and thus the spread of SARS-CoV-2.

- **The exact number of unreported cases of infected individuals is not known.** Up to now, only indirect estimates in the order of 2 to 5 times the number of infected persons identified are available, but these estimates are subject to great uncertainty. In the future, clarity about the actual number of undetected cases can be achieved using urgently needed representative cross-sectional studies of the population. At present, even the cross-sectional studies are subject to uncertainties, as the antibody tests are still not specific enough.

- **There are regional differences not just in the number of people infected, but also in the reproduction rate and the number of unreported cases.** These are caused, for example, by structural differences between regions and by different age structures. For this reason, caution is required when generalizing regional studies. On the other hand, these differences can also mean that different local measures may be useful as part of an overall strategy to contain COVID-19.

Propagation scenarios from the perspective of epidemiological model

- **Complete eradication or rapid infestation do not appear to be feasible at present.** Complete eradication of the virus is possible in principle, but would require international coordination and immense efforts. Such a worldwide eradication cannot be achieved in the near future. Rapid infestation implies a massive overload on our health care system and a corresponding number of avoidable deaths. Therefore, neither of the two scenarios represents a viable option.

- **For a *controlled* infestation of the population, contact restriction measures would have to be maintained for a very long time.** The controlled infestation scenario is based on the assumption that a sufficiently large infestation of the population should be reached as quickly as the capacity of the health care system allows. Our models agree that, even with optimistic estimates of the number of unreported cases, this would take years and cause many deaths. In this scenario, severe restrictions would have to continue and be constantly corrected so that R remains at 1 and thus N permanently remains just below the health system's capacity limit. The delayed observation of N and R makes timely corrections to policy measures very difficult, so the risk of an unforeseen overburdening of the health care system would be permanent. The long duration and difficult management make this scenario unrealistic.

- **The long-term effects of the COVID-19 disease on health are still unknown.** There are indications that not only the lungs, but also many other organs (e.g. heart, kidney, gastrointestinal tract, brain) can be affected by microcirculation disorders. The coming months and years will provide more clarity in this regard. This will require longitudinal studies that repeatedly examine the affected persons with regard to possible late effects. If these indications are confirmed, we would also advise against a further infestation of the population.

- **How long people are immune after surviving an infection is unknown.** The strategy of controlled infestation is based on the assumption that the infected persons are immune for many years. If there is no long-term immunity, this strategy will not achieve its goal. Longitudinal studies are also necessary to assess the development of the immune status over time.

- **From an epidemiological point of view, consistent containment of SARS-CoV-2 is currently the only sensible strategy.** Since neither the eradication of the virus nor a fast or slow infestation of the population are viable options, it is recommended that the spread of SARS-CoV-2 continues to be contained. It is possible that the number of new infections N will be reduced within weeks to such an extent that extensive contact restrictions can be replaced by efficient contact tracing. The more consistently measures are implemented, the smaller R becomes and the faster this can be achieved. Against this background, the development of an adaptive strategy to contain SARS-CoV-2 appears to be a sensible and efficient way back to a largely normal life.

- **New medical knowledge and pharmaceutical developments are of crucial importance for the long-term management of the SARS-CoV-2 pandemic.** The strategy proposed here needs to be adapted as soon as new knowledge makes this possible or a vaccine becomes available.

Outline of an adaptive containment strategy

We know that every contact restriction is an immense burden on everyone. Thanks to the discipline of the people over the past weeks, the number of cases has steadily decreased. This gives us a promising chance to contain the epidemic and return to as normal a life as possible. We therefore propose an adaptive containment strategy. In a first phase, contact restrictions are continued – insofar as is tolerable – and at the same time testing and tracing capacities are further expanded.

This phase will move to a second phase when new infections are reduced to a level that allows effective contact tracing. By interrupting chains of infection, contact tracing can gradually replace the contact restrictions and only be adaptively accompanied by them. The models include three pillars of structural measures that can ensure containment:

1. **hygiene measures**, such as wearing masks in shops and public places, or disinfection stations to reduce infections by unidentified carriers
2. **testing and tracing capacities** to detect local sources of infection at an early stage, isolate cases, track close contacts of infected persons, quarantine them as a precautionary measure, and thus interrupt chains of infection
3. **adaptive control of accompanying contact restriction measures** to prevent a renewed increase in new infections

Details on possible implementation of the three pillars:

- **Adaptive dosage of the contact restriction measures.** The aim is to reduce the number of new infections N and keep R below 1 at all times. In principle, the lower the reproduction rate R, the faster the number of new infections decreases. This would require close observation of the indicators and adaptive adjustment of the accompanying contact restriction measures, which may also differ locally. The target value for N is given by the possibility of local control of infection foci and is thus determined in particular by the quality of tracing methods and the effectiveness of isolation measures. How this target value might be achieved requires ongoing social discourse.

- **A sufficiently small number of new infections would facilitate a relaxation of measures.** If the number of new infections is small enough that the cases can be controlled by testing and tracing, we expect that it will be possible to relax contact restriction measures in the long term.

- **Expansion of testing and tracing capacities.** The aim is to be able to control the largest possible number of new infections. The capacity for contact tracing could be increased through structural measures. Possible measures include additional staff at the health authorities, the introduction of voluntary apps for contact tracing, and precautionary quarantining of contact persons of infected persons. In the models, effective contact tracing has an effect on the reproduction rate R.

- **Establishment of an early warning infrastructure based on targeted cross-sectional tests.** Cross-sectional tests could be carried out in order to control the number of undetected infections outside of traced infection chains and to identify local foci of infection, especially in areas with an increased risk of infection. If this is to be done on a large scale, an expansion of the testing capacities would be necessary.