COVID-19 Pandemic Planning Scenarios
Pandemic Planning Scenarios

Updated Sept. 10, 2020

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Summary of Recent Changes

Updated September 10, 2020:

- The Infection Fatality Ratio parameter has been updated to include age-specific estimates
- The parameter for Number of Days from Symptom Onset to Seeking Outpatient Care—which was based on influenza care seeking data—has been replaced with the Median Number of Days from Symptom Onset to SARS-CoV-2 Test among SARS-CoV-2 Positive Patients
- A new parameter for the likelihood of an infection being reported has been added: The Ratio of Estimated Infections to Reported Case Counts

CDC and the Office of the Assistant Secretary for Preparedness and Response (ASPR) have developed five COVID-19 Pandemic Planning Scenarios that are designed to help inform decisions by public health officials who use mathematical modeling, and by mathematical modelers throughout the federal government. Models developed using the data provided in the planning scenario tables can help evaluate the potential effects of different community mitigation strategies (e.g., social distancing). The planning scenarios may also be useful to hospital administrators in assessing resource needs and can be used in conjunction with the COVID-19Surge Tool.

Each scenario is based on a set of numerical values for biological and epidemiological characteristics of COVID-19 illness, which is caused by the SARS-CoV-2 virus. These values—called *parameter values*—can be used in models to estimate the possible effects of COVID-19 in U.S. states and localities. This document was first posted on May 20, 2020, with the understanding that the parameter values in each scenario would be updated and augmented over time, as we learn more about the epidemiology of COVID-19. The September 10 update is based on data received by CDC through August 8, 2020.

In this update, age-specific estimates of Infection Fatality Ratios have been updated, one parameter measuring healthcare usage has been replaced with the median number of days from symptom onset to positive SARS-CoV-2 test, and a new parameter has been included: Ratio of Estimated Infections to Reported Case Counts, which is based on recent serological data from a commercial laboratory survey in the U.S.[1]

New data on COVID-19 are available daily, yet information about the biological aspects of SARS-CoV-2 and epidemiological characteristics of COVID-19 remain limited, and uncertainty remains around nearly all parameter values. For example, current estimates of infection-fatality ratios do not account for time-varying changes in hospital capacity (e.g., in bed capacity, ventilator capacity, or workforce capacity) or for differences in case ascertainment in congregate and community settings or in rates of underlying health conditions that may contribute to a higher frequency of severe illness in those settings. A nursing home, for example, may have a high incidence of infection (due to close contacts among many individuals) and severe disease (due to a high rate of underlying conditions) that does not reflect the frequency or severity of disease in the broader population of older adults. In addition, the practices for testing nursing home residents for SARS-CoV-2 upon identification of a positive resident may be different than testing practices for contacts of confirmed cases in the community. Observed parameter values may also change over time (e.g., the percentage of transmission occurring prior to symptom onset will be influenced by how quickly and effectively both symptomatic people and the contacts of known cases are quarantined).

The parameters in the scenarios:

- Are estimates intended to support public health preparedness and planning.
- Are **not** predictions of the expected effects of COVID-19.
- Do not reflect the impact of any behavioral changes, social distancing, or other interventions.

The five COVID-19 Pandemic Planning Scenarios (Box 1) represent a range of possible parameters for COVID-19 in the United States. All parameter values are based on current COVID-19 surveillance data and scientific knowledge.

- Scenarios 1 through 4 are based on parameter values that represent the lower and upper bounds of disease severity and viral transmissibility (moderate to very high severity and transmissibility). The parameter values used in these scenarios are likely to change as we obtain additional data about the upper and lower bounds of disease severity and the transmissibility of SARS-CoV-2, the virus that causes COVID-19.
- Scenario 5 represents a current best estimate about viral transmission and disease severity in the United States, with the same caveat: the parameter values will change as more data become available.

Parameter values that vary among the Pandemic Planning Scenarios are listed in Table 1, while parameter values common to all five scenarios are listed in Table 2. Definitions of the parameters are provided below, and the source of each parameter value is indicated in the Tables.

Parameter values that vary across the five COVID-19 Pandemic Planning Scenarios (Table 1) include measures of viral transmissibility, disease severity, and pre-symptomatic and asymptomatic disease transmission. Age-stratified estimates are provided, where sufficient data are available.

Viral Transmissibility

- **Basic reproduction number (R_0):** The average number of people that one person with SARS-CoV-2 is likely to infect in a population without any immunity (from previous infection) or any interventions. R_0 is an estimate of how transmissible a pathogen is in a population. R_0 estimates vary across populations and are a function of the duration of contagiousness, the likelihood of infection per contact between a susceptible person and an infectious person, and the contact rate.[2]

Disease Severity

- **Infection Fatality Ratio (IFR):** The number of individuals who **die** of the disease among all infected individuals (symptomatic and asymptomatic). This parameter is not necessarily equivalent to the number of reported deaths per reported case because many cases and deaths are never confirmed to be COVID-19, and there is a lag in time between when people are infected and when they die. This parameter also reflects the existing standard of care, which may vary by location and may be affected by the introduction of new therapeutics.

Pre-symptomatic and Asymptomatic Contribution to Disease Transmission

A **pre-symptomatic case** of COVID-19 is an individual infected with SARS-CoV-2, who has not exhibited symptoms at the time of testing, but who later exhibits symptoms during the course of the infection. An **asymptomatic case** is an individual infected with SARS-CoV-2, who does not exhibit symptoms during the course of infection. Parameter values that measure the pre-symptomatic and asymptomatic contribution to disease transmission include:

- **Percentage of infections that are asymptomatic:** The percentage of persons who are infected with SARS-CoV-2 but never show symptoms of disease. Asymptomatic cases are challenging to identify because individuals do not know they are infected unless they are tested over the course of their infection, which is typically only done systematically as a part of a scientific study.
- **Infectiousness of asymptomatic individuals relative to symptomatic individuals:** The contribution to transmission of SARS-CoV-2 from asymptomatic individuals compared to the contribution to transmission of SARS-CoV-2 from symptomatic individuals. For example, a parameter value of 50% means that an asymptomatic individual is half as infectious as a symptomatic individual, whereas a parameter value of 100% means that an asymptomatic individual is just as likely to transmit infection as a symptomatic individual.
- **Percentage of transmission occurring prior to symptom onset:** Among symptomatic cases, the percentage of new cases of COVID-19 due to transmission from a person with COVID-19 who infects others before exhibiting symptoms (pre-symptomatic).

Parameter values that do not vary across the five Pandemic Planning Scenarios (Table 2) are:

- **Level of pre-existing immunity to COVID-19 in the community:** The percentage of the U.S. population that had existing immunity to COVID-19 prior to the start of the pandemic beginning in 2019.
- **Ratio of estimated infections to reported case counts:** The estimated number of infections divided by the number of reported cases. The level of case detection likely varies by the age distribution of cases, location, and over time.
- **Time from exposure to symptom onset:** The number of days from the time a person has contact with an infected person that results in COVID-19 infection and the first appearance of symptoms.
- **Time from symptom onset in an individual and symptom onset of a second person infected by that individual:** The number of days from the time a person becomes symptomatic and when the person who they infect becomes symptomatic.

Additional parameter values common to the five COVID-19 Pandemic Planning Scenarios are these ten measures of

Box 1 Description of the Five COVID-19 Pandemic Planning Scenarios

For each Pandemic Planning Scenario:

- Parameter value for **viral transmissibility** is the Basic Reproduction Number (R_0)
- Parameter value for **disease severity** is the Infection Fatality Ratio (IFR)
- Parameter values for the **pre-symptomatic and asymptomatic contribution** to disease transmission are:
  - Percentage of transmission occurring prior to symptom onset (from pre-symptomatic individuals)
  - Percentage of infections that are asymptomatic
  - Infectiousness of asymptomatic individuals relative to symptomatic individuals

For Pandemic Scenarios 1-4:

- These scenarios are based on parameter values that represent the lower and upper bounds of disease severity and viral transmissibility (moderate to very high severity and transmissibility). The parameter values used in these scenarios are likely to change as we obtain additional data about the upper and lower bounds of disease severity and viral transmissibility of COVID-19.

For Pandemic Scenario 5:

- This scenario represents a current best estimate about viral transmission and disease severity in the United States, with the same caveat: that the parameter values will change as more data become available.

Scenario 1:

- Lower-bound values for virus transmissibility and disease severity
- Lower percentage of transmission prior to onset of symptoms
- Lower percentage of infections that never have symptoms and lower contribution of those cases to transmission

Scenario 2:

- Lower-bound values for virus transmissibility and disease severity
- Higher percentage of transmission prior to onset of symptoms
- Higher percentage of infections that never have symptoms and higher contribution of those cases to transmission

Scenario 3:

- Upper-bound values for virus transmissibility and disease severity
- Lower percentage of transmission prior to onset of symptoms
- Lower percentage of infections that never have symptoms and lower contribution of those cases to transmission

Scenario 4:

- Upper-bound values for virus transmissibility and disease severity
- Higher percentage of transmission prior to onset of symptoms
- Higher percentage of infections that never have symptoms and higher contribution of those cases to transmission

Scenario 5:

Table 1. Parameter Values that vary among the five COVID-19 Pandemic Planning Scenarios. The scenarios are intended to advance public health preparedness and planning. They are **not** predictions or estimates of the expected impact of COVID-19. The parameter values in each scenario will be updated and augmented over time, as we learn more about the epidemiology of COVID-19. Additional parameter values might be added in the future (e.g., population density, household transmission, and/or race and ethnicity).

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5: Current Best Estimate
R_0*	2.0		4.0		2.5
Infection Fatality Ratio†	0-19 years: 0.00002 20-49 years: 0.00007 50-69 years: 0.0025 70+ years: 0.028		0-19 years: 0.0001 20-49 years: 0.0003 50-69 years: 0.010 70+ years: 0.093		0-19 years: 0.00003 20-49 years: 0.0002 50-69 years: 0.005 70+ years: 0.054
Percent of infections that are asymptomatic§	10%	70%	10%	70%	40%
Infectiousness of asymptomatic individuals relative to symptomatic¶	25%	100%	25%	100%	75%
Percentage of transmission occurring prior to symptom onset**	30%	70%	30%	70%	50%

*The best estimate representative of the point estimates of R_0 from the following sources:
Chinazzi M, Davis JT, Ajelli M, et al. The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. *Science*. 2020;368(6489):395-400; Imai N., Cori, A., Dorigatti, I., Baguelin, M., Donnelly, C. A., Riley, S., Ferguson, N.M. (2020). Report 3: Transmissibility of 2019-nCoV. *Online report*
Li Q, Guan X, Wu P, et al. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia. *N Engl J Med*. 2020;382(13):1199-1207
Munayco CV, Tariq A, Rothenberg R, et al. Early transmission dynamics of COVID-19 in a southern hemisphere setting: Lima-Peru: February 29th-March 30th, 2020 [published online ahead of print, 2020 May 12]. *Infect Dis Model*. 2020; 5:338-345
Salje H, Tran Kiem C, Lefrancq N, et al. Estimating the burden of SARS-CoV-2 in France [published online ahead of print, 2020 May 13] [published correction appears in Science. 2020 Jun 26;368(6498):]. *Science*. 2020;eabc3517.
The range of estimates for Scenarios 1-4 represent the upper and lower bound of the widest confidence interval estimates reported in: Li Q, Guan X, Wu P, et al. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia. *N Engl J Med*. 2020;382(13):1199-1207.
Substantial uncertainty remains around the R_0 estimate. Notably, Sanche S, Lin YT, Xu C, Romero-Severson E, Hengartner N, Ke R. High Contagiousness and Rapid Spread of Severe Acute Respiratory Syndrome Coronavirus 2. *Emerg Infect Dis*. 2020;26(7):1470-1477 (https://dx.doi.org/10.3201/eid2607.200282) estimated a median R_0 value of 5.7 in Wuhan, China. In an analysis of 8 Europe countries and the US, the same group estimated R_0 of between 4.0 and 7.1 in the pre-print manuscript: Ke R., Sanche S., Romero-Severson, & E., Hengartner, N. (2020). Fast spread of COVID-19 in Europe and the US suggests the necessity of early, strong and comprehensive interventions. *medRxiv.*

† These estimates are based on age-specific estimates of infection fatality ratios from Hauser, A., Counotte, M.J., Margossian, C.C., Konstantinoudis, G., Low, N., Althaus, C.L. and Riou, J., 2020. Estimation of SARS-CoV-2 mortality during the early stages of an epidemic: a modeling study in Hubei, China, and six regions in Europe. *PLoS medicine*, *17*(7), p.e1003189. Hauser et al. produced estimates of IFR for 10-year age bands from 0 to 80+ year old for 6 regions in Europe. Estimates exclude infection fatality ratios from Hubei, China, because we assumed infection and case ascertainment from the 6 European regions are more likely to reflect ascertainment in the U.S. To obtain the best estimate values, the point estimates of IFR by age were averaged to broader age groups for each of the 6 European regions using weights based on the age distribution of reported cases from COVID-19 Case Surveillance Public Use Data (https://data.cdc.gov

References

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2. Dietz K. The estimation of the basic reproduction number for infectious diseases. Stat Methods Med Res. 1993;2:23–41.

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