2023 Harvard/University of Global Health Equity
Mathematical Modeling for Infectious Disease Planning

COVID-19 Model with health outcomes- Part A

Time: 1 hour 40 minutes

At the end of this activity, you would:

i. Extend COVID-19 model to include health outcomes
ii. Understand how different outcomes impact model structure and equations

The natural history of COVID-19 can be described by an SLIAR (Susceptible (S)-Latent (L)-Infectious symptomatic (I) -Infectious asymptomatic (A)- Recovered (R)) model, with a mean latent period of 3 days (the duration of the latent period is $1/\alpha$) and a mean infectiousness period of 5 days (the duration of the infectiousness period is $1/\gamma$). The transmission rate is 0.5 (parameter β). People infected with COVID-19 may be either symptomatic or asymptomatic, with approximately 30% of infections estimated to be asymptomatic (parameter p). Asymptomatic and symptomatic individuals recover at the same rate. Asymptomatic individuals are approximately 50% as infectious as symptomatic individuals (parameter a).

1. Write down the **SLIAR compartments and equations** for the COVID-19 model, including the details above. (We encourage you to try and reproduce the answers again yourself, before referring to the answer key for the previous activity which had the same prompt).

2. Write down the SLIAR compartments and equations for COVID-19 with an additional compartment "D" to track the cumulative deaths from COVID-19 assuming a case fatality ratio of q. Assume that only infectious individuals can die from the disease.

3. How does the "D" compartment affect the number of individuals going into the recovered (R) compartment when they are no longer infectious?

4. Next, assume all individuals infected with COVID-19 become symptomatic (i.e., model without asymptomatic compartment). 20% of symptomatic individuals become hospitalized (H), and 80% move to the "R" compartment without being hospitalized. 10% of hospitalized patients die from COVID-19 and 90% recover. Let h represent the fraction of symptomatic individuals who become hospitalized and let r represent the fraction of hospitalized patients who recover. The mean hospitalization period is 3 days (the duration of the hospitalization period is $1/i$).

   i. Draw the flow diagram of the updated model.

ii. Write down the equations for the updated model.

2022-2023 Harvard/University of Global Health Equity
Mathematical Modeling for Infectious Disease Planning

COVID-19 Model with health outcomes- Part B

Time: I hour

Berkeley Madonna

1. This activity is a continuation of the COVID-19 Model with health outcomes activity. Use the provided **Covid_health_outcome** script to code in Berkeley Madonna and answer the following questions assuming a *q* (case fatality ratio) of 1.3%.

   a) Without looking at your code, make a list of all the parameters needed to simulate a) question 2 and b) question 4 from Part A.

Parameters needed to simulate model in question 2 from Part A (COVID-19 model with deaths and two infectious compartments)

Parameter	Description

Parameters needed to simulate model in question 4 (COVID-19 model with deaths and one infectious compartment)

Parameter	Description

   b) Simulate your model in **question 2 from Part A** and write down the number of deaths in the population after 365 days. Run the model in Berkeley Madonna using a

total population of 1,000,000. Start with 1 initial infected individual in each of the latent (L), infectious symptomatic (I), and infectious asymptomatic (A) compartments, and no individuals in the "R" and "D" compartments. Run the simulation for 365 days and a daily time step.

c) On what day(s) is there a peak in symptomatic and asymptomatic cases? Do these peak on different days?

d) Using your model in **question 2 from Part A,** what proportion of the population is symptomatic and asymptomatic at the peak?

e) Using your model in **question 4 from Part A**, how many hospitalized patients died from COVID-19 at the end of the simulation? [*Note: To simulate the model in question 4, use the same initial settings provided in b) and parameter values provided in the prompt. Set the number of initially hospitalized patients to zero*.]

f) BONUS: What interventions would you suggest to minimize the number of deaths among hospitalized individuals?