Supplementary Material*

Weissman GE, Crane-Droesch A, Chivers C, et al. Locally informed simulation to predict hospital capacity needs during the COVID-19 pandemic. Ann Intern Med. 2020. doi:10.7326/M20-1260

* This supplementary material was provided by the authors to give readers further details on their article. The material was reviewed but not copyedited.

Digital Appendix: Preparing for capacity strain using the COVID-19 Hospital Impact Model for Epidemics (CHIME): A locally informed epidemic simulation

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March 23, 2020

SIR Model Details

We constructed a traditional SIR model based on the framework proposed by Kermack and McKendrick (1). This approach assumes three states of patients, including those susceptible to disease (S), those infected with the virus (I), and those removed from developing the virus (R), due to acquired immunity or death. Our model does not distinguish between immunity or death once populations are considered removed. The changes in the relative size of these populations are given by the following system of differential equations:

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

Here β represents the rate of transmission of the virus and γ is the recovery rate (thus γ^{-1} is the duration of the infection during which transmission can occur). The total population (N) is assumed constant such that at any given time t,

$$S(t) + I(t) + R(t) = N.$$

The number of infections caused by each infected individual is determined by the number of susceptible invidivuals, the rate of transmission, and the time during which an individual is infectious, given by

$$R_0 = \frac{\beta S}{\gamma}$$

Although the dynamics of this SIR model may be reproduced using a closed-form analysis, we opted to use a discrete-time simulation to allow for future flexibility in modifiying population states and transitions.

Supplemental Tables and Figures

Table 1: Detailed model parameters, ranges, and distributions.

					Percentile				
Parameter	Base Case	Distribution	Location	Scale	2.5	25	50	75	97.5
Proportion of infections requiring hospitalization	0.025	gamma	6.33	0.004	0.01	0.019	0.025	0.032	0.051
Proportion of hospitalizations admitted to ICU	0.16	gamma	6.13	0.02	0.05	0.095	0.13	0.17	0.26
Proportion of ICU patients requiring ventilation	0.46	beta	5.22	3.08	0.3	0.52	0.64	0.75	0.9
Hospital Length of Stay	12	gamma	136.21	0.09	10	11	12	13	14
ICU Length of Stay	8	gamma	32.47	0.27	6	7.7	8.7	9.7	12
Proportion of ICU time on mechanical ventilation	0.75	beta	22.03	6.67	0.6	0.72	0.77	0.82	0.9
Days from infection to recovery	14	gamma	5.89	2.52	5.4	10	14	18	29

Table 2: Comparison of CHIME forecasts against other epidemic modeling tools.

Model	Time to peak number of infected cases (days)	Number of infected cases at peak	Online location
CHIME base case	63	166,268	https://github.com/pennsignals/chime_manuscript
Go Model (2)	62	125,498	http://gabgoh.github.io/COVID/index.html
Hill Model (3)	116	106,584	https://alhill.shinyapps.io/COVID19seir/

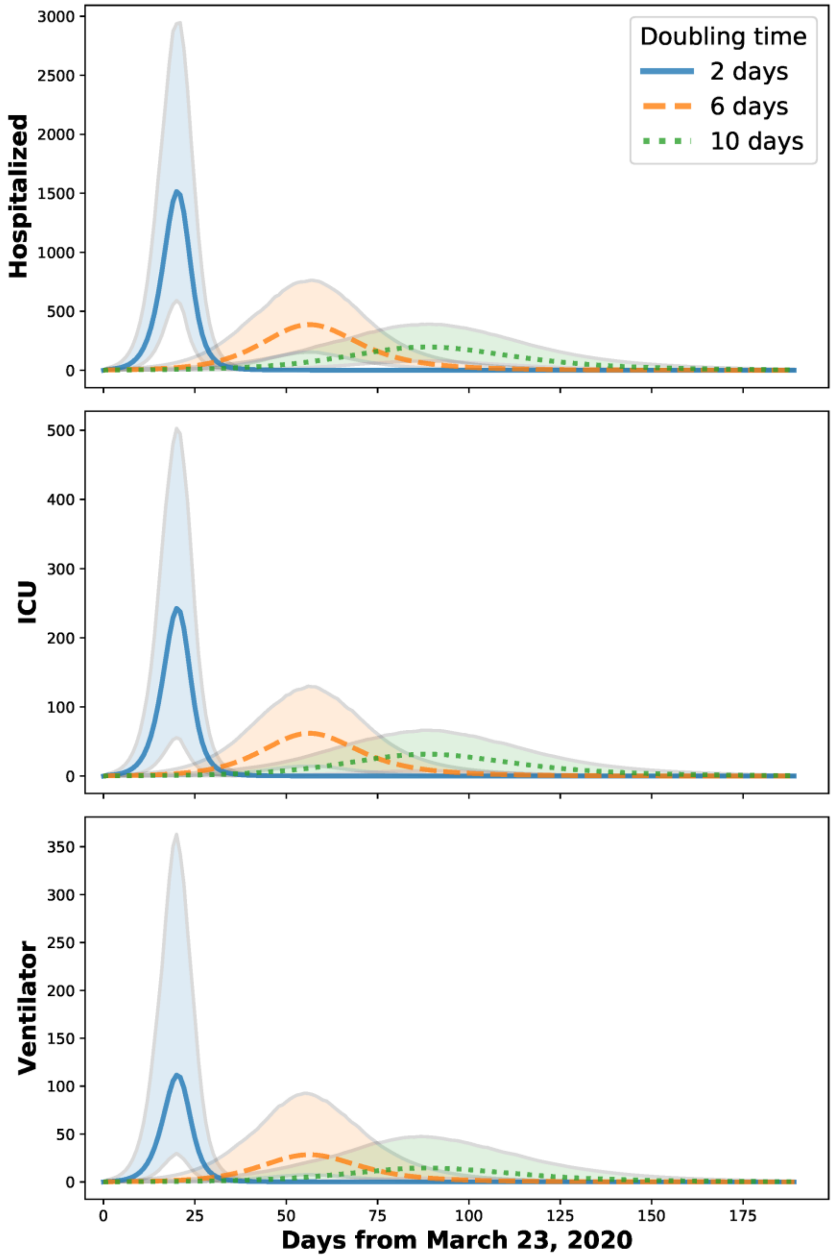

Figure 1: Projected total daily hospital admissions (top), those to the intensive care unit (ICU) census (middle), and those requiring invasive mechanical ventilation (bottom) for patients with COVID-19. Shaded regions represent 2.5% and 97.5% percentiles across 1,000 simulations representing upper and lower bounds on likely scenarios.

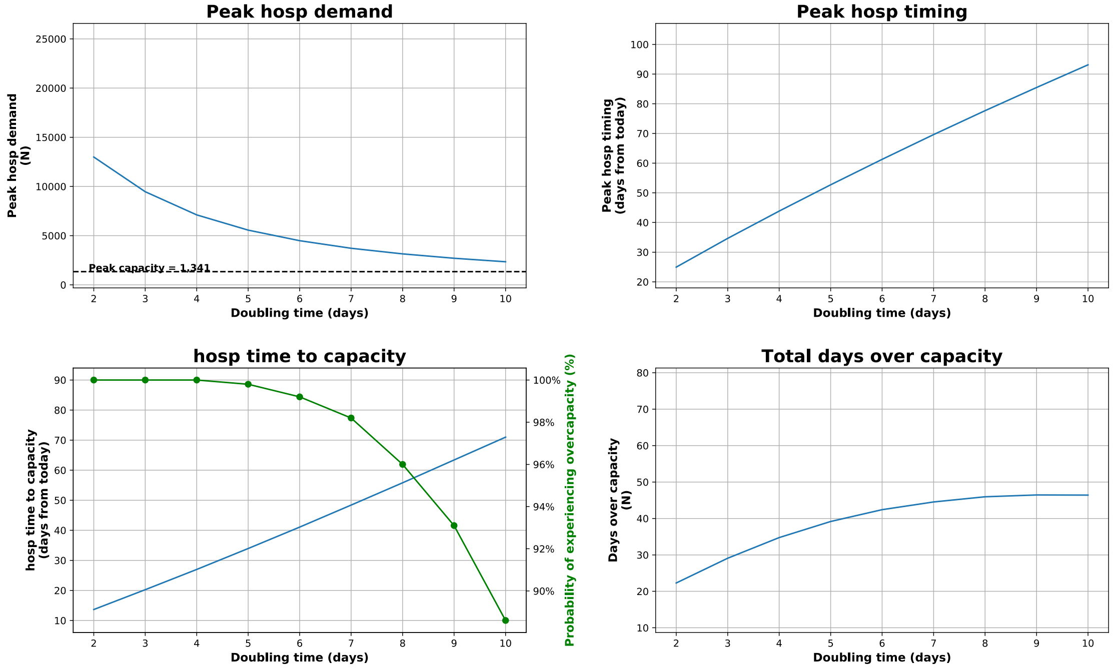

Figure 2: Sensitivity analysis results demonstrating a range of epidemic scenarios plotted against current hospital resources, including the peak demand for hospital beds (top left), the time to reach peak demand (top right), the time to exceed current health system capacity (bottom left), and the projected time spent over capacity (bottotm right) for patient with COVID-19.

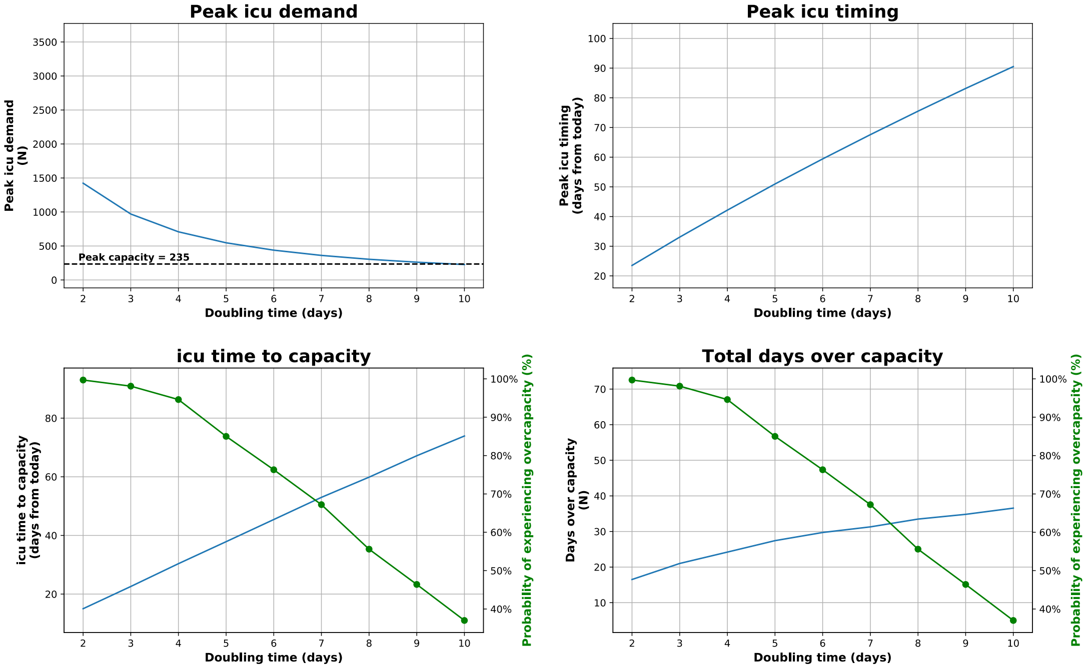

Figure 3: Sensitivity analysis results demonstrating a range of epidemic scenarios plotted against current hospital resources, including the peak demand for intensive care unit (ICU) beds (top left), the time to reach peak demand (top right), the time to exceed current health system capacity (bottom left), and the projected time spent over capacity (bottotm right) for patient with COVID-19.

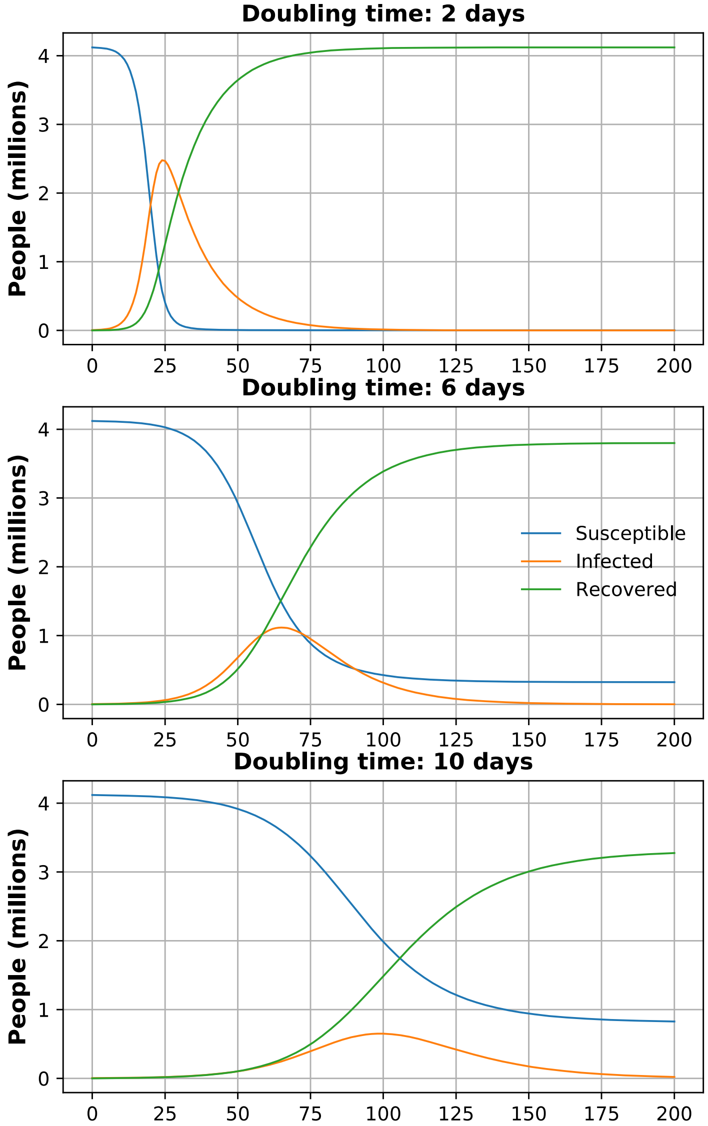

Figure 4: Expected course of susceptible, infected, and removed populations over time across different assumptions of the doubling times in the Philadelphia region.

References

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