Model-based estimates of time to maximum bed occupancy for COVID-19 care

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Results as of April 2, 2020 12:00 pm

What do we already know?

The global COVID-19 pandemic threatens to overload health care systems. Inpatient beds are limited and many hospitals are uncertain about if and when they will run out of adequate capacity to manage COVID patient care.

What does this report add?

We estimated the number of hospital beds available in the United States and, given the growth of the COVID-19 epidemic, at what point the number of serious infections requiring inpatient care are likely to exceed hospital capacity.

What are the implications for public health practice?

With only mild social distancing measures, most hospitals will be overwhelmed in just a few weeks. Moderate or aggressive social distancing measures may prevent many hospitals from ever exceeding capacity and extend the time that others have to prepare in order to adequately care for patients. If this is done quickly enough, in combination with mitigation strategies such as preventing staff absenteeism and expanding respiratory treatment availability, some additional hospitals are likely to be able to weather the epidemic peak without exceeding capacity.

Regardless of the epidemiological situation that hospitals find themselves in, they have the option to adopt their own mitigation strategies, such as postponing elective procedures or utilizing temporary (licensed but typically unstaffed) bed capacity. These coping strategies delay the arrival at full bed occupancy and also reduce the total time spent in a maximum occupancy state.

Executive summary

- **Purpose:** To estimate when and if the number of COVID-19 patients requiring inpatient treatment will exceed the available hospital bed capacity and how quickly placement delays will exceed safe levels.
- **Background:** The analysis was done using Covasim (for epidemic projections) and IDM's COVID healthcare systems model (for health systems requirements).
- **Geography:** US county-level hospital bed capacity; US-based population pyramid.
- **Epidemiological projections:** Estimated using the agent-based model Covasim using a population of 100,000 based on an average US-based population pyramid.

- **Health system projections:** Beginning with an initial incidence of 19 hospitalizations and 100 infections per 100,000 population (see appendix for details), with only mild social distancing measures, nearly all hospitals will run out of available beds in a few weeks. Increasing social distancing measures to moderate or aggressive levels allow many hospitals to avoid ever exceeding capacity while others are able to provide adequate care for patients for significantly longer. Additional mitigation strategies may allow some additional hospitals to weather the epidemic peak without exceeding capacity.

Introduction

The novel coronavirus SARS-CoV-2 emerged in Wuhan, China, in late Nov or early Dec 2019. After initial emergence in China, travel-associated cases started to appear in other parts of the world with strong travel connections to Wuhan (http://rocs.hu-berlin.de/corona/). As of 1 April 2020, it is responsible for 823,626 confirmed cases and 40,598 deaths of the disease COVID-19 (WHO).

Delays in care for those that require hospitalization can have a number of negative consequences. As we are seeing in Italy and South Korea, patients may die at home waiting for a hospital bed to become available. Those that are admitted to the hospital may receive lower quality care; delays in being transferred to the ICU from the ER have been shown to increase mortality rates (Chalfin et al, 2007).

In Wuhan, the number of patients requiring COVID-19 treatment exceeded hospitalization and ICU capacity for at least a month, despite the lockdown of the city intended to reduce transmission. This leads to delayed or reduced quality of care, for both COVID and non-COVID patients, and may increase the community transmission of COVID-19. Health care personnel are forced to triage patients and focus on those experiencing more severe symptoms.

Implementing interventions that delay and reduce the number of cases at the peak provides hospitals additional time to prepare. The primary need is to create additional space in hospitals for COVID-19 patients before the peak of the epidemic is reached. This can be achieved by freeing up space in both existing ICU and AAC beds, adding new capacity, and preventing the loss of capacity due to staff absenteeism and attrition.

Interventions put into place to buy time for hospitals to prepare for the epidemic peak have the added benefit of helping them after that peak hits. Expanded capacity both 1) delays the time to maximum capacity and 2) reduces the amount of time hospitals must operate in “crisis mode” above capacity. This directly reduces the excess mortality associated with turning away patients or delayed and inadequate patient care. Hospitals that are only slightly over capacity have greater opportunity to use interventions such as flex capacity and canceling elective procedures to increase effective bed availability.

Overcrowding has been well-studied and it is known to delay care and increase patient mortality (Eriksson et al, 2017). This is cause for concern, both for COVID-19 and non-COVID patients. In ICU patients, a delay of just six hours has been shown to increase mortality rates by 27% (Chalfin et al, 2007). For stroke and heart attack patients admitted to overwhelmed hospitals during a previous flu outbreak, their mortality rates were 15% and 20% higher than normal, respectively (Rubinson et al, 2013) . When interventions are in place that allow hospitals to operate below full bed capacity, this provides additional breathing room that reduces delays in admission and treatment.

Hospital capacity availability

We estimate that 19.3% of all true COVID-19 infections (whether or not they were identified) should be hospitalized and 5.8% of infections result in severe illness that would need ICU-level care (see Appendix 2). Care for COVID-19 complications is resource-intensive, generally requiring one to three weeks in an adult acute care (AAC) and/or intensive care unit (ICU) bed before discharge from the hospital. The burden this puts on the health care system, particularly at the peak of infection, can increase mortality rates as patients are unable to receive timely or adequate care.

Projections of hospital bed needs are essential for planning purposes so that health care facilities can gather resources in advance of patient demands. The following must be taken into consideration to project total bed occupancy/availability:

- Existing numbers of available beds and non-COVID occupancy rates
- The projected epidemiological curve
- The length of stay for COVID-19 patients
- Proportion of AAC vs. ICU beds

Available bed capacity is defined for the purposes of this report as the number of beds that are available for COVID-19 patient care. This was calculated as the total number of available beds, less the typical occupancy as reported by hospitals to the Centers for Medicare and Medicaid Services (CMS).

Available capacity in the US for AAC hospital beds varies substantially by state and county. We calculated these rates based on hospital-reported data that is publicly available from the CMS website (HCRIS DATA), in combination with county-level census data from the US Census Bureau.

The average number of available AAC beds per county in the United States is 87.5 per 100,000 population. The 25th percentile is 54.6, the 75th percentile is 138, and the 95th percentile is 255. The average number of available ICU beds per county is 9.95 per 100,000 population. The 25th percentile is 5.92, the 75th percentile is 16.7, and the 95th percentile is 30.4. (See Figures 1 and 2.)

This varies substantially by location. For example:

- Fulton County, GA (Atlanta): 50.6 per 100K AAC; 11.8 per 100K ICU
- King County, WA (Seattle): 44.6 per 100K AAC; 7.9 per 100K ICU
- Los Alamos, NM (Los Alamos): 180.9 per 100K AAC; 29.4 per 100K ICU
- Lubbock, TX (Lubbock): 238.4 per 100K AAC; 26.9 per 100K ICU
- Milwaukee County, WI (Milwaukee): 96.7 per 100K AAC; 17.8 per 100K ICU
- Missoula County, MT (Missoula): 87.5 per 100K AAC; 23.8 per 100K ICU
- New York, NY (New York City): 76.0 per 100K AAC; 16.2 per 100K ICU
- Owensboro, KY (Owensboro): 238.8 per 100K AAC; 10.0 per 100K ICU
- Suffolk County, MA (Boston): 94.4 per 100K AAC; 15.0 per 100K ICU

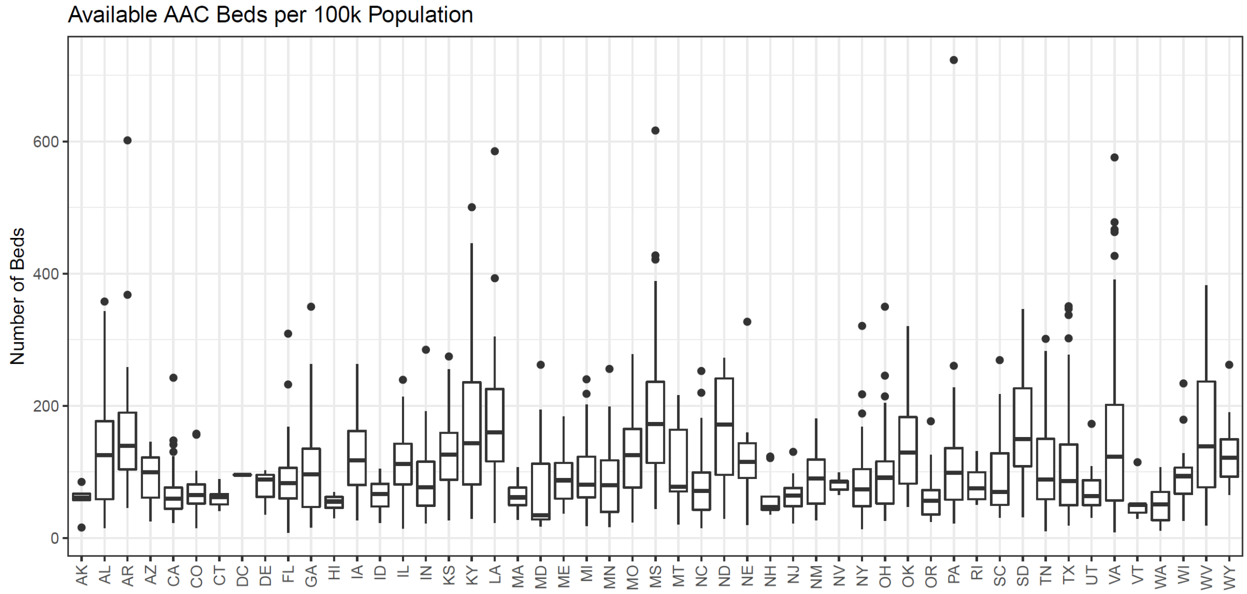

Figure 1. *Estimates of current AAC beds per 100,000 population for each county in the United States. Number of available beds by hospital, as reported by hospitals to the CMS in 2018. Population by county, as reported by the US Census Bureau for 2018. Each state's box has a line at the median county level and extends to the state's 25th and 75th percentile; lines extend to the 95th percent confidence interval.*

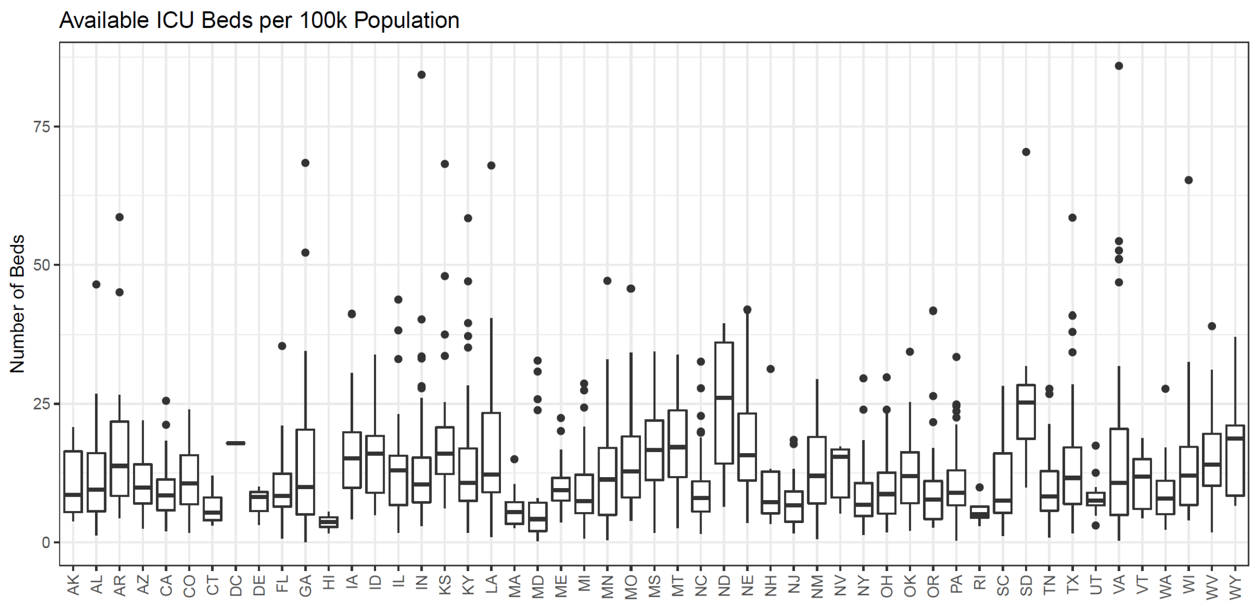

Figure 2. *Estimates of current ICU beds per 100,000 population for each county in the United States. Number of available beds by hospital, as reported by hospitals to the CMS in 2018. Population by county, as reported by the US Census Bureau for 2018. Each state's box has a line at the median county level and extends to the state's 25th and 75th percentile; lines extend to the 95th percent confidence interval.*

The healthcare system must be able to respond rapidly and have adequate capacity to diagnose, treat, and care for patients – both those with COVID-19 and those without. Depending on the rate at which the pandemic progresses, bed capacity may quickly be filled (some hospitals normally operate near 100% occupancy and thus would not have much space for additional volumes), leaving patients without access to prompt, high-quality care.

The benefits to the health system from a delayed and flattened outbreak are to reduce overcrowding and delayed care. More importantly, keeping the health system operating below maximum capacity has direct mortality benefits for both acutely ill COVID-19 patients and for others who will continue to need healthcare resources available to provide non-COVID care.

Modeling methods and assumptions

A detailed summary of our methods is available for transmission modeling in Appendix 1 and for health systems usage in Appendix 2. In brief, we have coupled an individual-based transmission model (COVID-19 Agent-based Simulator, or Covasim) to a discrete event simulation model of the hospital system as follows. COVID-19 transmission takes place on a fixed network of contacts with best-available disease parameters.

The epidemiological model assumes an average of 20 contacts per individual and a mean duration of infectiousness of 8 days. This roughly translates to R0 = 2.3 with a doubling period of 6-7 days. More details can be found in Appendix 1. Results from the transmission model feed directly into the hospital utilization model.

The hospital utilization model has the following structure.

- We modeled both AAC and ICU beds. We defined the number of beds needed as the inpatient census at the end of each simulated day and did not adjust for bed time lost due to turnover between patients. We assumed that a bed being occupied represents all of the equipment and staffing required and do not model that separately.
- If there is no room in an ICU bed, the patient remains in an AAC bed.
- Analyses are run sweeping through values of 50-300 AAC and 5-30 ICU beds per 100K.
- Day 1 of the analysis is defined by 100 cumulative cases, or 19 cumulative hospitalizations, per 100,000 population.

Available bed capacity is defined as the total number of staffed beds (including both ICU or AAC) minus those occupied by other patients. For example, if a hospital has 100 staffed AAC beds, of which 60 are typically occupied, there would be 40 AAC beds available for COVID patients. As hospitals experience absenteeism by staff, they may move to a scenario where they have fewer available beds, while on the other hand hospitals may free up capacity by postponing elective care. For these modeling purposes, we assume that capacity is fixed for the duration of the modeling duration. Using the previous example, the original 100 AAC beds could be reduced to 95 AAC beds as 5 are lost to absenteeism; if 40 are occupied by non-COVID patients, there are now only 55 available for COVID patients.

The hospital utilization model uses the following assumptions. (See appendix for data sources.)

- We use the US-based population age pyramid, as reported by the US census bureau.
- Of all infections, 19.3% require hospitalization and 5.8% have severe illness requiring an ICU bed.

- Length of stay is approximately 9-16 and 13-21 days for moderate and severe cases, respectively.
- ICU-bound patients spend the first half of their stay in an AAC bed.
- We assume no delays in discharge after a patient has been cleared as able to leave.
- If a patient's wait time for an inpatient bed placement exceeds 24 hours, they are turned away and referred for observational care.

We compared three potential scenarios which are plausible in the current socio-political environment:

- Mild social distancing [40% reduction in contacts], starting in week 3
- Moderate social distancing [60% reduction in contacts], starting in week 3
- Aggressive social distancing [80% reduction in contacts], starting in week 3

Results

We project the number of days to reach total hospital bed capacity for populations with a range of AAC and ICU bed capacity per 100,000 population (Figure 3). With only mild social distancing, nearly all hospitals would reach capacity within 6 weeks from the starting point of 19 hospitalizations per 100,000. Increasing social distancing measures to moderate (60% reduction in contacts) or aggressive (80% reduction) prevents many hospitals from ever exceeding bed capacity.

The grey areas on the plots indicate scenarios where bed occupancy never exceeds capacity over the twenty-week period that was modeled; for the moderate and aggressive social distancing scenarios, this is beyond the time of the epidemic peak. This is the benefit of social distancing. By reducing the rate of growth in the number of cases, the hospital system is able to maintain adequate capacity to care for COVID patients and we avoid excess mortality due to delays in care and overcrowding.

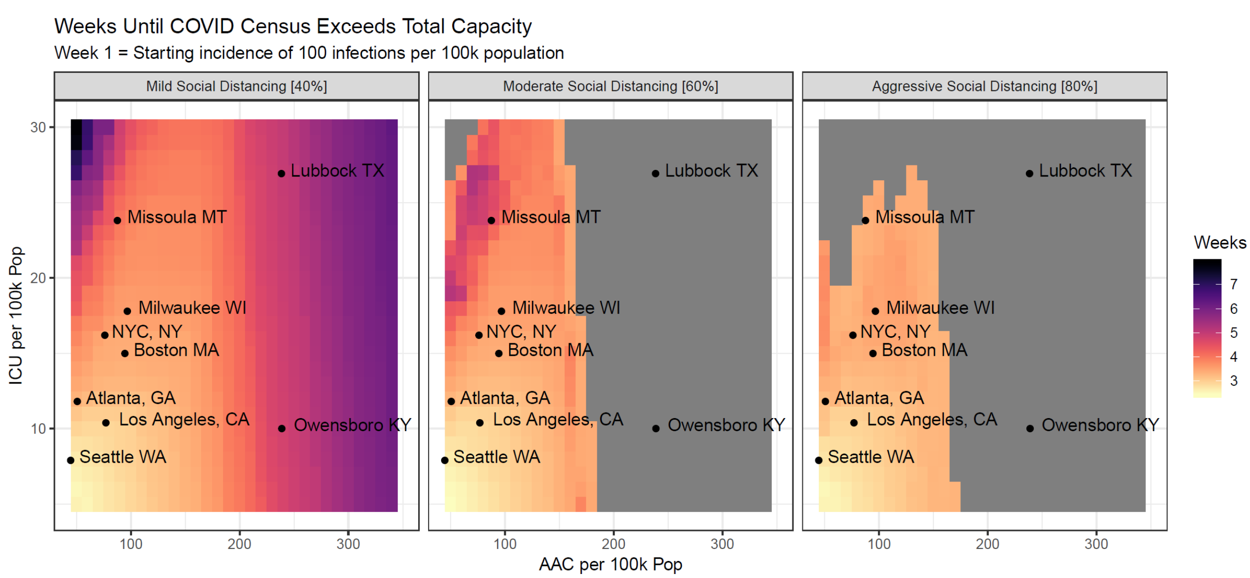

Figure 3. *The color gradient represents the number of days from the starting point (100 COVID-19 infections per 100,000 population) until available bed capacity has been exceeded. Lighter colors represent earlier onset of maximum capacity reached; darker colors represent longer periods where available beds remain. Gray portions represent scenarios where maximum bed capacity is never reached.*

The axes on these plots are defined as the number of available beds per 100,000 people where AAC = adult acute care and ICU = intensive care unit.

The gradient found on the moderate and aggressive social distancing scenarios is limited because hospitals with inadequate capacity quickly run out of beds in the first few weeks before social distancing has a chance to take full effect. This early influx of patients overwhelms their capacity. In contrast, hospitals with enough beds to withstand the initial wave are in better shape and thus they never achieve a full occupancy level.

The AAC and ICU beds interact with each other in a dynamic way, which results in some asymmetry in the time to maximum capacity. It is important to note when interpreting the results in Figure 3 that if an ICU bed is unavailable, but the patient is already in an AAC bed, they will remain there and wait for an ICU bed to become available; this inflates the AAC occupancy higher than it otherwise would be and results in a shorter time to maximum capacity. In contrast, if patients are not able to be placed in an AAC bed because there are not enough available, they are placed on a waiting list until a time at which an AAC (or if they are eligible, an ICU bed) becomes available, thus indirectly reducing the total bed occupancy because of the inability to place lower-acuity patients.

Additionally, we project the number of weeks that hospitals will be at full or over ICU capacity, assuming an adequate number of AAC beds are available, at each of the scenarios. With only mild social distancing measures, hospitals can expect to be operating at full ICU capacity for around four months, depending on ICU bed density. Moderate social distancing reduces the time spent at capacity, particularly for hospitals with higher numbers of ICU beds per 100,000. With aggressive social distancing measures, even hospitals with relatively few ICU beds per 100,000 can expect to spend less than 5 weeks at capacity.

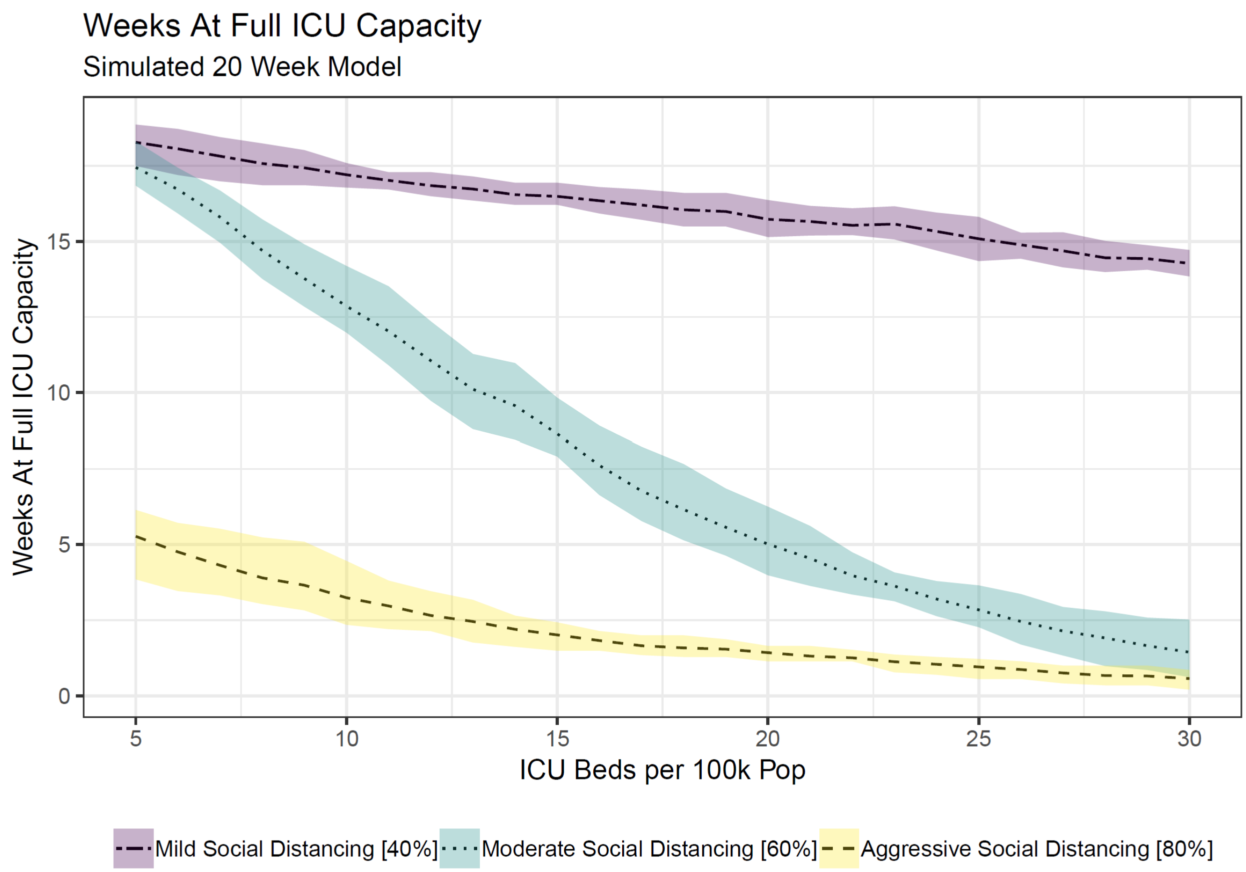

Figure 4. *The number of weeks during which the ICU bed capacity was at maximum occupancy, assuming adequate AAC beds are available. The model was run for 20 weeks, which was beyond the peak for each of the scenarios. This is defined as any day when the number of ICU beds is equal to the number of patients in ICU beds at the end of the day. Shaded areas represent 95th percent confidence intervals.*

FInally, we calculate the number of weeks from the starting point of 100 infections or 19 hospitalizations per 100,000 population until the waiting time for placement into an inpatient bed exceeds a 6 hour wait time, at which point mortality has been shown to increase in ICU-eligible patients. Given the number of available AAC and ICU beds per 100,000 and the social distancing measures in place, the table below shows the expected number of weeks until average patient waiting time exceeds 6 hours in a majority of the simulation model trials.

Model Scenario		Days Until the Average Delay for Patient Placement Exceeds 6 Hours		
# Available AAC Beds	# Available ICU Beds	Mild Social Distancing [40%]	Moderate Social Distancing [60%]	Aggressive Social Distancing [80%]
50	10	17.5 (15, 22.6)	17.3 (15, 21.7)	17.9 (15.5, 21.7)
150	10	30 (27.9, 31)	NA	NA
250	10	35.4 (33.5, 37.6)	NA	NA
350	10	44.4 (42, 46.6)	NA	NA
50	20	17.5 (15, 22.6)	17.3 (15, 21.7)	17.9 (15.5, 21.7)
150	20	24.8 (24, 26.1)	24.9 (23, 29.9)	23.6 (23, 25)
250	20	36.3 (34, 38)	NA	NA
350	20	45.4 (43.5, 47.6)	NA	NA
50	30	17.5 (15, 22.6)	17.3 (15, 21.7)	17.9 (15.5, 21.7)
150	30	24.9 (24, 26.1)	24.1 (23, 26)	23.7 (23, 25)
250	30	37.4 (35, 40.1)	NA	NA
350	30	46.3 (44.5, 48)	NA	NA
Model Scenario		Days Until the Average Delay for Patient Placement Exceeds 12 Hours		
# Available AAC Beds	# Available ICU Beds	Mild Social Distancing [40%]	Moderate Social Distancing [60%]	Aggressive Social Distancing [80%]
50	10	17.6 (15, 22.6)	17.4 (15.5, 21.7)	17.9 (15.5, 21.7)
150	10	24.9 (24, 26.1)	25.1 (23.5, 28.6)	23.6 (23, 25.1)
250	10	36.2 (34, 38)	NA	NA
350	10	45.6 (43.5, 47.6)	NA	NA
50	20	17.6 (15, 22.6)	17.4 (15.5, 21.7)	17.9 (15.5, 21.7)
150	20	25.6 (25, 26.6)	24.2 (23, 26.7)	23.4 (23, 24.6)
250	20	37.5 (35, 40)	NA	NA
350	20	46.5 (44.5, 48)	NA	NA
50	30	17.6 (15, 22.6)	17.4 (15.5, 21.7)	17.9 (15.5, 21.7)
150	30	25.6 (25, 26.6)	23.6 (23, 25.6)	23.4 (23, 25)
250	30	38.9 (35.5, 42.1)	NA	NA
350	30	47.3 (46, 49)	NA	NA

Table 1. *The number of days from the model starting point of 100 infections or 19 hospitalizations per 100,000 population until the delays for patient placement into an inpatient bed exceeds six hours. All values reported in days. The number of AAC and ICU beds are defined as beds available per 100,000 population. AAC = adult acute care. ICU = intensive care unit. Numbers in parentheses represent 95% confidence intervals.*

How to use these results

These results can be used in two ways:

First, to directly assess how much time an area has until they will experience full inpatient bed capacity and potentially dangerous waiting times for beds. Estimate when your region was or will be at 19 hospitalizations or 100 infections per 100,000 population and consider this “day 1”. Then consult the above figures to determine the length of time until hospital bed capacity is exceeded, how long it will operate at capacity, and how long until dangerous wait times occur given the AAC and ICU beds available and interventions in place.

Second, to evaluate trade-offs for interventions that are being considered. There are many strategies that could be used to increase hospital capacity to care for COVID patients, each of which comes at a different cost and has varying impact on bed availability. However, these results are applicable regardless of the specific intervention, and thus different combinations of strategies can be quickly evaluated against one another for cost-benefit.

Fundamentally, hospitals have three basic strategies:

1. **Increase the total available beds.** This can be achieved through building out new spaces, repurposing military or other facilities, or expanding staff skill sets.
2. **Reduce use of existing capacity**. This can be achieved by reducing use by non-COVID patients, most likely through cancellations of elective care and procedures. This may need to be financially offset by insurance and/or governments in order for hospitals to remain financially solvent. Additionally, patients can be moved out of ICU beds rapidly when they are discharged or stepped down to AAC beds; this requires coordinating health care and janitorial staff to clean the beds and make them available to new patients. To make additional space available in AAC beds, avoid observational patients that can remain at home and be remotely monitored.
3. **Prevent loss of existing capacity due to staff absenteeism and attrition.** This can be achieved by ensuring proper safety equipment (PPE) and eliminating barriers for staff work, such as by providing platforms for clinicians to work remotely.

Regardless of which strategies are chosen, the net impact on bed availability, combined with baseline bed capacity and occupancy rates, can be used to estimate the additional time to maximum load and unacceptable waiting times.

For example, let's say we have a city of 100,000 with 220 AAC and 30 ICU beds. They usually have 50% occupancy, which means they now have 110 AAC and 15 ICU beds for COVID patients. If they free up 30% of their typical AAC occupancy by cancelling electives, their beds available would be 220-110+110*0.3 = 143 AAC and 15 ICU. With those resources and moderate social distancing measures, hospitals will likely exceed capacity in approximately 3 weeks. However, adding aggressive social distancing and other mitigation strategies may be enough to avoid overburdening the healthcare system.

Recent work by IDM researchers has estimated the impact of social distancing interventions in Seattle, WA over several weeks in March 2020. The analysis would suggest that between March 16th, 2020 and March 28th, 2020, Seattle was in a scenario between moderate and aggressive social distancing.

Conclusions to date

Social distancing interventions are necessary to reduce the number of cases at the peak of the epidemic and provide enough time for hospitals to prepare for COVID-19 patients. Even with moderate social distancing interventions, relatively well-equipped health care systems may be overwhelmed in just a few weeks. More aggressive social distancing interventions, combined with interventions aimed at increasing AAC/ICU bed capacity, are likely necessary for many regions in the US.

This report provides estimates of when hospitals in a given region can expect to become overwhelmed by COVID-19 cases, given the available beds and interventions currently in place. This can be helpful in deciding how hospitals need to prepare and if additional social distancing measures are necessary. If this is done quickly enough, in combination with mitigation strategies such as preventing staff absenteeism and expanding respiratory treatment availability, some hospitals are likely to be able to weather the epidemic peak without exceeding capacity. Hospitals with adequate capacity are able to provide timely and adequate care to patients, reducing the excess mortality associated with turning away patients or delayed and inadequate patient care.

Appendix 1: Detailed transmission model methods

COVID-19 transmission was projected using an agent-based model, Covasim (available on GitHub). Covasim modeled a population of 100,000 with a US-based population pyramid. The model was seeded with a cumulative 100 infections to date as of day 1. On day 1, we therefore would expect to have seen 19 total hospitalizations per 100,000 population (100 cumulative cases x 0.193 admission rate (see below). The "days until" projections are all counted from the same day 1 of the simulation.

The model started with zero COVID-19 patients in the available bed capacity. Since the model begins with very low incidence, this is a reasonable starting point and allows the model to fill according to the epidemiological projections.

COVID-19 (SARS-CoV-2) infection within each individual is represented by four stages: susceptible, exposed, infectious, recovered (SEIR). The exposed (latent) period prior to the onset of viral shedding is normally distributed with a mean of 4 days and standard deviation of 1 day; this is one day shorter than the 5-day consensus estimate of the incubation period prior to symptom onset (MIDAS-network) to acknowledge reports of pre-symptomatic shedding. The infectious period is normally distributed with mean 8 days and standard deviation 2 days, based on measured upper-respiratory viral shedding after symptom onset (Lauer et al, 2020).

Viral transmission from one individual to the next proceeds on a fixed contact network with undirected edges. The degree distribution of the network is Poisson-distributed with rate parameter lambda = 20. Individual network edges are selected at random. On each day, an infectious individual exposes susceptible "close contacts" (neighboring nodes in the graph) to possible infection. The daily probability of an infectious individual infecting each neighboring susceptible individual is binomially distributed with $p = 0.015$. With an average of 20 contacts per individual and a mean duration of infectiousness of 8 days, this per-day probability roughly translates to R0 = 2.3 with a doubling period of 6-7 days. At this time, all infected individuals are equally infectious, and infectivity does not vary on a daily basis or by symptoms.

The three intervention scenarios modify the baseline scenario [mild social distancing], which represents approximately 40% reduction in social contacts via basic social distancing and hygiene practices. Contacts are reduced by 60% for moderate social distancing, and by 80% for aggressive social distancing. These potential scenarios were based on analysis done by Thakkar, et al. and Burstein, et al. on mobility changes after social distancing policies were put in place in Seattle, WA.

All health system modeling was performed using an IDM-developed and open-source model. The modeling files can be obtained via the public GitHub repository at https://github.com/InstituteforDiseaseModeling/covid-health-systems.

Appendix 2: Healthcare system modeling methods

There is still a high degree of uncertainty about the healthcare needs of COVID-19 patients in the United States, since the clinical care protocols are rapidly evolving and will depend substantially on the comorbidities and level of opportunistic infections that are seen in a given patient population. With that in mind, we have triangulated between several published sources in order to estimate parameters that fit reasonably well with what is currently known.

We utilize data released by the CDC as part of the morbidity and mortality weekly report on March 18, 2020 for inpatient and ICU utilization by age band for symptomatic cases in the United States. These are weighted according to the US population age mix and result in a net rate of 19.3% of infections requiring hospitalization and 5.8% of infections resulting in severe illness that requires an ICU bed as part of an inpatient stay.

Length of stay estimates are highly variable. We extrapolated from those reported by Bi et al. (2020), Yang et al. (2020), and Sanche et al. (2020). Each study uses different definitions for length of stay, broken out by severity and symptoms. Collectively, they indicate that severe cases have longer length of stay, and that most ICU-bound patients start out in an AAC bed and eventually progress to more severe symptoms that require ICU care. We reflect this in the model with length of stay with a uniform distribution for moderate-severe cases of 9.4-16.0 days, and for severe cases 12.5-21.2 days. Based on limited clinical protocol recommendations from Bouadma et al. (2020) in combination with expected length of stay, we assume that for ICU-bound patients, approximately 50% of their length of stay is first in an AAC bed. It is likely that these assumptions will need to be updated as we learn more about care in the United States.

The model is a discrete event simulation, which models each individual patient as they seek care and for their duration of time in the hospital. Patients arrive at the hospital with symptoms according to the pattern projected by the epidemiological model described above.

All health system modeling was performed using an IDM-developed and open-source model. The modeling files can be obtained via the public GitHub repository at https://github.com/InstituteforDiseaseModeling/covid-health-systems.

Appendix 3: Number of Days Until Delays Exceed a Threshold

Model Scenario		Days Until the Average Delay for Patient Placement Exceeds 6 Hours		
# Available AAC Beds	# Available ICU Beds	Mild Social Distancing [40%]	Moderate Social Distancing [60%]	Aggressive Social Distancing [80%]
50	5	18.3 (15, 23.6)	17.7 (15, 23.6)	18.2 (14.5, 23.6)
100	5	21.1 (19.5, 23.1)	21 (19.5, 23.1)	21.5 (19.5, 24)
150	5	24.1 (23, 25.6)	24.2 (23, 26.7)	23.6 (23, 24.6)
200	5	29.4 (28, 31)	NA	NA
250	5	35.1 (33, 37.6)	NA	NA
300	5	40.2 (37, 43)	NA	NA
350	5	44.2 (42, 46.6)	NA	NA
50	10	17.5 (15, 22.6)	17.3 (15, 21.7)	17.9 (15.5, 21.7)
100	10	21.1 (19.5, 22.6)	21.1 (19.5, 22.6)	21.7 (20, 23.6)
150	10	24.5 (23.5, 26.1)	24.8 (23.5, 27.7)	23.4 (23, 24)
200	10	30 (27.9, 31)	NA	NA
250	10	35.4 (33.5, 37.6)	NA	NA
300	10	40.9 (37.5, 43.6)	NA	NA
350	10	44.4 (42, 46.6)	NA	NA
50	15	17.5 (15, 22.6)	17.3 (15, 21.7)	17.9 (15.5, 21.7)
100	15	21.2 (19.5, 22.6)	21.1 (19.5, 22.6)	21.8 (20, 23.6)
150	15	24.8 (24, 26.1)	25.3 (23.5, 29)	23.4 (23, 24.6)
200	15	30.5 (28.5, 33.1)	NA	NA
250	15	35.9 (34, 38)	NA	NA
300	15	41.3 (38, 44)	NA	NA
350	15	45.2 (43.5, 47)	NA	NA
50	20	17.5 (15, 22.6)	17.3 (15, 21.7)	17.9 (15.5, 21.7)
100	20	21.2 (19.5, 22.6)	21.1 (19.5, 22.6)	21.8 (20, 23.6)
150	20	24.8 (24, 26.1)	24.9 (23, 29.9)	23.6 (23, 25)
200	20	31.5 (30, 34.6)	NA	NA
250	20	36.3 (34, 38)	NA	NA
300	20	41.8 (38.5, 44.6)	NA	NA
350	20	45.4 (43.5, 47.6)	NA	NA
50	25	17.5 (15, 22.6)	17.3 (15, 21.7)	17.9 (15.5, 21.7)
100	25	21.2 (19.5, 22.6)	21.1 (19.5, 22.6)	21.8 (20, 23.6)
150	25	24.9 (24, 26.1)	24 (23, 25.6)	23.7 (23, 25)
200	25	32.5 (30, 34.6)	NA	NA
250	25	36.7 (34, 39.6)	NA	NA
300	25	41.8 (38.5, 44.6)	NA	NA
350	25	45.7 (43.5, 47.6)	NA	NA
50	30	17.5 (15, 22.6)	17.3 (15, 21.7)	17.9 (15.5, 21.7)
100	30	21.2 (19.5, 22.6)	21.1 (19.5, 22.6)	21.8 (20, 23.6)
150	30	24.9 (24, 26.1)	24.1 (23, 26)	23.7 (23, 25)
200	30	33.2 (32, 35)	NA	NA
250	30	37.4 (35, 40.1)	NA	NA
300	30	42.3 (39, 45)	NA	NA
350	30	46.3 (44.5, 48)	NA	NA

Table 2. *The number of days from the model starting point of 100 infections or 19 hospitalizations per 100,000 population until the delays for patient placement into an inpatient bed exceeds six hours. All values reported in days. The number of AAC and ICU beds are defined as beds available per 100,000 population. AAC = adult acute care. ICU = intensive care unit. Numbers in parentheses represent 95% confidence intervals.*

Model Scenario		Days Until the Average Delay for Patient Placement Exceeds 12 Hours		
# Available AAC Beds	# Available ICU Beds	Mild Social Distancing [40%]	Moderate Social Distancing [60%]	Aggressive Social Distancing [80%]
50	5	18.6 (15.5, 23.6)	18 (16, 23.6)	18.3 (15, 23.6)
100	5	21.4 (19.5, 23.6)	21.5 (19.5, 23.6)	21.6 (19.5, 24)
150	5	24.5 (23.5, 26.1)	24.6 (23.5, 27.2)	23.6 (23, 24.6)
200	5	29.9 (28, 31)	NA	NA
250	5	35.7 (34, 37.6)	NA	NA
300	5	41.2 (38, 43.6)	NA	NA
350	5	45.1 (42.9, 47)	NA	NA
50	10	17.6 (15, 22.6)	17.4 (15.5, 21.7)	17.9 (15.5, 21.7)
100	10	21.2 (19.5, 22.6)	21.3 (20, 22.6)	21.8 (20.5, 23.6)
150	10	24.9 (24, 26.1)	25.1 (23.5, 28.6)	23.6 (23, 25.1)
200	10	30.7 (28.4, 33.7)	NA	NA
250	10	36.2 (34, 38)	NA	NA
300	10	41.7 (38.5, 44)	NA	NA
350	10	45.6 (43.5, 47.6)	NA	NA
50	15	17.6 (15, 22.6)	17.4 (15.5, 21.7)	17.9 (15.5, 21.7)
100	15	21.5 (19.5, 23)	21.5 (20, 23)	21.9 (20.5, 23.6)
150	15	25.2 (24, 26.6)	26.6 (23, 35.1)	23.3 (23, 24)
200	15	31.6 (30, 34.6)	NA	NA
250	15	36.8 (34.5, 39.1)	NA	NA
300	15	41.8 (38.5, 44.6)	NA	NA
350	15	46 (43.5, 48)	NA	NA
50	20	17.6 (15, 22.6)	17.4 (15.5, 21.7)	17.9 (15.5, 21.7)
100	20	21.6 (19.5, 23)	21.6 (20, 23)	21.9 (20.5, 23.6)
150	20	25.6 (25, 26.6)	24.2 (23, 26.7)	23.4 (23, 24.6)
200	20	32.9 (31, 35)	NA	NA
250	20	37.5 (35, 40)	NA	NA
300	20	42.4 (38.9, 45)	NA	NA
350	20	46.5 (44.5, 48)	NA	NA
50	25	17.6 (15, 22.6)	17.4 (15.5, 21.7)	17.9 (15.5, 21.7)
100	25	21.6 (19.5, 23)	21.6 (20, 23)	21.9 (20.5, 23.6)
150	25	25.6 (25, 26.6)	24 (23, 26.6)	23.4 (23, 25)
200	25	33.4 (32, 35)	NA	NA
250	25	38.2 (35.5, 41)	NA	NA
300	25	42.6 (39.5, 45)	NA	NA
350	25	46.8 (44.9, 48.6)	NA	NA
50	30	17.6 (15, 22.6)	17.4 (15.5, 21.7)	17.9 (15.5, 21.7)
100	30	21.6 (19.5, 23)	21.6 (20, 23)	21.9 (20.5, 23.6)
150	30	25.6 (25, 26.6)	23.6 (23, 25.6)	23.4 (23, 25)
200	30	33.8 (32, 36)	NA	NA
250	30	38.9 (35.5, 42.1)	NA	NA
300	30	42.9 (39.9, 45.6)	NA	NA
350	30	47.3 (46, 49)	NA	NA

Table 3. *The number of days from the model starting point of 100 infections or 19 hospitalizations per 100,000 population until the delays for patient placement into an inpatient bed exceeds twelve hours. All values reported in days. The number of AAC and ICU beds are defined as beds available per 100,000 population. AAC = adult acute care. ICU = intensive care unit. Numbers in parentheses represent 95% confidence intervals.*