COVID-19 in North Carolina

Hospital Capacity and the COVID-19 Epidemic in North Carolina: Preliminary Estimates

Introduction

SARS-CoV-2, the novel virus causing COVID-19, has been spreading around the globe for several months. Currently, there is no vaccine to prevent becoming infected with this virus. Many important policy decisions must be made to limit its negative impacts on the health of North Carolinians.

This brief examines the probability that demand for hospital services generated by COVID-19 will outstrip the state's available hospital acute and intensive care unit (ICU) bed supply under two different social distancing scenarios. Of note, social distancing policies are only effective at slowing transmission if communities adhere to and support them.

We summarize preliminary results of work in progress to inform near-term policy decisions in North Carolina in the weeks and months ahead. The contents of this brief are current as of April 4, 2020. We plan to continually update our analyses with new data as more information becomes available.

Approach

As an informal and independent group of North Carolina epidemiologists and data scientists, we developed a simple "weather forecasting" modeling approach that relies on best-available information from three independent research models (Appendix A). Given the many uncertainties about the COVID-19 pandemic, our approach is to draw preliminary insights from independent models and established modeling teams to estimate the likelihood that North Carolina hospital bed shortages might occur under different scenarios. We then combine results from each independent model to yield composite results.

Like a weather forecast, these composite predictions do not forecast an absolute outcome (e.g., "It will definitely rain on Thursday at 3:20 pm"). Rather, synthesizing results from three independent models, these predictions characterize the likelihood that certain outcomes will occur (e.g., "There's a 20% chance of rain on Thursday"). Given the probabilistic assessment produced by these models, policymakers can make assumptions about the required next steps to absorb the care needs of those infected.

Questions Discussed in this Brief

COVID-19-related hospital caseloads are growing but currently manageable. However, considering how COVID-19 has impacted other jurisdictions (e.g., Italy, New York, Massachusetts), there are concerns that North Carolina may not have sufficient hospital capacity to meet potential health care needs resulting from the COVID-19 epidemic.

Two responses that the State could pursue to minimize this possibility are:

- "Flattening the curve" through policies and their adoption by people to increase/maintain social distancing and other efforts to slow the transmission of the virus, and/or
- Increasing the capacity of the health care system to prepare for a possible COVID-19-related inpatient surge.

To generate some preliminary estimates about social-distancing policies, we considered two different scenarios:

1. Scenario 1 ("Maintain"): Maintain a range of aggressive policies (and assumed adherence) to limit SARS-CoV-2 transmission beyond the end of the current stay-at-home order (which expires near the end of April, 2020).[1]
2. Scenario 2 ("Lift"): Maintain current policies (and assumed adherence) until the end of April (i.e., the end of the current stay-at-home order), and then suspend all social distancing policies thereafter.

[1] As we also state elsewhere, we are not assuming or recommending that the same policies can or should be extended in their current form; we are assuming continuation of existing policies or introduction of some other collection of policies that have similar assumed effectiveness as current policies.

Insufficient time has elapsed since policies were implemented in this state to evaluate their effects. Therefore, we attempt to assess the collective potential impact of these policies by using observations of jurisdictions with outbreaks that have grown ahead of the one in North Carolina to model similar impacts here.

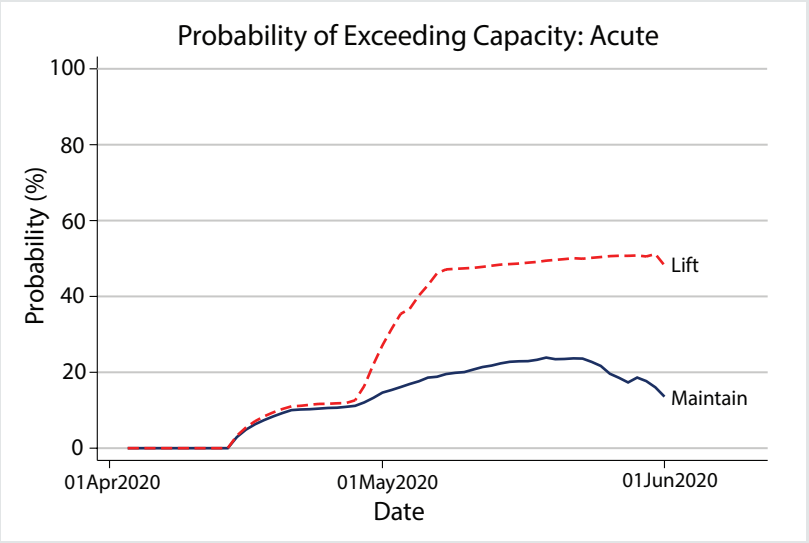
Next, to explore how expanding available hospital capacity might affect our estimates, we considered various levels of hospital "surge" capacity that might theoretically be achieved. We defined "surge" as an increase in available hospital beds to prepare for demand on inpatient health care services. We specify acute hospital care as excluding newborn, psychiatric, hospice, and rehabilitation care. We estimated the probability that demand for services would exceed available supply if we stretched our existing stock of acute and ICU beds to various thresholds in conjunction with, or with the potential elimination of, all social distancing policies.[2]

Available acute and ICU hospital beds

We follow prior methods for estimating the number of acute and ICU beds available in North Carolina by pulling data from Medicare Cost Reports for 2018 and considering licensed hospital bed data from the North Carolina Division of Health Service Regulation for 2018.[3] It is well documented that hospitals are decreasing elective procedures in order to reduce occupancy and plan for a surge in acute and ICU beds potentially needed.[4] We assumed that North Carolina hospitals decrease occupancy by 45%.[5] This implies an average daily number of available acute (ICU) beds of 14,093 (1,962) for current availability, 18,245 (2,598) for a 20% surge, and 24,472 (3,554) for a 50% surge, respectively.[5]

Preliminary Results on April 4, 2020

Exhibit 1 Composite estimates across three models of the probability that demand for acute hospital beds will exceed available supply in North Carolina



"Maintain" means maintain some form of aggressive social distancing policies after April and "Lift" means suspend policies after April.

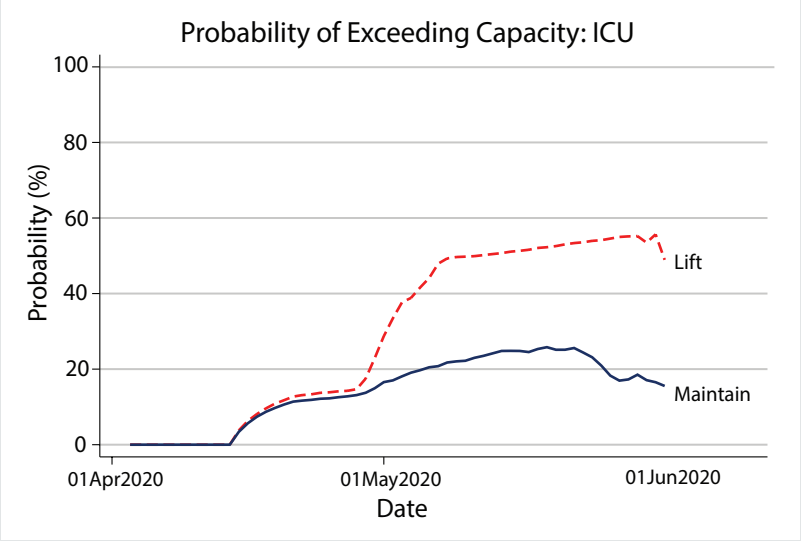
Under current policies, our models suggest that the volume of available acute care beds throughout the state will be sufficient to handle growing COVID-19-related case volume in the next few weeks. In the second half of April, estimates for the near-term suggest a substantial increase in confirmed state case volumes, to as many as 5,500-6,500 confirmed cases by April 15, up from approximately 2,402 confirmed cases on April 4.[6] The probability that acute care bed demand will outstrip available supply will likely increase by mid-April but remains low (<10%) as the available capacity is likely sufficient.

In May, the situation likely changes. Our medium-term estimates assume that current policies remain in effect through April 2020. In early May 2020, we see a divergence in estimated probabilities depending on the two social distancing scenarios.

[2] It's important to note that at this stage, we are not evaluating the feasibility nor the specific strategies to achieve these expansions. For example, a 50% increase in hospital beds (which we label "super surge") would require a substantial increase in healthcare workers.
[3] Occupancy Rates in Rural and Urban Hospitals: Value and Limitations in Use as a Measure of Surge Capacity. North Carolina Rural Health Research Program. https://www.ruralhealthresearch.org/alerts/334
[4] Triangle hospitals are delaying non-urgent surgeries to prepare for coronavirus https://www.newsobserver.com/news/coronavirus/article241364136.html
[5] One of our three models used slightly (but immaterially) different values for census reductions.
[6] This short-term estimate was developed by comparing the trajectory of case growth in North Carolina to that of other states with earlier starts to their outbreaks, and projecting North Carolina's future confirmed case count based on a weighted average of the states that North Carolina's COVID-19 epidemic most closely tracks so far. The weighted average of the similar states is referred to as a "synthetic control group."

- If, past April 2020, the state maintains some forms of social distancing with similar transmission reduction effectiveness,[7] the peak stress on available acute care capacity in our current estimates (which run through June 1) will likely occur in mid-to-late May. At that time, we estimate a roughly 1-in-4 chance (~25%) that acute care bed capacity will be insufficient to meet growing COVID-19-related demand.
- However, under a scenario in which all social distancing policies are fully lifted after April 2020 (and are not replaced by other policies with similar assumed effectiveness for reducing infection transmission), we predict a 1 in 2 (~50%) chance that acute care beds will not be able to meet new demand from COVID-19 patients throughout the state. While our current estimates consider North Carolina as a whole, these probabilities will likely vary by region.[8]

Exhibit 2 Composite estimates across three models for the probability of exceeding ICU bed capacity in North Carolina



"Maintain" means maintain some form of aggressive social distancing policies after April and "Lift" means suspend policies after April.

For ICU beds, the estimates are similar to the acute care bed estimates, with a slightly higher likelihood that COVID-19-related demand will outstrip available ICU bed supply in the same time frame (mid-to-late May 2020).

Finally, we estimate the degree to which expanding hospital bed capacity would decrease the probability that demand would outstrip available supply. We explored this possibility in the context of fully relaxing social distancing policies at the end of 2020 and not replacing them with other policies equally effective in slowing infection transmission.

As an illustration of the potential impact of a hospital bed surge, we also examined the probability of exceeding hospital acute and ICU bed capacity as of June 1 using two of the constituent models. We found that while expanding hospital capacity does (as expected) lower the probability that bed demand will exceed available supply, the effect is small in relation to the reduced probabilities estimated for social distancing. The difference in probabilities of demand exceeding bed supply across the surge levels is approximately 2 to 4 percentage points.

- **The bottom line:** expanding hospital bed capacity (and, crucially, identifying the workforce necessary to staff those beds) is very important as the state prepares for new demand from COVID-19 patients. However, absent other policies to also slow infection spread, expanding hospital capacity alone will likely be an insufficient response to estimated COVID-19-related demand. Both will need to be addressed: demand for beds (by reducing infection spread) and supply of beds (by flexing health care capacity and the associated workforce).

[7] Again, we are not directly evaluating nor suggesting that the same social distancing policies must remain in place, just some combination of policies that have the same assumed effect as current policies.
[8] We plan to continue work to explore impact at the regional level.

To put the findings in context, the models' composite estimates indicate that approximately 750,000 people in North Carolina may be infected with the virus by the end of our forecast period, June 1, 2020. This is if the social distancing policies are fully lifted at the end of April and are not replaced by other policies with equal assumed effectiveness to reduce transmission. On the other hand, if the same policies (or some other policies with similar effect) remain in place, the composite estimates indicate that an estimated 250,000 North Carolinians may be infected by June 1.[9]

These findings suggest that social distancing may "flatten the curve" — thereby spreading COVID-19 incidence over a longer time period, allowing the health care system to better absorb the influx of patients.

Discussion

Without a vaccine to prevent infection with the virus causing COVID-19, transmission may continue, infecting a large portion of the state's population. Practicing social distancing and having the policies in place to support it may reduce morbidity and mortality. With social distancing policies in place, the virus may continue to spread, albeit more slowly, giving the health care system a better chance to manage an influx of patients. Though most people with COVID-19 may manage their symptoms at home, reports from other jurisdictions indicate that when infection spreads quickly through a population, the demand can exceed the health system's supply of hospital beds and related staff. Therefore, our focus in this brief has been to understand the likelihood that various levels of viral transmission would stress North Carolina's hospital capacity.

To summarize the main implications of our findings:

1. Maintaining social distancing policies such as those in place now will give us the best chance of ensuring our health care system has sufficient capacity to manage the growing number of SARS-CoV-2 infections.
2. Lifting all social distancing policies soon after April 29 may lead to a greater than 50% probability that hospital acute care and ICU bed capacity will be outstripped. Our current best estimate is that if, after April 29, we immediately return to the rates of viral transmission occurring prior to widespread social distancing, stress on hospitals to cope with rising demand from COVID-19 patients could begin as soon as Memorial Day.
3. Various levels of hospital "surge capacity" (in conjunction with lifting social distancing policies at the end of April) could provide some help, but will not materially reduce the probability of bed shortages in the absence of some form of social distancing to slow viral transmission. Put simply, our analysis suggests that in the absence of sufficient social distancing, we cannot "surge" our hospital capacity to the extent we may need.
4. There are many challenges to maintaining social distancing. This brief is not recommending or suggesting that current policies (e.g., statewide stay-at-home order) can or necessarily should remain in place indefinitely. Rather, in the weeks and months ahead, the key policy challenge North Carolina leaders face is how to implement a comprehensive strategy to effectively maintain lower levels of viral transmission in the months ahead.
5. Therefore, as policy officials and health care leaders consider modifying social distancing policies in the future, gathering data on the epidemic and infections is of paramount importance.

[9] Note that these estimates include unconfirmed infections. Thus, the additional stress imposed on the health care system is a direct result of having roughly three times as many infected North Carolinians (750,000 vs. 250,000) over the same time period.

Appendices

A Models

Model	Brief description	High-level technical assumptions
UPenn COVID-19 Susceptible-Infected-Recovered[10] (SIR) Hospital Impact Model adapted to North Carolina	Model type commonly used to project the spread and impact of infectious diseases; it models the progression of individuals in a population through stages of disease: susceptible, infectious, and recovered.	Assumes 4.4% hospitalization rate among all COVID-19 cases, both confirmed and unconfirmed, and 30% rate of ICU need among those hospitalized, with average length of stay of 8 days for acute, and 10 days for ICU.[11] **Scenario 1** samples R_0 between 0.75 and 1.5.[12] **Scenario 2** samples R_0 between 0.75 and 1.5 before the end of April, then samples R_0 between 1.5 and 2.5 after the end of April.[12]
Deterministic compartmental epidemiological model[13]	Similar approach to the adapted Penn model above, but with explicit consideration of viral dynamics associated with additional compartments, such as asymptomatic vs. pre-symptomatic vs. symptomatic cases and diagnosed vs. undiagnosed cases. This model uses a time-varying beta to reflect changes in human contact rates under different social distancing scenarios.	Assumes an average of 20.7% of diagnosed cases are hospitalized[14] and 30% of hospitalized patients require ICU care.[11] Assumes a pre-symptomatic period of median 5.1 days[15] (during which transmission can occur), and a median time between symptom onset and diagnosis of 4.25 days.[16] **Scenario 1** assumes declining beta to a floor of 50% of pre-epidemic contact, maintained through and past the end of April. **Scenario 2** assumes beta at 50% of pre-epidemic contact through April, then beta returns to 100% of baseline contact rate after April.
Stochastic agent-based model[13]	Utilizes a geospatially explicit synthetic population reflecting the sociodemographic characteristics of the NC population and the measured/assumed case doubling time to simulate the spread of infection and resulting outcomes.	Assumes 4.4% of all agents acquiring COVID-19, both confirmed and unconfirmed, seek hospitalization and 30% of those hospitalized require ICU care.[11] Assumes a 14-day average length of stay.[12] The number of COVID-19 cases, including both confirmed and unconfirmed cases, introduced at the beginning of the model run is a function of the number of reported cases in each county. Reported cases are multiplied by 25 to reflect the additional unreported cases.[12] **Scenario 1** samples an approximated R_0 between 1.3 and 2.5[17,18,19] **Scenario 2** samples an approximated R_0 between 2.5 and 3.0 after the end of April.[19]

[10] https://penn-chime.phl.io/
[11] Ferguson NM, Laydon D, Gemma NG., et al. Impact of NPIs to reduce COVID-19 mortality and healthcare demand. March 16, 2020. https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf
[12] Subject matter expertise of the collaborators
[13] Model developed in-house by the collaborators
[14] CDC COVID-19 Response Team. MMWR, March 26, 2020; 69(12): 343-346. https://www.cdc.gov/mmwr/volumes/69/wr/mm6912e2.htm
[15] Lauer SA, Grantz KH, Bi Q, et al. Annals of Internal Medicine 2020. doi:10.7326/M20-0504.
[16] Famulare M. Institute for Disease Modeling report. https://institutefordiseasemodeling.github.io/COVID-public/analyses/first_adjusted_mortality_estimates_and_risk_assessment/2019-nCoV-preliminary_age_and_time_adjusted_mortality_rates_and_pandemic_risk_assessment.html
[17] Li W., Guan X., Wu P., et al. Early transmission dynamics in Wuhan, China, of novel coronavirus – infected pneumonia. January 29, 2020. https://www.nejm.org/doi/full/10.1056/NEJMoa2001316
[18] Ma S., Zhang J., Zeng M., et al. Epidemiological parameters of coronavirus disease 2019: a pooled analysis of publicly reported individual data of 1155 cases from seven countries. https://www.medrxiv.org/content/medrxiv/early/2020/03/24/2020.03.21.20040329.full.pdf?%253fcollection
[19] Muniz-Rodriguez K., Chun-Hai Fung, I., Ferdosi S., et. al. Transmission potential of COVID-19 in Iran. March 10, 2020. https://www.medrxiv.org/content/10.1101/2020.03.08.20030643v1

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