COVID-19 Modeling by the Wisconsin Department of Health Services
March 26, 2020

Background

In the early stages of a pandemic, estimating how the disease will spread is essential for identifying appropriate containment strategies (e.g. mass gathering bans, social distancing orders) and planning for medical surge capacity. This type of modeling is especially valuable in Wisconsin's current situation where testing for the disease is very limited (due to scarce testing supplies) and thus disease surveillance is limited.

Several early mathematical models raised concerns about the burden of the COVID-19 pandemic in Wisconsin. For example, COVID ACT NOW [1] predicts, assuming no action, that Wisconsin will experience 125,000 hospitalizations by April 28 and ultimately 117,000 Wisconsin deaths. The goal of our modeling was to conduct our own analysis to assess whether the growth of Wisconsin's cases is consistent with such catastrophic results.

The objective of this analysis is to estimate the total number of COVID-19 cases (clinical cases) in Wisconsin during the early phases of the Pandemic. Clinical cases means cases that will most likely be diagnosed and treated in our public health and healthcare system.

Methods

Exponential growth

Since there is no way to accurately forecast the exact number of COVID-19 cases over an extended period, a variety of epidemiologic models predict estimated cases by capturing the dynamic aspects of disease transmission, clinical progression, and healthcare system assets. These models vary in methodological details and predictions, but share one simple feature: **exponential growth during an early phase**[2].

Using the Wisconsin Electronic Disease Surveillance System (WEDSS), we modeled the growth of the number of confirmed COVID-19 cases. Our data revealed an exponential growth over a period from March 3 – 15 with a doubling time of 3.4 days. This is consistent with doubling times observed worldwide[3].

It is important to note that since there is a lag between the disease onset date and the lab confirmation date, the number of confirmed cases posted on the DHS 'Outbreaks in Wisconsin' web site[4] is necessarily less than or equal to the number of cases.

Duration of the exponential growth phase

Since we do not have a clear understanding of the disease parameters (i.e. incubation period, infectious phase, etc.) we cannot know how long the exponential growth period will last. Different reported models[5] suggest that exponential growth will continue until more than one percent of the population is

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[1] https://covidactnow.org/state/WI
[2] From a paper by Marc Lipsitch, "It is well known that these counts increase exponentially in the initial phase of an epidemic."
[3] https://www.forbes.com/sites/startswithabang/2020/03/17/why-exponential-growth-is-so-scary-for-the-covid-19-coronavirus
[4] https://www.dhs.wisconsin.gov/outbreaks/index.htm
[5] For example, https://alhill.shinyapps.io/COVID19seir/

infected. Other countries have experienced exponential growth over a 3-week period with doubling times comparable to that currently seen in Wisconsin.

Since we do not know how long exponential growth will continue in Wisconsin, we believe it is important not to underestimate its duration.

Case fatality rate

Descriptions of the severity of the COVID-19 pandemic have focused on the case fatality rate (CFR) which is **the proportion of diagnosed cases that result in death**. For example, the CFR reported in Italy is 7.7%[6]. However, interpreting the CFR is complicated for several reasons. The reported CFR certainly does not include mild or asymptomatic cases that were not confirmed by a laboratory test. Furthermore, applying a published CFR to all estimated cases (including asymptomatic), as opposed to the number of cases severe enough to be identified would substantially **overestimate** the total number of deaths. And finally, there is a time lag from the initial infection to death. Given an unambiguous definition of a COVID-19 case, dividing the number of deaths by the number of cases can substantially **underestimate** the CFR.

Taking into account that the COVID-19 definition changed over time, as well as the criteria for testing cases, we cannot predict a case fatality rate with high confidence. Therefore, based on our records of confirmed cases, our forecast focuses on the most severe cases and we chose a range of CFR, 2-7% based on reported literature[6].

Results

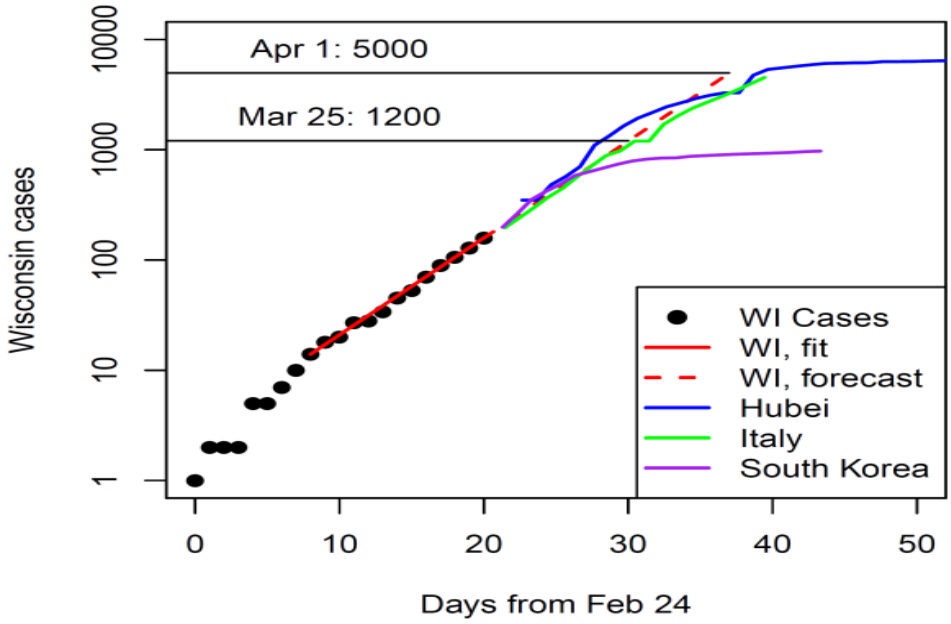
Forecast of the number of clinical cases

We estimated the number of COVID-19 clinical cases, N, using

$$N = 106 \times 2^{t/d}$$

where 106 is the total number of clinical cases based on onset date reported on or before March 13 (our reference date), $d = 3.4 \pm 0.3$ is the estimated doubling time, and t is the number of days from March 13. This model predicts case counts of about 1,200, 5,200, and 22,000 on March 25, April 1, and April 8, respectively. Importantly, this model projects the number of people infected with COVID-19, i.e. those who would test positive if they were tested. At current time, due to testing capacity constraints, the number of positive test results received are less than the number of people infected with COVID-19.

[6] https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(20)30110-8/



Wisconsin cases and near term forecast

Table 1. Near term forecasting of Wisconsin morbidity and consequent mortality due to COVID-19.

Model	Doubling time (days)	Weeks from 3/18/2020 Morbidity (Deaths)		
		By 03/25	By 04/01	By 04/08
Wisconsin cases	3.4	1,200 (9.4-87)	5,000 (100-350)	22,000 (440-1,500)
No intervention (worst case)	2	6,800 (140-470)	77,000 (1,500-5,400)	NA (interventions in place)
Hubei province (best case)	6.4	390 (7.8-27)	830 (17-58)	1,800 (38-120)

The projections are reasonably alarming but less catastrophic than what we have seen in other models. In an earlier analysis, we posted a more conservative estimate case count of 585 for March 25 using a doubling time of 6.4, but we experienced 707, therefore ruling out the conservative model. Ultimately, this conservative model estimated 2,700 **clinical cases** by April 8. Based on our experience, the above analysis used a shorter doubling time of 3.4 days. While we still do not know precisely how many cases we will have by April 8, all models predict that it will strain our healthcare systems, based on our current estimates of how many people will experience serious disease and the current number of hospital beds available and ICU capacity. Importantly, these projections describe the number of clinical cases (i.e. people who became symptomatic and presented in a clinical setting) by the set intervals (03/25, 04/01, and 04/08) projected to die from COVID-19, without further intervention. It does not represent the number of people projected to die from COVID-19 by the set intervals.

Summary

We explored global data on the COVID-19 pandemic and projected morbidity and mortality for Wisconsin's population. We concluded that this pandemic presents an urgent concern. We find that the growth rate of COVID-19 cases at this early phase of the pandemic in Wisconsin is consistent with serious consequences during the next two weeks.