Model-Driven Observations of Coronavirus

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I recently created a publicly available mathematical model for the spread of Coronavirus. At its best, model building teaches a handful of valuable insights that may be entirely non-mathematical. I share here some dominant, non-math lessons for Coronavirus. Some lessons come directly from the model while others emerge when applying the model.

Take note! The "invisible infected," "infection tail," and "infection echo" are and will be very important global concepts!

Invisible Infected: Infected people who recover within the illness period; do not seek medical attention; may not have realized their own illness; were never tested

Infection Tail: The months-long period after the peak rate of new infections during which coronavirus illnesses and deaths decline steadily

Infection Echo: A projected bump higher in the infection rate during the Infection Tail as healthy people exit isolation

Surprisingly, the number of "confirmed cases" is not a directly useful concept. Rather, far more useful is the number of hospitalized patients for the simple, yet critical, reason that we can measure hospitalizations far more reliably than infections. The "confirmed cases" depend more on the (dubious) accuracy, availability, population sampling, and timeliness of coronavirus testing than they do on the actual number of infected people. Math models, though, must "think" in terms of the number of infected people since both the recoveries and contagiousness of infected people are critical to a model's projections of illness and death. As a necessary consequence, then, we employ "newly hospitalized patients" as a (delayed) proxy for "newly infected people." We will "guess" that there's a constant multiplier we can apply to the number of newly hospitalized people to approximate a number of newly infected people. This multiplier depends primarily on the nature of the disease – both its infectiousness and the degree to which some or many infected people are not significantly impacted (*i.e.*, not hospitalized). For Covid-19, absent reliable information, this multiplier might lie anywhere in the range of 1-1,000. Call this multiplier "IM" (for "infection multiplier"). Hence, we'll think of the number of newly infected people on day N as being equal to IM multiplied by the number of newly hospitalized people on day N+14 – reflecting the model assumption that it takes 14 days for an infected person to degrade to a state requiring hospitalization OR to recover without the need for hospitalization. We consider the infected people who will never be hospitalized to be the "invisible infected."

The 14-day illness period is a critical element of the spread of Covid-19. This is an important lesson that the math model teaches. Infected people are "removed" from the population in roughly 2-3 weeks or shorter. Removal means both recovery without hospitalization and hospitalization ending in recovery or death. The spread of coronavirus would be diminished if this illness period were shorter. Conversely, a longer illness period would extend the time and severity of the virus spread.

The time during which Covid-19 increases exponentially is short. Many commentators describe infections as increasing exponentially. Yet, as a second lesson of the math model, the duration of exponential increase cannot persist as the fraction of infected people grows. (By "exponential growth," we mean that the number of infected people increases by roughly the same multiplier every day for some significant number of consecutive days.) When this fraction reaches 10%, approximately speaking, the growth will slow noticeably and is no longer exponential. The growth rate will then tend to fall and ultimately reverse to negative growth when the number of days after hitting 10% total infections approaches and exceeds the 14 days of the illness period.

Hospitalization admittances are not growing exponentially. Across the world, and especially within the United States and individual states of the

U.S., daily new hospitalizations do not appear to grow exponentially once these numbers become significant relative to the local number of hospital beds. (Of course, it still remains possible to swamp the available medical resources in this slower disease growth stage.)

IMPORTANT: Therefore, there must be a very large number of "invisible infected" people. Since new patient hospitalization admittances are not exponential, the number of infected people must be large (greater than 10% of the population, say). Yet the hospitalization numbers are nowhere near 10%. For example, the New York City (NYC) population is approximately 8.7 million while Covid-19 hospitalization in the vicinity of NYC is approximately 16,000 (~0.18% of the total population) as of March 31, 2020. The multiplier IM would need to be greater than 50 to get the total infected population to a value greater than 10%. To emphasize this fascinating point, the observation that daily hospitalization rates in a specific location do not grow exponentially coupled with our assumed proportionality between infection and hospitalization rates implies that the total (local) infected population must be greater than 10% of this population.[1,2]

New deaths will peak after the peaks for newly hospitalized people and newly infected people. As a consequence of the model's sequence of infection followed first by hospitalization for a subset of the infected and then followed by death for yet a smaller subset of the hospitalized, the daily number of new deaths will lag the daily numbers of new infections and new hospitalizations.

[1] **NOTE ADDED ON APRIL 22:** I wrote this article and published it to LinkedIn on April 1. On April 13 there appeared this Letter to the Editor of the *New England Journal of Medicine* titled "Universal Screening for SARS-CoV-2 in Women Admitted for Delivery." This letter finds that ~15% of women admitted in the date range of March 22 to April 4 at one of two Manhattan hospitals had active Covid-19 infections. This finding supports my analytical estimate.

[2] **NOTE ADDED ON APRIL 27:** On April 23 there appeared this news of New York Governor Cuomo reporting sampled measurements of the New York City population. The finding is that 21% have Covid-19 antibodies. Since antibodies can take as long as 6 weeks to appear in the blood after infection, the result constitutes additional evidence that the fraction of the NYC population infected with coronavirus in late March was well above 10%.

There will be a long “infection tail.” Consistent with both the nature of infectious diseases such as Covid-19 and our math model, the number of new infections will grow quickly in an early stage, then grow more slowly to reach a peak and decline over time thereafter. But this decline period will extend for many months. So while it’s good that the new numbers of sick and dying people will dwindle, the numbers will not drop abruptly to zero. In fact, the more society has done to “flatten the curve,” the longer will be this “tail” of infection, hospitalization, and death.

There will be an “infection echo” within this tail as the U.S. population returns to normal life. To determine when the U.S. “goes back to work,” the criterion should arguably not be “zero projected illnesses and deaths.” Rather, society must decide what will be the acceptably low illness and death rates for resumption of normal life. When this resumption of normality occurs, though, society’s infection rate will bump higher to some extent as healthy people exit isolation and expose themselves to a diminished number of remaining infected people. It will be an infection echo that is decidedly weaker than the current, menacing infection curve.

Return to normality should progress in stages. The country must return to its embrace of community life, activity, and freedom during the infection tail. Such a return is ultimately a calculation of risk versus reward and also of coronavirus risk versus other health risks that are ignored, exacerbated, or inadequately treated under quarantine life. Those people at greatest risk to coronavirus should continue, voluntarily, to exercise caution and prudence. Work from home a bit longer, if possible. Forego the handshake ritual. Be mindful of “where your hands have been” and keep carrying the pocket Purell. Coronavirus will decline with every passing cautious month.

The credibility and reliability of all data and information are unknown. Let’s sound a warning about all models, all information, and all data. As we wrote above, the number of “confirmed cases” is not a reliable measure of the actual number of infected people. But the information available for the numbers of hospitalizations, patients in intensive care units (ICUs), and deaths are also potentially unreliable. The quality of reporting by hospitals and government intermediaries may be poor. Assignment of illnesses as Covid versus non-Covid can be erroneous. Reports by government entities can be wrong and misleading intentionally or unintentionally. What this means is that the builders and users of models must be skeptical of all information whether supportive or not of one’s preliminary conclusions and biases. Intellectual and experiential coherence, which one might also call “common sense,” are essential tools. Don’t form temporary judgments until a preponderance of (apparently credible) information, logic, experience, and model results align. All judgments are temporary and one must improve them continuously by considering updated information and alternative possibilities.

#InfectionEcho #InvisibleInfected #InfectionTail #InfectionMultiplier
#Coronavirus