Effect of social distancing interventions on the spread of COVID-19 in the state of Vermont

Kunpeng Mu[1], Ana Pastore y Piontti[1], Matteo Chinazzi[1], Jessica T. Davis[1], Xinyue Xiong[1], and Alessandro Vespignani[1]

1.Laboratory for the Modeling of Biological and Socio-technical Systems, Northeastern University, Boston, MA USA

Introduction

Motivated by the local spread of COVID-19 in the United States we study the impact of different non-pharmaceutical interventions to mitigate the outbreak by using modeling scenarios. In particular we focus on the effects of social distancing measures (school closure, “stay home” or “shelter in place” policies) that may mitigate or suppress the epidemic. Modeling suggests that “Stay Home” mitigation policies are effective if sustained for several weeks. We provide a specific model that takes into account the mitigation measures as implemented in the State of Vermont and project infections and deaths in the next four weeks.

Disclaimer: There are very large uncertainties around the transmission of COVID-19, the effectiveness of different policies and the extent to which the population is compliant to social distancing policies. The presented material is based on modeling scenario assumptions informed by current knowledge of the disease, and subject to change as more data will be available. Future decisions on when and for how long to relax policies will need to be informed by ongoing surveillance. Additional modeling and data studies are required to assess the level and effectiveness of additional non-pharmaceuticals interventions required to lift current social distancing interventions.

Results

Key projections Results

- **Our model for Vermont points to the week of April 5,2020 as the peak day for hospital and ICU beds needed.**
- **Based on the last projections, a total of 63 COVID-19 deaths (range of 39 to 89) are currently predicted through April 26th, 2020.**

Figure 1A shows the daily incidence of deaths for an unmitigated scenario (no-interventions) and the scenario implementing social distancing. On average the peak for the deaths daily incidence is in the first two weeks of April, 2020. In Table 1 we report the mean expected cumulative number of deaths and the 90%CI, in the case of a “stay home” policy extended during the month of April, 2020.

Figure 1B shows the daily incidence of new infections in Vermont. This number is indicative of the epidemic trajectory in the state. However it is not directly comparable with the number of confirmed cases because of the large fraction of subclinical cases and the variations in testing rate. The plot shows however that the number of infections is expected to decline starting in the first week of April. In fig. 1B) we report the cumulative attack rate (infections per 10,000 individuals in the population). In Table 1, we report the cumulative attack rate (percentage of infected population) during the month of April 2020. These estimates should be revisited as more data on clinical and subclinical infections by age will be available (see https://www.medrxiv.org/content/10.1101/2020.03.24.20043018v1).
It is important to stress that the curves for new infections and deaths are not accounting for delay in reporting, so inflection points in real data may be delayed even more with respect to the start of interventions. Real data curves are also expected to be more noisy because of the clumping of cases or deaths from different dates that are reported on a single day.

In Fig. 1B we report the number of hospitalized patients with COVID-19. Figure 2B shows the number of ICU beds needed under the different assumptions. In an unmitigated scenario the state capacity could have been surpassed by the end of March. In the case of considering interventions, the number of ICU beds appear within capacity. However, possible heterogeneities across the state and potential clusters of cases in senior facilities might generate spikes in demand that the model cannot account for. The results on hospital and ICU occupancy is based on the assumption of a 30% overall rate of sub-clinical cases among infected people (https://www.medrxiv.org/content/10.1101/2020.03.24.20043018v1). Sensitivity analysis for different rates ranging from 20% to 50% is available on request.

Discussion

In summary the results show that aggressive social distancing measures ("stay home" or "shelter in place" policies) may keep the epidemic under control and induce a decay of the epidemic activity only if sustained for several weeks. These results suggest that additional non-pharmaceuticals interventions at scale such as testing, contact tracing, early isolation of exposed contacts and asymptomatic individuals should be implemented before lifting stringent social distancing interventions. Additional modeling and data studies are required to assess the level and effectiveness of additional non-pharmaceuticals interventions required to lift current social distancing interventions.

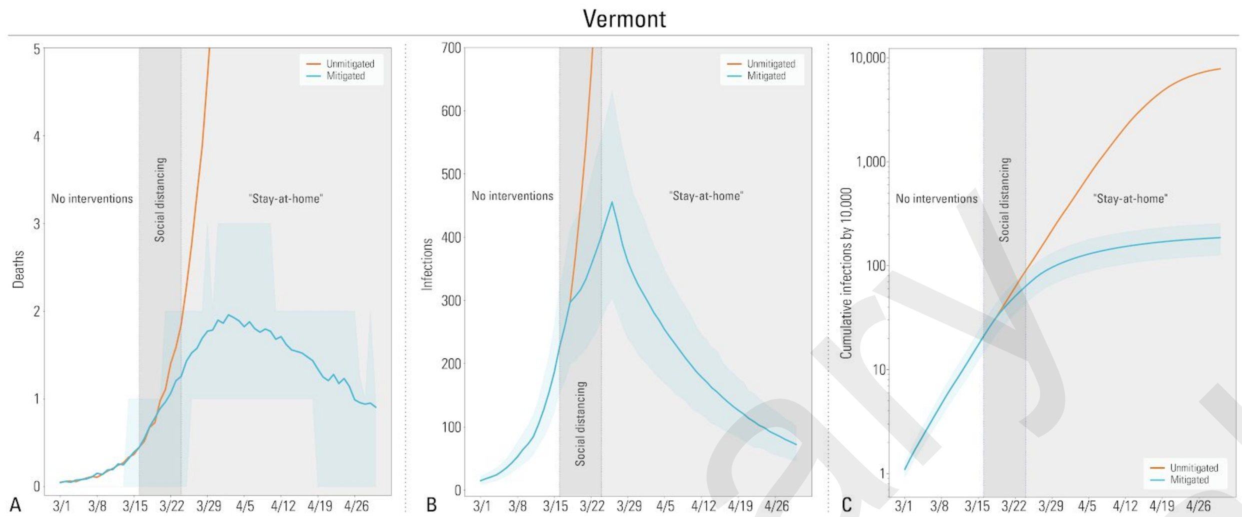

Figure 1. A) Daily incidence of deaths, B) daily new infections incidence, and C) cumulative new infections per 10,000, for the two scenarios we consider here: an “Unmitigated” scenario and a “Mitigated” scenario, where we first consider the school closure and smart working together with social distancing to then shift to a “Stay at home” situation. The solid lines represent the mean values, while the shaded areas the (A) inter-quartile range or the 90% confidence interval (B and C).

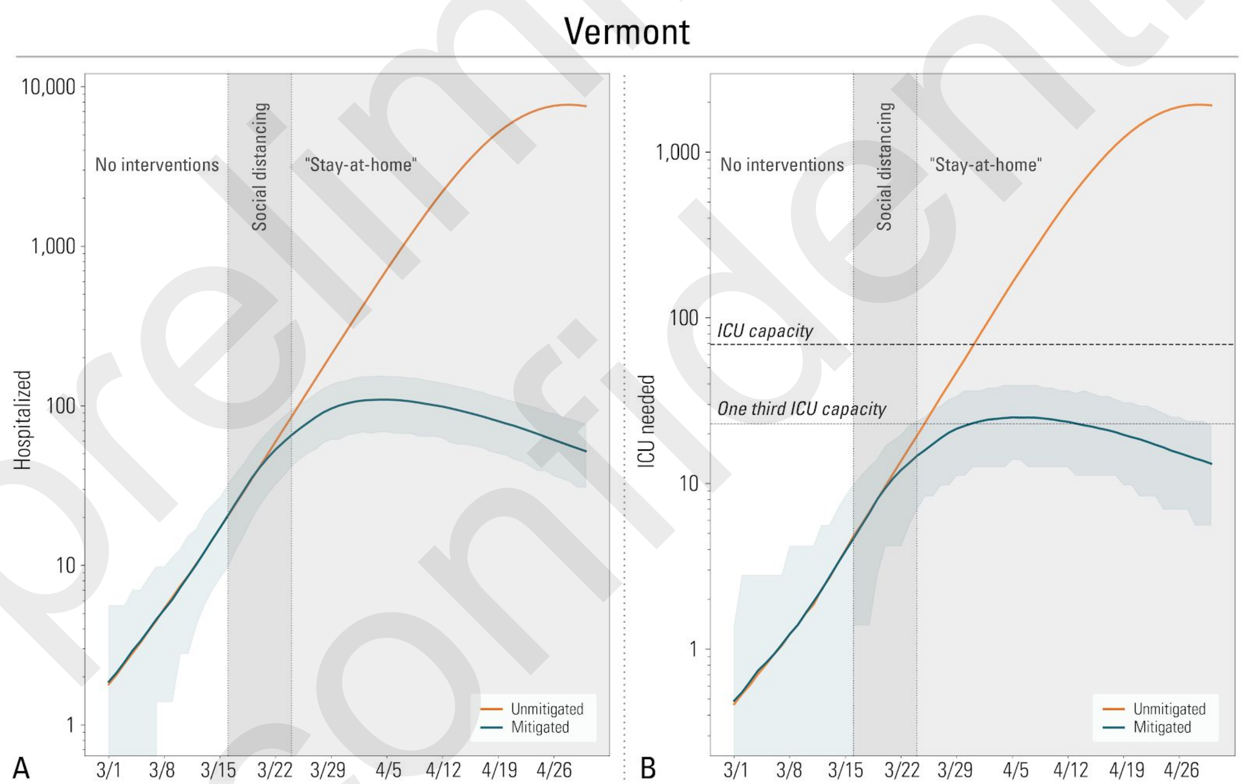

Figure 2. A)Number of hospitalized individuals and B) Number of ICU beds needed for the two scenarios we consider here: an “Unmitigated” scenario and a “Mitigated” scenario, where we first consider the school closure and smart working together with social distancing to then shift to a “Stay at home” situation. The solid lines represent the mean values, while the shaded areas the 90% confidence interval. The dark blue line is the number of ICUs occupied by COVID cases by using a 70% rate clinical case over all infections (1.4 the model estimate).

	Vermont			
	Unmitigated projection		Mitigated projection	
	Clinical AR(%) (90%CI)	Deaths (90%CI)	Clinical AR(%) (90%CI)	Deaths (90%CI)
April 5	7.36 [5.1-9.9]	99 [64-141]	1.29 [0.88-1.78]	32 [18-47]
April 12	21.73 [15.97-27.95]	320 [220-434]	1.53 [1.04-2.10]	44 [27-64]
April 19	47.75[39.36-55.59]	885 [658 -1123]	1.70 [1.15-2.32]	54 [34-78]
April 26	71.03 [65.70-75.36]	1827 [1516-2129]	1.81 [1.23-2.47]	62 [39-89]

Table 1: Cumulative attack rate (AR) and cumulative number of deaths in the unmitigated scenario versus the scenario where we consider a stay at home order from April 3 until the end of April. The deaths assume the infectious fatality rate reported in [5].

Model

We developed an age-structured compartmental model of COVID-19 transmission. This model accounts specifically for the different classes of infectious individuals (symptomatic, pre-symptomatic, and asymptomatic), as well as patients who are hospitalized and in need of intensive care units (ICU). Age mixing patterns specific for each state in the United States are derived from Mistry et al. [1]. To initialize the model in each state we consider an initialization provided by the Global Epidemic and Mobility model (GLEAM) used to study the worldwide spread of the COVID-19 outbreak from mainland China [2]. The model is calibrated using international exportations from China. The parameters defining some of the major characteristics of the model are reported in the Appendix 1.

It is important to stress that the following analysis is based on models that draw on previous research. The assumptions and caveats are discussed in a separate section. Furthermore, the model may change as new data become available, thus providing specific characteristic rates and times estimates.

We streamlined the interventions according to the following timeline:

Before March 16: Business as usual

March 16- March 23: Governor announces all bars and restaurants to be takeout-and-delivery only as of March 17 at 2:00 p.m., through at least April 6. Non-essential gatherings limited to less than 50 people or 50% of legal occupancy. Excludes offices and retail/grocery. School closure, smart working.

March 24 - Governor issues “Stay Home / Stay Safe” order mandating that all Vermonters stay home, leaving only for essential reasons and all workers work remotely when possible, that all businesses suspend in-person activities except for essential services and functions. Similar to other states' shelter-in-place orders.

This is translated in three different modeling implementations of the social contacts in the population:

- **No intervention (NI):** considers schools are open until the summer following a usual schedule and re-open in September. In addition, we consider that schools are closed over the weekends. In this way the NI scenario, even though it does not consider interventions, accounts for the reduction of the number of contacts due to weekend school closure that would normally happen.
- **SC-WR-SD: school closure, work reduction, social distancing** (regular interaction in households, no school, 50% reduced work interaction, 10% casual social contacts). This corresponds to a transmissibility reduction of about 60%.
- **"Stay Home" scenario**: we assume a stay at home policy (in some states referred to as "shelter in place") from March 16 through March 31st and then from April 16 onward for different periods of time, namely 2, 4, 8 and 12 weeks. This corresponds to a transmissibility reduction of about 70%.

We initialize our model according to the GLEAM outputs. Until March 16th, we consider there is no/minimal intervention in place. On March 16th according to the above timeline we start interventions ramping up on March 24th to the "stay home" scenario that stays until the end of April.

Note: we do not consider in the scenarios specific strategies for enhancing contact tracing, testing and early isolation of cases. We are also not considering potential changes to the virus transmissibility due to environmental factors, in particular seasonal drivers such as temperature and humidity.
The model is stochastic and age structured, considering the interaction of individuals in single years from 0 to 85+. The contact patterns account for the interaction of individuals in different settings: households, schools, workplaces, and the general community. This compartmentalization of settings allows us to implement the different interventions, controlling for the level of interaction in each one of them separately. In particular we can provide school closure, reduction of work-place contacts and causal community contacts.

Caveats and assumption

These results were obtained under several assumptions. The first is that we use modeling estimates for the effect of school closures, smart working and social distancing effects on the transmissibility of COVID-19. The model is considering the ICU capacity at the state level, however relevant heterogeneity may lead to exceed this capacity in specific urban areas earlier than at the state level. All estimates do not consider the likely introduction of specific suppression or mitigation policies issued to lower the transmissibility in specific states that experience elevated epidemic activity. Finally, we are not considering superspreading events and differential transmissibility across age brackets. Even in the presence of these limitations we hope that the information provided here can be of help in assessing the risk of transmission of COVID-19 in the US.

References

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Appendix 1

Parameter	Value
R_0	2.4-2.8
Incubation period	4 days
Infection fatality rate (%)	0–4: 0.002% 5–17: 0.00433% 18–49: 0.0364% 50–64: 1.1333% 65+: 4.45625%

Hospitalization ratio(%)	0–4: 0.1% 5–17: 0.2166% 18–49: 1.475% 50–64: 12.33% 65+: 22.0813%
ICU % among hospitalized	0–4: 5% 5–17: 5% 18–49: 5% 50–64: 17.267% 65+: 39.99%