Planning Scenarios for COVID19 in Vaud

Updated 2020-04-09

The aim of this model is to provide estimates about the course of the epidemic under a specific set of assumptions for planning purposes. **These are not direct forecasts of the epidemic.**

Summary

This report compares the health impact and surge capacity needs for the COVID-19 epidemic in Canton de Vaud. The underlying model is based on our best understanding of SARS-CoV-2 natural history and transmission, and uses current demographic and epidemiologic data from Vaud and other locations (Table 1). We project the number of hospitalizations, ICU admissions, and deaths in both the short and long term under different public-health intervention scenarios.

Table 1. Key parameters and assumptions used in the Vaud model. Hospitalization values derived from Canton de Vaud reflects our current estimate under the available data. As so, it underestimate the durations as it's biased towards short hospital stays. As more data become available, we'll provide better estimates.

Parameter	Value	Source
Population size of Canton VD	793'129	Federal Statistical Office
Generation time	6.5 to 8.2 days	IDD@JHU (mailto:IDD@JHU) analysis of reported cases
Basic reproduction number R0	1.8 to 3.3	Multiple
Reproduction number with current measures	0.45 to 1.71	Multiple
Duration of hospitalization	6.8 days	VD data
Duration of ICU stay	6.3 days	VD data
Proportion of ICU cases among hospitalized patients	20%	VD data
Ratio death / hospitalization	10%	VD data
Ratio hospital death / total death	0.66	VD data

Short-term cantonal estimates with current measures in place

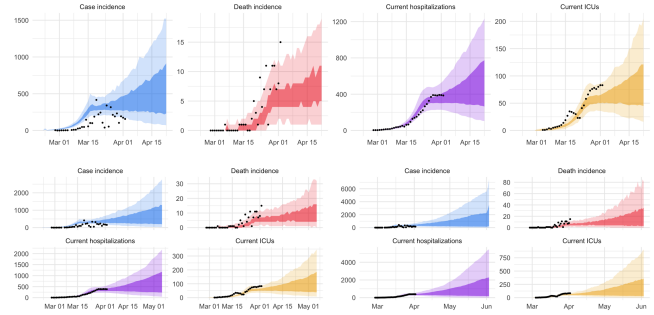

Figure 1. Modelled incidence of cases and death, along with current hospital and ICU occupancy at horizons 2 weeks (top line), 4 weeks (bottom left) and 8 weeks (bottom right). The black dot represents cantonal data, the dark colored region the 50% confidence interval and the lightly colored region the 95% confidence interval.

Table 2. Short term projections. In all tables, we display the mean accross all simulations, along with the 95% interquartile range.

	2 weeks		4 weeks		8 weeks	
	median	95%CI	median	95%CI	median	95%CI
Peak current hospitalizations	500	(290-1,200)	600	(290-2,200)	800	(300-5,000)
Peak current ICUs	90	(50-200)	100	(50-300)	140	(50-900)
Cumulative cases	16,000	(8,000-30,000)	23,000	(9,000-60,000)	40,000	(10,000-180,000)
Cumulative ICUs	500	(270-800)	700	(310-1,600)	1,300	(400-5,000)
Cumulative hospitalizations	2,500	(1,400-5,000)	4,000	(1,600-9,000)	7,000	(1,800-28,000)
Cumulative deaths	190	(120-300)	300	(150-600)	600	(170-2,100)

Long term planning under different scenarios

We consider three planning scenarios:

- **Current Measures**, which assumes measures as they were instituted in canton de Vaud:
- School closure on March 13,
- Physical distancing measures progressively established from March 16 to March 20.

We assume these moderately restrictive non-pharmaceutical interventions (NPIs) to reduce transmission by 48 - 75% (R0 from 0.45 to 1.71) based on a city with similar social distancing measures in place during the 1918 influenza pandemic and on the most recent R0 estimates in Switzerland. In this scenario, these measures are maintained for the foreseeable future.

- **Current Measures Stopped May 31**, the measures described in the Current Measures scenario are held up until May 31st, then we assume a return to high transmissibility (R0 from 1.8 to 3.3) for the foreseeable future.
- **Full lockdown**, which assumes that very aggressive non-pharmaceutical interventions that reduce transmission by 81 - 88% (R0 from 0.25 to 0.63) are put in place from April 5 on. This scenario is based on the Wuhan lockdown that started on January 23, 2020.

Hospital and ICU usage

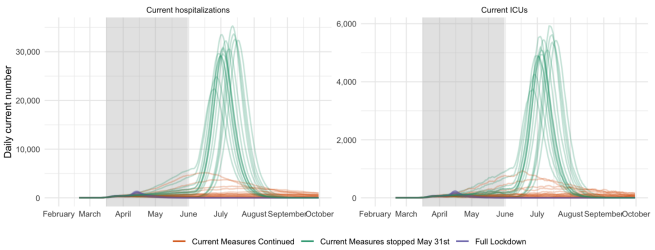

Figure 2. Time series for 15 random example simulations for three planning scenarios of SARS-CoV-2 spread in Vaud. Interventions in the Current Measures Discontinued Scenario are applied from March 16 to May 31 (grey box), while in other scenarios measures are continued until October.

Table 3. Current Measures Continued

	May 1		June 1		September 1	
	median	95%CI	median	95%CI	median	95%CI
Peak current hospitalizations	500	(270-1,900)	700	(270-5,000)	900	(280-5,000)
Peak current ICUs	90	(50-280)	120	(50-700)	170	(50-900)
Cumulative cases	19,000	(9,000-50,000)	40,000	(10,000-160,000)	110,000	(10,000-400,000)
Cumulative ICUs	600	(280-1,300)	1,100	(300-5,000)	4,000	(400-14,000)
Cumulative hospitalizations	2,900	(1,500-7,000)	6,000	(1,800-25,000)	19,000	(1,900-70,000)
Cumulative deaths	230	(130-500)	500	(170-2,000)	1,700	(190-7,000)

Table 4. Current Measures Stopped May 31st

	May 1		June 1		September 1	
	median	95%CI	median	95%CI	median	95%CI
Peak current hospitalizations	500	(290-1,800)	800	(300-5,000)	30,000	(24,000-40,000)
Peak current ICUs	90	(50-270)	140	(50-800)	5,000	(4,000-6,000)
Cumulative cases	20,000	(9,000-50,000)	40,000	(10,000-160,000)	700,000	(700,000-800,000)
Cumulative ICUs	600	(300-1,300)	1,200	(300-5,000)	27,000	(26,000-27,000)
Cumulative hospitalizations	3,100	(1,600-7,000)	6,000	(1,800-25,000)	130,000	(130,000-140,000)
Cumulative deaths	250	(140-500)	500	(170-1,800)	13,000	(13,000-14,000)

Table 5. Full Lockdown

	May 1		June 1		September 1	
	median	95%CI	median	95%CI	median	95%CI
Peak current hospitalizations	800	(400-1,600)	800	(400-1,600)	800	(400-1,600)
Peak current ICUs	150	(80-280)	150	(80-280)	150	(80-280)
Cumulative cases	19,000	(11,000-30,000)	21,000	(12,000-30,000)	21,000	(12,000-30,000)
Cumulative ICUs	700	(400-1,100)	700	(400-1,300)	700	(400-1,300)

Cumulative hospitalizations	3,000	(2,000-6,000)	4,000	(2,100-6,000)	4,000	(2,100-6,000)
Cumulative deaths	290	(180-500)	400	(200-600)	400	(200-600)

ICU Capacity exceedence

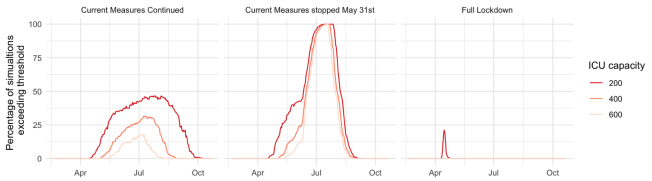

Figure 3. Fraction of simulations exceeding ICU capacity thresholds. In each scenario, we show the percentage of simulations exceeding the 200, 400, 600 ICU beds threshold.

Contributors

Prepared by Joseph Lemaitre, Javier Perez-Saez, Andrew Azman, Andrea Rinaldo, Jacques Fellay.

Pipeline from Johns Hopkins ID Dynamics Working Group (http://www.iddynamics.jhsph.edu/): Kyra H. Grantz, Joshua Kaminsky, Lindsay T. Keegan, Steve Lauer, Elizabeth C. Lee, Joseph Lemaitre, Justin Lessler, Hannah R. Meredith, Shaun A. Truelove.

Contact: joseph.lemaitre@epfl.ch (mailto:joseph.lemaitre@epfl.ch?subject=Hyperlinks), jacques.fellay@epfl.ch (mailto:jacques.fellay@epfl.chh?subject=Hyperlinks)

Limitations

We note several limitations to our work, among which:

There remains considerable uncertainty around some of the key epidemiologic features of COVID-19, including the average duration of infectiousness and time to recovery or death. We have used commonly accepted and well supported estimates and believe that they are appropriate for planning purposes.

We assume equal risk of infection and progression to hospitalization or death among all individuals in the canton at a given time point. There is evidence of age-specific differences in clinical burden and perhaps in susceptibility to infection that are not (yet) considered here.

We assume Re, the effective reproductive number, to be constant in each scenario, other than changes due to onset of non-pharmaceutical interventions. As capacity for surveillance, contact tracing, and testing improve, and as the general public becomes increasingly aware of the outbreak and modifies their own behavior, we might expect that Re will decrease dynamically, perhaps even as a function of the perceived COVID19 burden. As the outbreak continues, it will be possible to refine the scenarios considered here to better reflect the actual epidemic situation.

We do not explicitly model the role of asymptomatic infection when calculating the number of expected hospitalizations. All infectious individuals are considered at risk of hospitalization, though some may recover or die prior to hospitalization. A substantial asymptomatic burden may reduce the number of hospitalized cases.

Model assumptions

We built a stochastic, Susceptible-Exposed-Infected-Recovered (SEIR) model of SARS-CoV-2 transmission in canton Vaud.

Population. The total population and age distribution were collected from the website of the Swiss Federal Statistical Office. The entire population of the canton is assumed to be susceptible at the beginning of the model. We assume equal risk of infection for all individuals at a given time.

Initial conditions. We used the first confirmed cases recorded in Vaud on February 25 to inform the importations that seeded our epidemic model. We assumed that there was a reporting rate of 20% during this period using Poisson draws with a rate parameter five times the cumulative number of cases. Baseline transmissibility in the model is similar to the early days of the Wuhan epidemic (R0 = 2-3.3).

Reproductive Number. The reproductive number R0, or the average number of secondary cases caused by a single infected individual in a susceptible population, varies by scenario. Note that the reproductive number is highly-context specific. There is still uncertainty in the range of possible R0 values for SARS-CoV-2, and varying effectiveness of non-pharmaceutical interventions, including social distancing, improved hand hygiene, and case detection and isolation, may further reduce R0.

COVID-19 Natural History. From analysis of 181 confirmed SARS-CoV-2 cases among travelers and other publicly reported cases, we estimate the incubation period, or the time from exposure to symptom onset, to follow an exponential distribution with mean 5.2 days (IQR 1.5, 7.21 days) (Fig. S1). The average duration of infectiousness following symptom onset is between 1.3 days and 3, following an Erlang distribution with 3 compartments. We thus sample across a range of possible mean serial intervals (time from symptom onset of an index case to symptom onset of a secondary case infected by the index) from 6.5 to 8.2 days.

Rates of Death and Hospitalization. From our analysis of 391 confirmed SARS-CoV-2 infections in Shenzhen, China, we estimate the average time to hospitalization from symptom onset follows a log-normal distribution with median 3.42 days (IQR 2.01, 5.83) (Fig. 3). Other rates where derived from CHUV and Vaud hospitalization data. We fitted a log normal distribution to the observed distribution of time hopsitalized, time in ICU, time from hospitalization to ICU and time to death. We estimate from current data that, among those hospitalized, 20% will be admitted to the ICU.

Filtering. Simulated time series of incidence and hospitalizations are based on 30'000 random draws from reasonable bounds of the parameter values (Table 1). Among these draws, we resample to narrow the set to a simulation that matches the observed reality in hospitalization. Namely, we assign to each simulation a weight that is proportional to the likelihood w.r.t the incident hospitalization.

We use simple statistical models using the cumulative distribution of times to hospitalization, ICU admission, and death, as well as the durations of hospitalization and ICU stay to calculate the number of incident and cumulative hospitalizations and ICU admissions and deaths per day, accounting for appropriate delays since infection and symptom onset.

Uncertain parameters include the length of the serial interval, R0 and the probability of hospitalization. Simulated time series of incidence and hospitalizations are based on 30'000 random draws from reasonable bounds of the parameter values (Table 1). Simulated trajectories are then resampled based on the degree to which they match the observed time series of cumulative hospitalizations, which gives a set of simulations which represent well the observed data.

Key Sources

- Impact of broad scale non-pharmaceutical intervetions is based on the observed impact of such programs in 1918 as reported in (Bootsma and Ferguson 2007). We took parameter estimates on the effectiveness of interventions from Milwaukee in this study.
- School closure impacts based on data from (Jackson et al. 2020), (Cauchemez et al. 2008) and (Litvinova et al. 2019)
- Approximate generation time is based on data from (Bi et al. 2020)

Appendix

Hospitalization data analysis

Key points:

- 956 have been hospitalized
- The mean hospitalized CFR in the past 3 days is of 11%
- 20% of patients where treated in an ICU
- The mean hospitalization time is of 6.4 days
- The mean ICU time is of 5.6 days

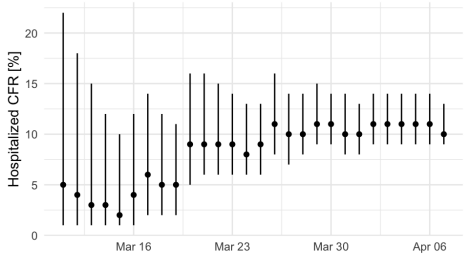

Figure A.1. Hospitalized case fatality ratio (hCFR). Estimates of hCFRs where based on the methods of Ruan et al. (2020) (https://doi.org/10.1371/journal.pone.0006852) (points are the Maximum Likelihood estimates and bars give 95% CIs).

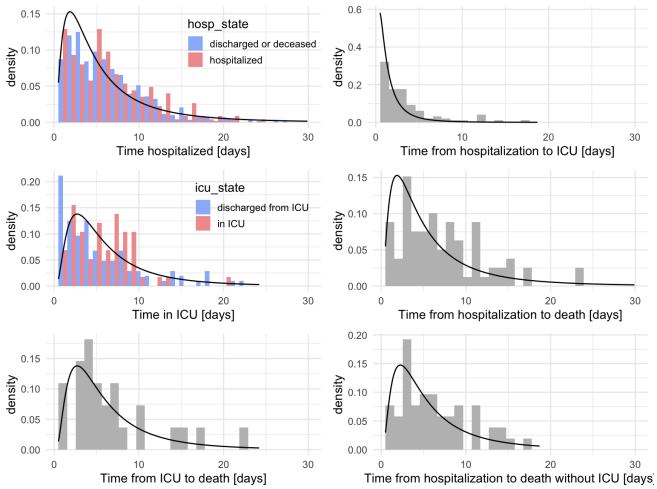

Figure A.2. Time distributions of modelled hospitalization processes. Bars represent data from alll VD hospitals and lines estimated probability distribution functions as used in the model.

Epidemic dynamics under different scenarios