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CHAPTER 5

Coronavirus disease COVID-19 tracking the global outbreak. SEIR compartmental model applied to SARS-CoV-2 epidemic in Romania

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5.1 Introduction

Viral infections have been and probably will remain a major issue for the World Health Organization. Thus, at the beginning of the 21st century, humanity was confronted with the epidemic of severe acute respiratory coronavirus syndrome (SARS-CoV) and in 2009 with the H1N1 flu epidemic.

At the end of 2019 in the city of Wuhan, an extremely crowded and well-known place in China, there was a significant increase in the number of cases of patients arriving in hospitals with low respiratory infections. Initially, the researchers considered that these patients were suffering from a certain type of pneumonia, but continuous research showed that it was actually a condition caused by a virus belonging to the coronavirus (CoV) family.

On February 11, 2020, the disease caused by this virus was officially named COVID-19. In the last two decades, coronavirus has caused other epidemics, such as MERS-CoV.

The CoVs became the key pathogens of emerging respiratory illness outbreaks. They are an oversized family of single-stranded RNA viruses (+ssRNA) which can be isolated in several animal species. For reasons yet to be elucidated, these viruses can cross species barriers and may cause in humans illnesses starting from the usual cold to more severe diseases like MERS and SARS. Remarkably, these latter viruses have probably originated from bats and then entered into other mammalian hosts—the Himalayan palm civet for SARS-CoV, and also the dromedary camel for
MERS-CoV—before leaping to humans. The dynamics of SARS-CoV-2 are presently unknown, but there is theoretical speculation that it also has an animal origin.

The prospective for these viruses to develop to become a worldwide pandemic seems to be a significant public health risk. With regard to COVID-19, the WHO extended the threat of the CoV epidemic to the “very high” level, on February 28, 2020. Probably the consequences of the epidemic caused by the new CoV have yet to emerge because the situation is quickly evolving. On March 11, because the number of COVID-19 cases outside China had increased 13-fold and also the number of states involved had tripled with more than 118,000 cases in 114 countries and over 4000 deaths, WHO declared the COVID-19 a pandemic.

The treatment is symptomatic, and oxygen therapy represents the key treatment intervention for patients with severe infection. Mechanical ventilation may be also necessary in cases of respiratory failure refractory to oxygen therapy, whereas hemodynamic support is important for managing septic shock.

Initial data suggest the reported death rate ranges from 1% to 2% depending on the study and country. The majority of the fatalities have happened in patients over 50

### Table 5.1 Sampling of the estimates for epidemic parameters.

| Location               | Reproduction number $R_0$ | Incubation period $T_{inc}$ | Infection period $T_{inf}$ |
|------------------------|---------------------------|-----------------------------|-----------------------------|
| Kucharski (2020)       | Wuhan 3.0 (1.5–4.5)       | 5.2                         | 2.9                         |
| Li et al. (2020)       | Wuhan 2.2 (1.4–3.9)       | 5.2 (4.1–7.0)               | 2.3 (0.0–14.9)              |
| Wu et al. (2020)       | Greater Wuhan 2.68 (2.47–2.86) | 6.1                         | 2.3                         |
| Word Organization Health (2020a) | Hubei 1.95 (1.4–2.5)   |                             |                             |
| Word Organization Health (2020b) | Hubei 2.25 (2.0–2.5) | 5.5 (5.0–6.0)               |                             |
| Liu, Hu, et al. (2020) | Guangdong 4.5 (4.4–4.6)  | 4.8 (2.2–7.4)               | 2.9 (0–5.9)                 |
| Rocklöv, Sjödin, and Wilder-Smith (2020) | Princess Diamond 14.8 | 5.0                         | 10.0                        |
| Backer, Klinkenberg, and Wallinga (2020) | Wuhan 6.5 (5.6–7.9) |                             |                             |
| Read, Bridgen, Cummings, Ho, and Jewell (2020) | Wuhan 3.11 | (2.39–4.13)                 |                             |
| Bi et al. (2020)       | Shenzen 4.8 (4.2–5.4)    |                             |                             |
Figure 5.1 Epidemic calculator results for the $R_t = 2.2$ (do nothing).

Figure 5.2 Epidemic calculator results for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 50.
Figure 5.3 Epidemic calculator results for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 60.

Figure 5.4 Epidemic calculator results for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 70.
years old. Young children seem to be somewhat infected but may serve as a vector for extra transmission.

In particular, severe and critically ill persons, whose condition changes rapidly, often with multiple organs infected, require the sustenance from a multidisciplinary team (MDT).

Organized analysis is at the core of MDT discussion. Senior patients with underlying health conditions are liable to become critically ill. While meticulously monitoring the progression of COVID–19, the patient’s elementary status, complications, and daily examination results should be analyzed comprehensively to work out how the disease will progress. It is necessary to intervene ahead to prevent the disease from deteriorating and to require proactive measures like antivirals, oxygen therapy, and nutritional support.

The goal of MDT discussion is to realize personalized treatment. The treatment plan should be adjusted to every person when considering the dissimilarities among individuals, courses of infection, and patient types. Following global experience it had been noticed that the support from MDT teamwork can significantly improve the efficiency of the diagnosis and treatment of COVID–19.

At the beginning of March 2020 Tomas Pueyo reported that the difference between the cases by date of symptom and the cases by date of diagnosis illustrated lag

![Epidemic calculator](image)

**Figure 5.5** Epidemic calculator results for the $R_t = 0.95$ (decrease transmission by 57%), intervention on day 50.
time between the start of illness and the diagnosis of COVID-19 by viral nucleic acid testing. The first few cases of pneumonia of unknown etiology were shown on December 26 \((n = 4)\) and 28\(\sim 29\ (n = 3)\) (Pueyo, 2020). Most cases in December that showed such symptoms were discovered later, when a retrospective investigation was performed.

What lessons can be learned from this pandemic:

- by comparing the fatality rates, the calendar of events and the interventions of the public health institutions, it was found that the death rates were about 50% lower in the cities that implemented preventive measures earlier, compared to those that undertook them very much later or not at all. The most effective efforts were materialized by the simultaneous closure of schools, churches, and theaters and the ban on public gatherings. These gave time for the development of the vaccine and diminished the strain on the healthcare system;

- intervention measures that were relaxed too early could cause the relapse of an otherwise stabilized city. St. Louis, for example, was so encouraged by the low death rate that the city lifted restrictions on public meetings less than 2 months after the outbreak. Soon an eruption of new cases followed. Of the cities that

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**Figure 5.6** Epidemic calculator results for the \(R_t = 0.95\) (decrease transmission by 57%), intervention on day 60.
did the interventions on the spot, none experienced a second wave of high death rates;

- interventions were credited with reducing transmission rates by 30%–50%. New York City, which responded at the earliest to the crisis with obligatory isolation and staggered working hours, recorded the lowest fatality rate on the East Coast;
- in 1918 studies determined that the key to flattening the curve is social distancing. And this probably remains true a century later, in the current battle against coronavirus (Wu & McGoogan, 2020);
- the risk of exposure of persons in a group to coronavirus increases exponentially with the size of the event, as suggested by the results of modeling by Maggiacomo and Greshko (Maggiacomo & Greshko, 2020).

In another theoretical model that closely resembles Hubei, waiting another day creates 40% more cases. So, possibly, if the authorities in Hubei declared lockdown on January 22 instead of January 23, they could have reduced the number of cases to 20,000 (Chinazzi et al., 2020; Pueyo, 2020). This is a model created by epidemiologists and is still uncertain. If a big difference has not been spotted, then the model holds true. It is very difficult to see any change in the development of the epidemic. The researchers estimate that, in general, the travel ban in/from Wuhan

Figure 5.7 Epidemic calculator results for the $R_t = 0.95$ (decrease transmission by 57%), intervention on day 70.
delayed the spread of the virus in China by 3–5 days (Chinazzi et al., 2020). If the transmission rate drops by 25% (through social distancing), it flattens the curve and delays the peak by 14 weeks. Reducing the transition rate by 50%, the epidemic doesn’t register even after a quarter (Li et al., 2020). Moreover, in a recent report it can be observed how transmissions could have been caused by presymptomatic infections (Liu, 2020).

It was estimated that 23% (correlation range: 12%–28%) of Shenzen transmissions could have been caused by presymptomatic infections. Due to the accelerated isolation of cases after the onset of symptoms, this percentage increased to 46% (21%–46%), which means that approximately 35% of secondary infections were prevented, among the symptomatic cases (Bi et al., 2020). These results were resistant to the use of reports of incubation periods and serial intervals from other settings. Presymptomatic transmission may be essential to consider COVID-19 containment and mitigation strategies.

### 5.2 Model overview and epidemic calculator

The epidemic calculator is intended to model the spreading of infectious diseases. There is ongoing research on how the disease spreads and the percentage of the

![Epidemic calculator](image)

**Figure 5.8** Epidemic calculator results including "Recovered" parameter for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 50.
population that becomes infected or dies due to the virus (Croccolo & Roman, 2020; Kermack & Mckendrick, 1927; Wu, Leung, & Leung, 2020). The epidemic calculator used here implements an infectious disease model—SEIR (Susceptible → Exposed → Infected → Removed) (Gao, Teng, Nieto, & Torres, 2007; Harko, Lobo, & Mak, 2014)—an idealized model of spread still employed in the frontline of research (e.g., Croccolo & Roman, 2020; Kucharski, 2020; Wu et al., 2020). The dynamics of this model are characterized by a collection of four ordinary differential equations that correspond to the stages of the disease’s progression. In addition to the transmission dynamics, this model uses the employment of extra timing information to model the death rate and healthcare load. Note that one can use this calculator to measure one’s hazard exposure to the disease for any given day of the epidemic: the possibility of getting infected on day 218 given close contact with 40 persons is 0.00088% given an attack level of 0.45% (Burke et al., 2020).

The clinical dynamics in this model are an elaboration on SEIR that simulates the disease’s development at an upper resolution, subdividing I, R into mild (patients who recover without the necessity for hospitalization), moderate (patients who necessitate hospitalization but live), and fatal (patients who require hospitalization and don't live). Each of those variables follows its own path to the ultimate

![Epidemic calculator](image)

Figure 5.9 Epidemic calculator results including “Recovered” parameter for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 60.
outcome, and therefore the sum of those compartments adds up to the values projected by SEIR (Beckley et al., 2013; Harko et al., 2014). Note that it is assumed, for ease of calculation, that every one of the fatalities comes from hospitals, as all fatal cases are admitted to clinics shortly after the infectious period.

A sampling of the estimates for epidemic parameters is provided in Table 5.1.

A detailed survey of current estimates of the reproduction number were reported by Liu, Gayle, Wilder-Smith, and Rocklöv (2020). Parameters for the diseases' clinical characteristics are taken from the WHO Report (World Organization Health, 2020b).

This computer model was run for the population of Romania in 2019 of 19,364,557 (Worldometer, 2020).

The following situations were analyzed:

- do nothing;
- take action (social distancing) on day 50, 60, 70;
- check two values of the transmission rate;
- the situation of elimination of the population through isolation and/or immunization was introduced at the end and is presented in the (Figs. 5.1–5.10) (Tables 5.2–5.11).

![Epidemic calculator results including “Recovered” parameter for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 70.](image)
Table 5.2 Summary of the epidemic calculator results for the $R_t = 2.2$ (do nothing).

|                                    | $R_t = 2.2$ (do nothing) | Day # |
|------------------------------------|--------------------------|-------|
| Exposed (pop currently in incubation) | 2,355,356                | 135   |
| Infectious (actively circulating)   | 1,285,225                | 137   |
| Hospitalized                       | 1,582,299                | 157   |
| Fatalities                         | 279,118                  | 199   |

Table 5.3 Summary of the epidemic calculator results for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 50.

|                                    | $R_t = 0.88$ (decrease transmission by 60%) | Day # |
|------------------------------------|-------------------------------------------|-------|
| Exposed (pop currently in incubation) | 421                                       | 50    |
| Infectious (actively circulating)   | 202                                       | 54    |
| Hospitalized                       | 251                                       | 94    |
| Fatalities                         | 91                                        | 199   |

Table 5.4 Summary of the epidemic calculator results for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 60.

|                                    | $R_t = 0.88$ (decrease transmission by 60%) | Day # |
|------------------------------------|-------------------------------------------|-------|
| Exposed (pop currently in incubation) | 1,382                                     | 60    |
| Infectious (actively circulating)   | 670                                       | 64    |
| Hospitalized                       | 854                                       | 103   |
| Fatalities                         | 292                                       | 199   |

Table 5.5 Summary of the epidemic calculator results for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 70.

|                                    | $R_t = 0.88$ (decrease transmission by 60%) | Day # |
|------------------------------------|-------------------------------------------|-------|
| Exposed (pop currently in incubation) | 4,557                                     | 70    |
| Infectious (actively circulating)   | 2,225                                     | 74    |
| Hospitalized                       | 2,811                                     | 113   |
| Fatalities                         | 932                                       | 199   |
Table 5.6 Summary of the epidemic calculator results for the $R_t = 0.95$ (decrease transmission by 57%), intervention on day 50.

| $R_t = 0.95$ (decrease transmission by 57%) | Day # |
|------------------------------------------|-------|
| Exposed (pop currently in incubation)    | 402   | 50   |
| Infectious (actively circulating)        | 200   | 54   |
| Hospitalized                             | 335   | 109  |
| Fatalities                               | 126   | 199  |

Table 5.7 Summary of the epidemic calculator results for the $R_t = 0.95$ (decrease transmission by 57%), intervention on day 60.

| $R_t = 0.95$ (decrease transmission by 57%) | Day # |
|------------------------------------------|-------|
| Exposed (pop currently in incubation)    | 1,268 | 60   |
| Infectious (actively circulating)        | 643   | 64   |
| Hospitalized                             | 1,036 | 119  |
| Fatalities                               | 384   | 199  |

Table 5.8 Summary of the epidemic calculator results for the $R_t = 0.95$ (decrease transmission by 57%), intervention on day 70.

| $R_t = 0.95$ (decrease transmission by 57%) | Day # |
|------------------------------------------|-------|
| Exposed (pop currently in incubation)    | 4,570 | 70   |
| Infectious (actively circulating)        | 2,271 | 74   |
| Hospitalized                             | 3,403 | 127  |
| Fatalities                               | 1,267 | 199  |

Table 5.9 Summary of the epidemic calculator results including “Recovered” parameter for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 50.

| $R_t = 0.88$ (decrease transmission by 60%) | Day # |
|------------------------------------------|-------|
| Exposed (pop currently in incubation)    | 411   | 50   |
| Infectious (actively circulating)        | 207   | 54   |
| Recovered                                | 4,774 | 218  |
| Hospitalized                             | 276   | 90   |
| Fatalities                               | 93    | 218  |
5.3 Conclusions

From the above results (which indicate the closeness of computed data, to the results of day 60 of action) it can be concluded that:

1. the zero case was not on February 25, 2020;
2. it was not a singular case.

From the results of the last graphs, where we introduced the population eliminated by isolation/immunization, the withdrawal from the population pool of infected persons (symptomatic and/or asymptomatic) by means of mass testing gets special importance.

Finally, running a program written in Python in the environment “Google collab” on the Romanian cases, applying the logistic model, leads to the forecasting of the date of April 14 (105 days from January 1, 2020) as the peak of the COVID-19 crisis (value forecasted by the authorities, as well) (Fig. 5.11).

| Table 5.10 | Summary of the epidemic calculator results including “Recovered” parameter for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day 60. |
|------------|-------------------------------------------------------------------------------------------------|
| $R_t = 0.88$ (decrease transmission by 60%) | Day # |
| # of people | |
| Exposed (pop currently in incubation) | 1,314 | 60 |
| Infectious (actively circulating) | 640 | 64 |
| Recovered | 14,409 | 218 |
| Hospitalized | 882 | 104 |
| Fatalities | 278 | 218 |

| Table 5.11 | Summary of the epidemic calculator results including “Recovered” parameter for the $R_t = 0.88$ (decrease transmission by 60%), intervention on day: 70. |
|------------|-------------------------------------------------------------------------------------------------|
| $R_t = 0.88$ (decrease transmission by 60%) | Day # |
| # of people | |
| Exposed (pop currently in incubation) | 4,295 | 70 |
| Infectious (actively circulating) | 2,107 | 74 |
| Recovered | 45,982 | 198 |
| Hospitalized | 3,095 | 116 |
| Fatalities | 880 | 198 |
Figure 5.11 Evolution of the total number of infected people (by logistic model) starting from January 1, 2020, fitting on real data.
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