COVID-19 Medical Inventory Prediction

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Abstract

This document describes the assumptions behind the estimated medical inventory requirement for attending to COVID-19 patients in hospitals, as projected in https://covid19medinventory.in. The estimated patient counts have been obtained from https://mesoscalelab.github.io/covid19/. The projections are themselves dynamic, and can change every week depending on newly available evidence. The medical inventory list and the formule for its dependence on the type of patients is also dynamic, and will change as we find better relationships with actual field data.

1 Basic Assumptions

The number of COVID-19 positive patients obtained from the district-wise projection[1] is denoted as N. This could be the current number or the projected number in future weeks. According to WHO statistics[2], the number of patients who actually need various levels of care[3] is given in the table below:

Type of patient	Type of care	approx %	Symbol used here
Total positive	–	100%	N
Mild	Symptomatic, Home Quarantine/isolation (out-patients)	40%	N_{q}
Moderate	In-patient ward	40%	N_{i}
Severe	Supportive care, oxygen therapy	15%	N_{s}
Critical	ICU, mechanical ventilation	5%	N_{cr}
Deceased	–	2.5%	N_{d}

2 Inventory Estimates

The tables below gives the inventory list, the estimation logic, and formula, and an example calculation for $N = 100$ positive cases.

In the example case the patient estimates are given below. In the website, some of the numbers are rounded higher to the nearest 10 or 50, depending on their magnitude.

Category	Symbol	Estimate
Total positives	N	100
Mild	N_{q}	40
Moderate	N_{i}	40
Severe	N_{s}	15
Critical	N_{cr}	5
Deceased	N_{d}	2.5

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Let C denote the number of patients currently in critical care, A for the number in acute care and S in supportive care. We assume the following scenario:

1. Critical care patients who are discharged spend τ_c amount of time in the ICU, following which they are taken to the supportive care unit for recuperation.
2. A fraction f_d of the critical care patients do not survive and die in a time τ_d.
3. Acute care patients spend a time τ_a before recovering.
4. Supportive care patients spend a time τ_s before recovering.
5. The fraction of infection persons who need critical, acute, and supportive care are: f_c, f_a, and f_s respectively.
6. The rate of infection is denoted by Q_I.

The evolution of the critical care patients is given by:

$$\begin{aligned}\frac{dC}{dt} &= \text{Rate of admissions} \\ &\quad - \text{Rate of discharge (to supportive care)} \\ &\quad + \text{Mortality rate} \\ &= f_c\, Q_I - (1 - f_d)\,\frac{C}{\tau_c} + f_d\,\frac{C}{\tau_d}\end{aligned} \tag{1}$$

here, C/τ is the rate at which C patients take a time τ to be out of critical care. Similar equations can be written for the acute and supportive care (taking into account influx from ICU):

$$\frac{dA}{dt} = f_a\, Q_I - \frac{A}{\tau_a} \tag{2}$$

$$\frac{dS}{dt} = f_s\, Q_I - \frac{S}{\tau_s} + (1 - f_d)\,\frac{C}{\tau_c} \tag{3}$$

Typical values for the residence times are

$$\tau_c = 7 \quad \text{days} \tag{4}$$

$$\tau_d = 9 \quad \text{days} \tag{5}$$

$$\tau_s = 14 \quad \text{days} \tag{6}$$

$$\tau_a = 14 \quad \text{days} \tag{7}$$

Assuming,

$$\tau = \tau_c \approx \tau_d \approx \frac{\tau_s}{2} \approx \frac{\tau_a}{2} \tag{8}$$

the evolution equation can be simplified as

$$\frac{dC}{dt} = f_c\, Q_I - \frac{C}{\tau} \tag{9}$$

$$\frac{dA}{dt} = f_a\, Q_I - \frac{A}{\tau} \tag{10}$$

$$\frac{dS}{dt} = f_s\, Q_I - \frac{S}{\tau_a} + (1 - f_d)\frac{C}{\tau} \tag{11}$$

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4 Errors and Omissions

Though the authors have taken sufficient care in estimating the quantity of the inventory, the proportions used here may change depending on the actual field data in India for the patients and the inventory usage pattern. Please email your comments and suggestions with justifications to p.sunthar@iitb.ac.in for inclusion in the future updates of the software.

A Patient projection model

The key formulae from patient prediction model[1] is given here. Let the case fatality rate (CFR) as defined by number deceased N_d to the total number of cases N be

$$m = \frac{N_\mathrm{d}}{N} \tag{12}$$

It is assumed that the CFR is same for all districts of a state.

The number of critical patients N_cr is taken to be bounded by the two different death rates (as per predictions given under):

$$2\,N_\mathrm{d,low} \le N_\mathrm{cr} \le 4\,N_\mathrm{d,high} \tag{13}$$

where the lower bound factor (of 2) is based on world averages[2] and the upper bound is based on ??. Here, $N_\mathrm{d,low}$ and $N_\mathrm{d,high}$ are the deaths predicted by the lower and higher death-growth rates, respectively (see below).

A.1 Growth predictions

The weekly growth of number of deaths is given by

$$N_\mathrm{d}(t+n) = g(n)\,N_\mathrm{d}(t) = g(n)\,m\,N(t) \tag{14}$$

where g is a weekly growth factor and n is the number of weeks from a reference date at t. There are two scenarios for the values of g: Low growth and High growth, which are bounds of the death growth rates obtained by fitting the growth rates across the world[1]. The low growth factor for values of $n = \{1,2,3,4\}$:

$$g_\mathrm{low} = \begin{cases} \{4, 27.85, 85, 160\} & N_\mathrm{d} < 10 \\ \{5.5, 20.70, 150\} & N_\mathrm{d} \ge 10 \end{cases} \tag{15}$$

Similarly, the high growth factor for values of $n = \{1,2,3,4\}$:

$$g_\mathrm{high} = \begin{cases} \{6.5, 42, 110, 300\} & N_\mathrm{d} < 10 \\ \{7.6, 35, 108, 230\} & N_\mathrm{d} \ge 10 \end{cases} \tag{16}$$

These growth factors provide the corresponding projected $N_\mathrm{d,low}$ and $N_\mathrm{d,high}$ from Eq. (14).

References

[1] Santosh Ansumali and Aloke Kumar. A district-wise projection map for covid-19 in india. Technical report, JNCASR and IISc, 2020.

[2] *Operational considerations for case management of COVID-19 in health facility and community*. World Health Organisation. 19 March 2020.

[3] *COVID-19 Preparedness document*. AIIMS, New Delhi. 27 March 2020.