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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ICU patients at a given day t

$$
\begin{aligned}
N_{\mathrm{ICU}}(t) &= \text{New admissions on } t \\
&\quad - \text{Deaths on } t \\
&\quad - \text{Discharged on } t \text{ after } m \text{ days of admission} \\
&\quad + \text{Continuing on } t \text{ from the last } m-1 \text{ days} \\
&= \Delta N_{\mathrm{cr}}(t) - \Delta N_{\mathrm{d}}(t) - (1-f_{\mathrm{d}})\,\Delta N_{\mathrm{cr}}(t-m) + (1-f_{\mathrm{d}}) \sum_{r=1}^{m-1} \Delta N_{\mathrm{cr}}(t-r)
\end{aligned} \tag{1}
$$

where, the new ICU admissions, or deaths on a day is the increase in the number of critical patients from the previous day:

$$\Delta N_{\mathrm{cr}}(t) = N_{\mathrm{cr}}(t) - N_{\mathrm{cr}}(t-1) \tag{2}$$

$$\Delta N_{\mathrm{d}}(t) = N_{\mathrm{d}}(t) - N_{\mathrm{d}}(t-1) \tag{3}$$

The number of deaths on a given day is a fraction of the admissions n days earlier:

$$\Delta N_{\mathrm{d}}(t) = f_{\mathrm{d}}\,\Delta N_{\mathrm{cr}}(t-n) \tag{4}$$

or alternatively:

$$\Delta N_{\mathrm{cr}}(t) = \frac{1}{f_{\mathrm{d}}}\,\Delta N_{\mathrm{d}}(t+n) \tag{5}$$

Since the model estimates the deaths correctly Eq. (1) can be rewritten as:

$$N_{\mathrm{ICU}}(t) = \frac{1}{f_{\mathrm{d}}}\left(\Delta N_{\mathrm{d}}(t+n) - f_{\mathrm{d}}\Delta N_{\mathrm{d}}(t) - (1-f_{\mathrm{d}})\,\Delta N_{\mathrm{d}}(t-m+n) + (1-f_{\mathrm{d}}) \sum_{r=1}^{m-1} \Delta N_{\mathrm{d}}(t-r+n)\right) \tag{6}$$

Similarly, we can estimate the number of persons in acute care (ACU, for the severe cases) and supportive care (SCU for moderate and/or mild cases). Assuming the residence time of Acute Care is m_{a} and that for Supportive Care (in-patient) is m_{i} current number of patients in each of these care units is:

$$
\begin{aligned}
N_{\mathrm{ACU}}(t) &= \text{New admissions on } t \\
&\quad - \text{Discharged on } t \text{ after } m_{\mathrm{a}} \text{ days of admission} \\
&\quad + \text{Continuing on } t \text{ from the last } m_{\mathrm{a}}-1 \text{ days} \\
&= \Delta N_{\mathrm{s}}(t) - \Delta N_{\mathrm{s}}(t-m_{\mathrm{a}}) + \sum_{r=1}^{m_{\mathrm{a}}-1} \Delta N_{\mathrm{s}}(t-r)
\end{aligned} \tag{7}
$$

In the case of SCUs, in addition to the above, the patients discharged from the ICUs are recuperated for the same m_{i} days. However, this number is small compared to the number admitted afresh (3 against 40 to 80), therefore is ignored.

$$
\begin{aligned}
N_{\mathrm{SCU}}(t) &= \text{New admissions on } t \\
&\quad - \text{Discharged on } t \text{ after } m_{\mathrm{i}} \text{ days of admission} \\
&\quad + \text{Continuing on } t \text{ from the last } m_{\mathrm{i}}-1 \text{ days} \\
&= \Delta N_{\mathrm{i}}(t) - \Delta N_{\mathrm{i}}(t-m_{\mathrm{i}}) + \sum_{r=1}^{m_{\mathrm{i}}-1} \Delta N_{\mathrm{i}}(t-r)
\end{aligned} \tag{8}
$$

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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

$$m = \frac{N_\mathrm{d}}{N} \tag{9}$$

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):

$$2\,N_\mathrm{d,low} \le N_\mathrm{cr} \le 4\,N_\mathrm{d,high} \tag{10}$$

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

$$N_\mathrm{d}(t+n) = g(n)\,N_\mathrm{d}(t) = g(n)\,m\,N(t) \tag{11}$$

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 $n = \{1, 2, 3, 4\}$:

$$g_\mathrm{low} = \begin{cases} \{4, 27.85, 85, 160\} & N_\mathrm{d} < 10 \\ \{5.5, 20.70, 150\} & N_\mathrm{d} \ge 10 \end{cases} \tag{12}$$

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

$$g_\mathrm{high} = \begin{cases} \{6.5, 42, 110, 300\} & N_\mathrm{d} < 10 \\ \{7.6, 35, 108, 230\} & N_\mathrm{d} \ge 10 \end{cases} \tag{13}$$

These growth factors provide the corresponding projected $N_\mathrm{d,low}$ and $N_\mathrm{d,high}$ from Eq. (11).

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.