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[AP2-E1-3-03] Modelling and Forecasting the Capacity Needs and Patient Load in Designated COVID Hospitals in Underserved Areas

*Pramod D Jacob[1], Verghese A Thomas[1], Simran Agrawal[2] （1. DHIndia Association, India, 2. Goa Institute of Management, India）

Keywords: COVID-19, Prediction Modelling, Forecasting, Capacity Planning and Management, Designated COVID-19 Hospitals

The global COVID-19 pandemic has posed significant threats to health care systems in developing countries such as India which were operating under infrastructural and manpower constraints before the pandemic reached Indian populations. One of the major challenges of the pandemic has been to anticipate the requirement for hospital beds in COVID-19 designated hospitals between a week to four weeks into the future. DHIndia Association (Digital Health India Association) has been offering the power of Information Technology to some selected hospitals in underserved areas of rural India to provide them with estimates of caseloads from a day to a month ahead to aid in their hospital planning and to guide protocols. The methodology used was a predictive model based on the SIR (Susceptible Infected Recovered) paradigm from the University of Pennsylvania. The model gave predicted numbers of cases for almost a month in advance. The model was applied to a hospital in Jalna, Maharashtra and Simdega, Jharkhand. The estimates from the model were found to be close to the actual number of patients admitted in these hospitals. The results of the model runs were used to guide the hospital administrators and health officials in managing their COVID-19 protocols and infrastructure so that their hospital capacity and supplies would not be exceeded. These case studies demonstrate a timely and unique application of health information technology for the benefit of remote Indian hospitals working amongst underserved communities.

Modelling and Forecasting the Capacity Needs and Patient Load in Designated COVID Hospitals in Underserved Areas

Pramod D. Jacob[a], **Verghese A. Thomas**[a] and **Simran Agrawal**[b]

[a] *DHIndia Association, India*
[b] *Goa Institute of Management, India*

Abstract

The global COVID-19 pandemic has posed significant threats to health care systems in developing countries such as India which were operating under infrastructural and manpower constraints before the pandemic reached Indian populations. One of the major challenges of the pandemic has been to anticipate the requirement for hospital beds in COVID-19 designated hospitals between a week to four weeks into the future. DHIndia Association (Digital Health India Association) has been offering the power of Information Technology to some selected hospitals in underserved areas of rural India by providing them with estimates of caseloads from a day to a month ahead to aid in their hospital planning and to guide protocols. The methodology used was a predictive model based on the SIR (Susceptible Infected Recovered) paradigm from the University of Pennsylvania. The model gave predicted numbers of cases for almost a month in advance. The model was applied to a hospital in Jalna, Maharashtra and Simdega, Jharkhand. The estimates from the model were found to be close to the actual number of patients admitted in these hospitals. The results of the model runs were used to guide the hospital administrators and health officials in managing their COVID-19 protocols and infrastructure so that their hospital capacity and supplies would not be exceeded. These case studies demonstrate a timely and unique application of health information technology for the benefit of remote Indian hospitals working amongst underserved communities.

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Introduction

The need for access to healthcare services is a challenge in a developing nation like India which has a large population and inadequate resources available for healthcare compared to higher income countries [1]. With the onset of the COVID-19 pandemic in India in March 2020, the country's health care infrastructure was not prepared for a high caseload of COVID-19 patients [2]. One of the major challenges in the battle against COVID-19 is to anticipate the requirement for hospital beds in COVID-19 designated hospitals between a week to four weeks into the future. A forecast of the expected future caseload would inform hospital administrators of requirements for ICU capacity, ventilators, PPEs, non-ICU beds and most importantly oxygen supply before the actual needs materialised. The need of increasing capacity by having additional beds in ancillary set ups such as empty schools, tents and even in rail coaches would also be indicated by a forecasting system. Additionally, it would guide modifications to protocols for admission, discharge, ICU and mechanical ventilation. This is crucial given that there are no precedents to reliably inform clinical and administrative decision making during the current pandemic.

To aid such hospitals, DHIndia Association (Digital Health India Association) has been offering pro-bono, the power of Information Technology to some selected hospitals in underserved areas to provide them with forecasting and estimates of caseloads from a day to a month ahead. The service was provided to hospitals in rural and semi- rural parts of Maharashtra, Gujarat, Madhya Pradesh and Jharkhand. It helped the government authorities and hospital management make timely and proactive course correcting decisions in order to better manage the increased case load due to COVID-19, which otherwise may have overwhelmed health systems.

Several COVID-19 forecasting tools have been deployed since the start of the pandemic to aid hospital capacity planning. There are significant variations in the attributes of these tools. Systems such as the Regional Hospital Capacity Calculator from Harvard University [3], the Localized COVID-19 Model and Scenario Planner from Qventus [4] and the Capacity Planning and Analysis System (CPAS) of the UK NHS [5] are location specific and are meant for use within the US and UK. The COVID-19 Forecasting tool from the University of Washington Institute of Health Metrics and Evaluation [6] provides forecasting for several countries but currently India is not among them. Other tools such as the COVID-19 Hospital Impact Model for Epidemics (CHIME) from the University of Pennsylvania [7] can be used in any country by modifying parameters using local data. The tools also vary regarding the capacity requirements which are projected. The icu-covid-sim tool by the University of Amsterdam [8] and CPAS in the UK [5] are specific for ICU projections while others like CHIME and the COVID-19 ICU and Floor Projections from Stanford University [9] include non-ICU capacity projections. There are also variations in the resolution to which the forecasts can be applied. Some provide forecasts for individual hospitals while others only provide forecasts at wider levels such as health referral regions, state and country levels.

DHIndia was introduced to the CHIME tool in May 2020. As it was applicable to our needs, easy to use, accessible and it was found to be accurate in pilot model runs, the CHIME tool was used for providing the COVID-19 forecasting service to hospitals in underserved areas in India.

Materials and Methods

The methodology used for the case study was a modelling methodology that assisted hospitals in understanding the hospital capacity requirements by predicting the number of admissions, ICU patients and the number of patients requiring ventilators up to 4 weeks in advance. The predicted quantities aided capacity planning by the hospitals. The model used was the SIR model, i.e., Susceptible, Infected and Recovered paradigm from the University of Pennsylvania (COVID-19 Hospital Impact Model for Epidemics - CHIME) [3]. The model provided accurate forecasts and gave predictions for almost a month in advance.

Two categories of data were needed for running the model- “one-time data” which was required at the start of the modelling and the “data which was required almost on the regular basis”. The one time data included the catchment population of the selected state or district (catchment population means the population of that district where a COVID-19 designated hospital is located), share of the catchment population (e.g., if this is one of the two designated COVID-19 hospitals, with this one having 100 beds and the other having 50 beds, the share of the catchment population would be 66.7%), date of the first Covid positive hospitalised/ admitted patient and the count of the infectious days (number of days an infected person can infect another irrespective of whether symptomatic or asymptomatic). This was taken as 10 as Covid generally follows this thumb rule of infectious days.

The data required on a regular basis (once in two or three days) as the epidemic curve started rising included the number of hospitalised patients present at the time of making a forecast, present doubling time in the catchment area (if the date of the first hospitalised patient was not known), date of the lockdown or the social distancing norms that came into effect, percentage of the social distancing norms, percentage of the active positive patients who were hospitalised, percentage of the active positive patients who were in ICU, the percentage of active positive patients who were ventilated, the average number of days in ICU, average hospital length of stay in days, days that this disease was infectious for someone infected, average number of days on ventilator, the current date, the number of days to project and a logarithmic scale option which automatically modified the graph such that the patients discharged were taken out of the graph automatically, instead of linear line display.

Results

Jalna, Maharashtra

Jalna is one of the districts in the interiors of Maharashtra located east of Aurangabad with a population of around 24 lacs or 2.4 million. The district has its own designated Covid hospital which is a stand-alone dedicated building with 120 total Covid beds, 80 non-ICU beds with oxygen supply, 40 ICU beds of which 35 beds are with ventilators. The hospital also has additional capacity which can be converted to designated Covid wards if required. The testing and admissions in the hospital started around 25th April. Initially the hospital’s protocol was to admit all the patients who tested positive.

A modelling run was done on May 19, 2020. The forecasting system projected the number of patients before and after May 19, 2020. The retrospective estimates were compared to the actual number of patients admitted at the hospital before May 19 and found to be similar as shown in the table and screenshot of the model output given below.

Table 1- Data for model for Jalna 19, 2020

Date	**April 19th**	**May 2nd**	**May 17th**	**May 19th**
Number of patients predicted	2	8	29	35
Actual number of patients admitted in Hospital	2	8	28	34

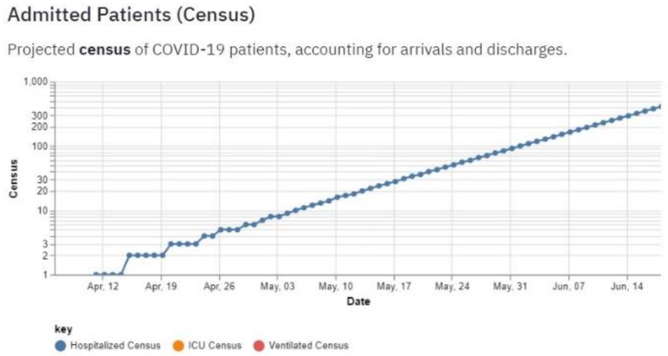

Figure 1- Screen shot of model output for Jalna May 19, 2020

This projection predicted that the capacity of 120 beds would be crossed on June 4, 2020. This projection was found to be accurate until May 29, 2020 i.e. on most days the number of patients hospitalised correlated closely with the projections from the model.

The next modelling run was done on May 31, 2020. There was little difference found between the actual hospital data and the output provided by the model for the period before May 31.

Table 2- Data for model for Jalna 31, 2020

Date	**April 19th**	**May 3rd**	**May 17th**	**May 26th**	**May 31st**
Number of patients predicted	2	8	25	55	80
Actual number of patients admitted	2	8	28	56	79

The number of hospitalised patients at the hospital was expected to cross 120 by June 6, 2020. In light of this projection the admissions and discharge protocols were changed as follows: for admissions the officials shifted the asymptomatic and mildly symptomatic patients to rural hospitals or primary health centres, so that the main COVID-19 hospital would admit only moderate and severe cases. For discharge, a retest for COVID-19 infection was omitted. Discharge was given only on the tenth day from admission if the patient was stable and asymptomatic for at least 5 days.

Subsequently on June 6, 2020 the number of admitted patients was 104 and the hospital's capacity was not exceeded.

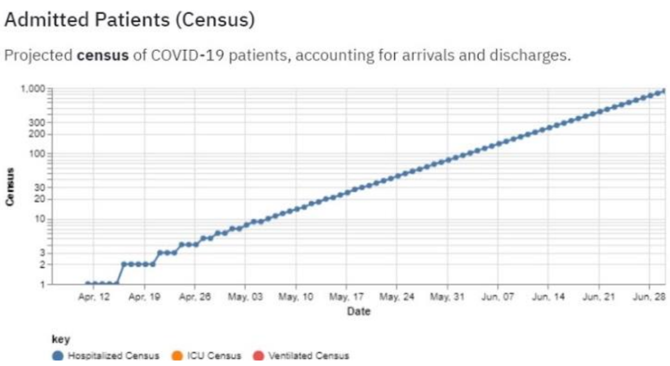

Figure 2- Screen shot of model output for Jalna May 31, 2020

Simdega, Jharkhand

Simdega district in Jharkhand is about 120 kms south west of Ranchi and has a population of around 7 lacs (mostly tribal). The hospital for which the forecasting was made was the Shanti Bhawan Hospital, a designated district Covid hospital for the district. The total COVID-19 beds in the hospital were 32, of these 22 were non-ICU beds with oxygen supply. Of the 10 ICU beds in the hospital 4 were with ventilators.

There were many challenges faced by Shanti Bhawan Hospital, as the hospital is located in a rural part of Jharkhand with minimal healthcare facilities and infrastructure. The total number of doctors in the hospital are 4 including the director, and the nurses and clinical staff are also limited in number. Although the hospital only has the capacity to handle 15 Covid cases, the district administration directed the hospital to assign 32 beds for COVID-19. Due to its remote location it takes 4-5 days to get the results of COVID-19 tests from the samples collected from patients of the hospital because of which the hospital had to admit and quarantine family contacts of patients till their results came back. Furthermore, it takes two days to replenish the oxygen supply as the oxygen tanks are refilled across the state border in Rourkela Industrial estate, Orissa. When they first started getting COVID-19 patients, the hospital followed the protocol of admitting all COVID-19 positives as per the directions given by the govt. health authorities Given these challenges, information to guide the hospital administration was crucial.

The first modelling run for Shanti Bhawan Hospital was done on 1st June, 2020 and the output for the period before 1st June, 2020 was compared with actual past data and the two were found to be similar.

Table 3- Data for model for Simdega, June 1, 2020

Date	**May 21st**	**May 29th**	**May 31st**	**June 1st**
Number of patients predicted	0	7	10	12
Actual number of patients admitted in Hospital	1	8	10	13

As per the first projection the requirement for beds would exceed the capacity of 32 beds around June 6, 2020.

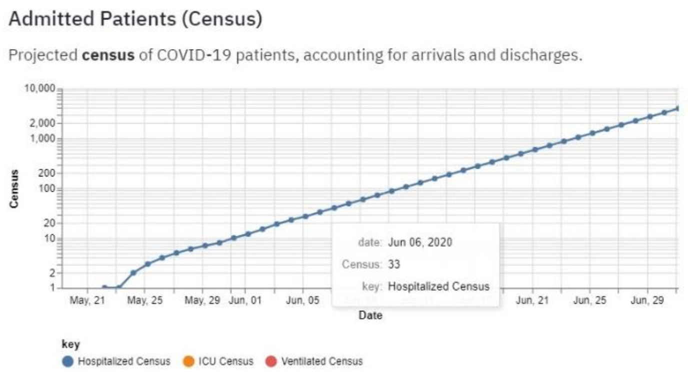

Figure 3- Screen shot of model output for Simdega June 1, 2020

The second modelling run was done on June 4, 2020 and the output was compared with the actual past data.

Table 4- Data for model for Simdega, June 4, 2020

Date	**May 29th**	**June 1st**	**June 4th**
Number of patients predicted	7	13	23
Actual number of patients admitted in Hospital	8	12	24

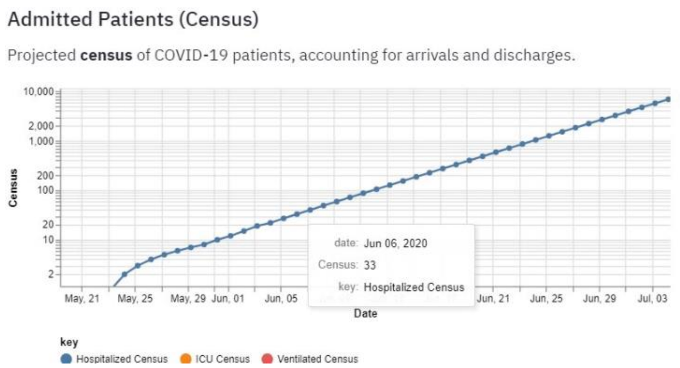

Figure 4- Screen shot of model output for Simdega June 4, 2020

As with the first projection of June 1, this second projection of June 4 also predicted that the capacity of 32 beds would be crossed around June 6 (33). The ICU did not have any patients till date so the projection did not show any ICU projection.

The results of the second projection led to modifications of the admitting protocols by the government health authorities. Two alternative sites were arranged for asymptomatic patients and the patients with low risk of severe illness, thereby leaving 32 beds in Shanti Bhawan Hospital for moderate to severe COVID-19 patients along with COVID-19 positive pregnant women.

Discussion

A number of prediction models have been deployed in North America and Europe for case projection and capacity planning [3-9]. However, examples of such projections being used for health care planning in lower- and middle-income countries are not well known. The publications on predictive modelling for India pertain to projections of caseloads for the country as a whole or its regions [10-11]. It can be surmised that the application of predictive modelling to aid hospital planning reported in this article is unique in India among remote rural hospitals if not among the many well connected large urban hospitals in India as well. It should also be noted that although the CHIME model was developed and deployed in the USA, we have found it useful in the very different socio demographic context of rural India. The tool has only one demographic input parameter – the size of the regional population of the hospital being modelled. Although we were unable to account for socio demographic differences between the USA and India in the modelling runs, we still found the predictions were accurate. Apart from population size, COVID-19 spread and contact parameters such as the doubling time and social distancing are also parameters which are external to the hospitals forecasted in the CHIME model. We used data from the health authorities to derive these inputs.

While sociodemographic factors are well documented determinants of the levels of illness in pandemics [12], the CHIME model does not require inputs on these factors while predicting the number of cases to be expected at a hospital. It is unclear why our application of the model to rural Indian settings was found to be accurate in spite of the socio demographic differences between the USA and India. This requires further investigation. A potential starting point for such an investigation could be to determine whether the effects of the sociodemographic factors in the population were accounted for in the input parameters on COVID-19 spread and contact used in the CHIME model.

Conclusions

The results of our model runs were used for the benefit of remote rural Indian hospitals which are among the health systems most vulnerable to being over-run by the COVID-19 pandemic. Using the information provided by the forecasting, system administrators and health officials were able to ensure that their facilities were prepared in time for the rising number of cases and their capacity was not exceeded. Our case studies demonstrate that predictive modelling using health information technology systems for case projection and capacity planning is feasible and beneficial for remote hospitals in India and should be developed further.

Compliance with Ethical Standards

The authors declare no conflict of interest

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2. Dr Christopher Moses, Jalna

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Address for Correspondence

Dr Pramod D. Jacob
DHIndia Association
F1303, Purva Venezia, Yelahanka New Town
Bangalore – 560065, India.
E-mail: ceo@dhindia.org