

PREDICTION OF DISEASE BURDEN AND HEALTHCARE RESOURCE UTILIZATION THROUGH SIMPLE PREDICTIVE ANALYTICS USING MATHEMATICAL APPROACHES, AN EXPERIENCE FROM UNIVERSITY OF MALAYA MEDICAL CENTRE

Azzeri A^{1,2}, Hakim NFA¹, Jaafar H², Dahlui M^{1,3,4,5}, Othman S^{1,6}, and T Kamarul⁷.

¹Department of Research, Development and Innovation, Universiti Malaya Medical Centre, 50603 Kuala Lumpur, Malaysia

²Department of Primary Care, Faculty of Medicine and Health Sciences, Universiti Sains Islam Malaysia, 71800 Negeri Sembilan, Malaysia

³Department of Social and Preventive Medicine, Faculty of Medicine, University of Malaya, 50603 Kuala Lumpur, Malaysia

⁴Centre for Population Health (CePH), Faculty of Medicine, University of Malaya, 50603 Kuala Lumpur, Malaysia

⁵Faculty of Public Health, University of Airlangga, Surabaya, Indonesia

⁶Department of Primary Care Medicine, Faculty of Medicine, University of Malaya, 50603 Kuala Lumpur, Malaysia

⁷National Orthopaedic Centre of Excellence for Research and Learning (NOCERAL), Department of Orthopaedic Surgery, University of Malaya, 50603 Kuala Lumpur, Malaysia

Correspondence:

Tunku Kamarul Zaman bin Tunku Zainol Abidin,
National Orthopaedic Centre of Excellence for Research and Learning (NOCERAL),
Department of Orthopaedic Surgery,
Faculty of Medicine,
University of Malaya, 50603 Kuala Lumpur, Malaysia
Email: tkzrea@ummc.edu.my

Abstract

The sudden surge in the number of healthcare utilizations compels the hospital to plan for its future needs. Several time-series projections of Covid-19 were conducted to forecast the disease burden and resources utilization through simple predictive analytics. The projections revealed a rapid increase in the number of cases and patient in care at the hospital. It was estimated that the number of patients in care to range from 62 to 81 and 89 to 121 patients daily in the second and third phase of movement control order respectively. It was estimated that more than 100,000 plastic aprons, 80,000 sterile and non-sterile isolation gowns, 40,000 masks N95 and face shields, 30,000 gloves and nearly 17,000 bottles of hand sanitizers are needed until late May. Hence, a simple mathematical algorithm is a helpful tool to manage hospital resources during the pandemic.

Keywords: Covid-19, Projection of Burden, Healthcare Utilisations

Introduction

Critical shortages of health resources from the increasing number of Covid-19 are seen in many countries. Medical supplies such as facemasks, hand sanitizers and personal protective equipment (PPE) are reported to be insufficient in many healthcare centres (1), including Malaysia. Inadequate production and mounting disruption of medical supplies caused by the rising demand during the outbreak may endanger and put the risk to the patients as well as the healthcare workers. The World Health Organization (WHO) estimated that nearly half a million sets of PPE have been delivered to several countries. However, the supplies are still insufficient and rapidly depleting (2).

The sudden surge in the number of healthcare utilizations through casualty and outpatient visits, inpatient admissions, number of respiratory supports needed and other clinical services forces the hospital management to utilize the available resources as efficiently as possible and to plan for the future needs. In many countries, before the Movement Control Order (MCO) or national lockdown, the process to obtain medical supplies is faster. Presently, with the current Covid-19 condition worldwide, the supplies take months to deliver with extensive market manipulation and surge in prices (3).

University of Malaya Medical Centre (UMMC) is one of the dedicated university hospitals to screen and treat

Covid-19 patients in Malaysia. The centre receives patients mainly from two identified red zones in Kuala Lumpur, which are Lembah Pantai and Petaling Jaya, resulted in a rapid influx of hospital users during the outbreak. The hospital management must plan for the right strategies and management practices to optimize resources and alleviate shortages, particularly the PPEs to ensure delivery of care is uninterrupted. Importantly, the safety of the healthcare workers is secured with adequate supply of PPE. Proper utilisation of PPEs can prevent spread of the infection within the hospital when managing confirmed or suspected Covid-19 cases. Therefore, a simple predictive analysis using mathematical methods and algorithms was conducted to forecast the disease burden and PPE utilization at the medical centre. Findings from the analysis could facilitate decision making to provide adequate medical supplies and to optimize the resources used during Covid-19 outbreak (4, 5).

Materials and Methods

Several time-series projections of Covid-19 were conducted gradually to forecast the disease burden and resources utilization at UMMC. Before the announcement of MCO, an initial national projection was conducted by using daily rate and trend of positive cases from 25th February until 8th of March 2020 in Italy. The numbers from Italy were used due to the possibility of an exponential surge of cases from identified clusters in Malaysia, as seen in Italy. Through the projection, cumulative and daily positive cases in Malaysia were estimated by using similar rates and trends. Based on available data, Italy recorded an explosion of Covid-19 infection, 50 days since its first case was detected. Similarly, in Malaysia it was found that a sudden surge of cases following the second wave in the middle of March reached 1306 total cases, 60 days since the first cases in Malaysia was reported. Even though the magnitude is smaller, Malaysia's cases seemed to be following the pattern of Italy's cases (6, 7).

After a more detailed and specific national data became available, such as daily and cumulative tests conducted, daily and cumulative positive cases, daily and cumulative number of patients in care, daily and cumulative admission to intensive care unit, daily and cumulative requirement for ventilators, daily and cumulative death and daily and cumulative discharge, second projections with several scenarios were done to explore the different possibilities of Covid-19 implications in Malaysia. In the second projections, a decision tree technique (8) was used to estimate a cumulative number of positive cases based on the present clusters of Covid-19 and also several events that could have caused another surge of infection. The second projections included several parameters such as the probability of infection among symptomatic and asymptomatic patients (50% in each group) and R^0 from available literature, which was 2 and 4. The rate and trend of daily positive cases, the proportion of patient in care, the fraction of patient admitted to the intensive care unit and the number of death followed the retrospective data reported by the Ministry of Health Malaysia.

Based on the data obtained, the daily median growth rate of cumulative positive cases was estimated at 0.98 and the growth acceleration was predetermined at 20. From 1st of April 2020 onwards, the daily median growth rate was expected to be higher at 1.14. Based on the retrospective national data, the maximum daily growth rate was 1.3 and in order to factor in the impact of the possible mass gathering event, the panic events and exodus of people who had returned to their hometowns following Movement Control Order announcement the average of 0.98 and 1.3 was used, which is 1.14, because the magnitude of growth rate of cumulative positive cases due to the events is unknown. It was estimated that for every day that passes, the number of cumulative cases would increase by that fixed amounts respectively. Of the cumulative positive cases, rate of cumulative discharge and rate of cumulative death were estimated to be constant at 0.03 and 0.002 respectively, following the reported national data. The number of patients in care was obtained by subtracting the number of patients discharged and the number of deaths. Then, cumulative number of patients in intensive care unit (ICU) was estimated at 0.033 of the patients in care. Based on the national findings, the number of patients in care at UMMC was estimated accordingly with the same rates and proportions and the findings were presented in the results and in figures provided.

Subsequently, an updated and refined projection was conducted by using the same methods as described above with more recent national data after the first phase of MCO had completed. The projection was revised and refined accordingly as a different trend was seen following the MCO which could be due to many external factors such as an increase in the number of screening, increase laboratory capacity to process screening tests, presence of new clusters, and increase in MCO compliance rate. The latest projection estimated the number of screening conducted and number of patients in care until the end of April 2020 in Malaysia. The methods used were adapted and adopted to obtain similar statistics at UMMC. Finally, the amount of PPE required from the volume of users estimated and the average consumption rate of PPE based on the standard clinical practice for Covid-19 management was assessed (7).

The projection of number of Covid-19 screening and patient in care in UMMC were made by using the assumption that they are proportionate with daily rates and trends of cumulative positive cases reported in Malaysia. The median growth of the number of screening was fixed at 0.68 while patient in care was fixed at 0.33 from the previous day. Using the assumption that the number of PPE used depends on the number of patients screened and patient in care, a ratio between the variables was estimated and weightages were developed based on reported actual usage of every PPE items in UMMC. A simple model was then used to forecast the number of PPE required until the end of May 2020. Subsequently, simple moving average method was used to get an overall idea of daily PPE trend usage, since it is easy to use and useful to separate out random variation of daily PPE usage within a 2 weeks period.

Results

Findings of this analysis were described and presented in sequence order. For the first projection, by using rate and trend from Italy, a steady increase in the number of

cumulative cases was seen until 9th of April 2020 followed by an exponential increase in the number of cumulative positive cases as described in Figure 1.



Figure 1: Projection of cumulative number of positive Covid-19 cases in Malaysia based on Italy’s rate and trend of Covid-19 cases

In the second projection, through the decision tree technique, the total number of positive cases from the present and possible clusters was estimated to be approximately 18,000 nationwide and of that 3,000 patients are expected to be treated at UMMC. Similarly, an exponential increase in the number of cases was seen

until the number of possible cases was saturated which was estimated to be around mid of April 2020. By April 2020, the estimated number of patients in care at UMMC is expected to be approximately 4,000 with over 100 patients in the intensive care unit as presented in Figure 2.

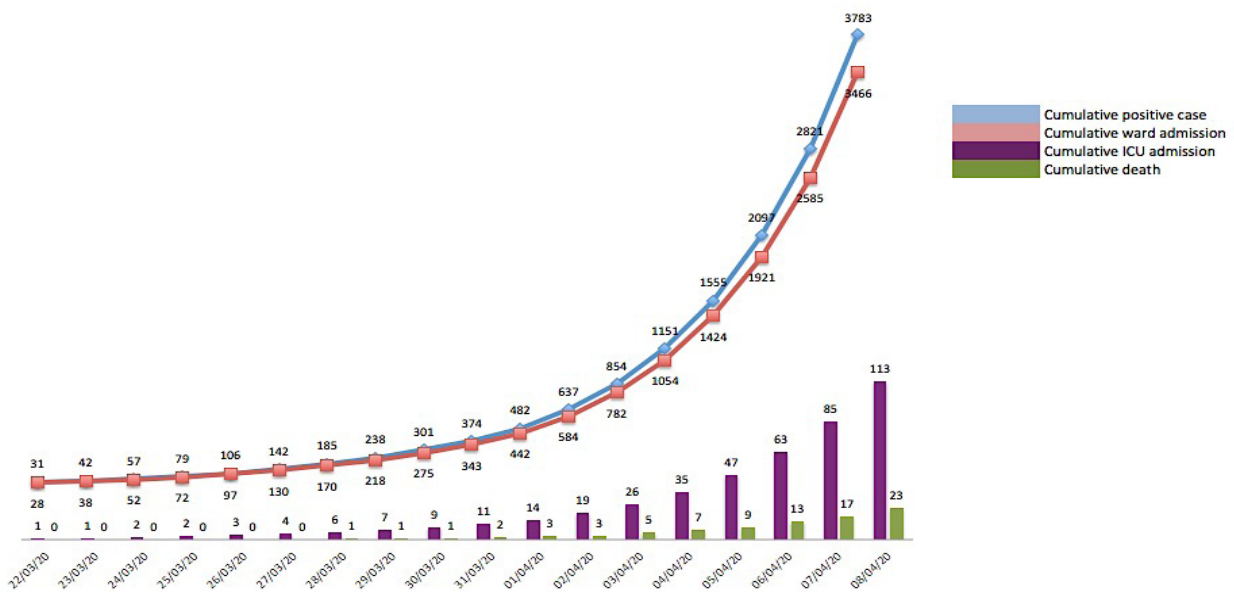


Figure 2: Projection of cumulative number of positive Covid-19 cases at UMMC based on projected cases of national data through decision tree technique from 22 March – 8 April 2020

The latest revised projection revealed a steady rather than a rapid increase in the number of cases as projected earlier. It was estimated that the number of patients in care at UMMC ranged from 62 to 81 patients daily in the second phase of MCO and 89 to 121 patients daily in the

third phase of MCO, with more dynamic rates and trends were expected. It was also projected that the number of screenings will be five times higher in late April as compared to late March 2020 as presented in Figure 3.

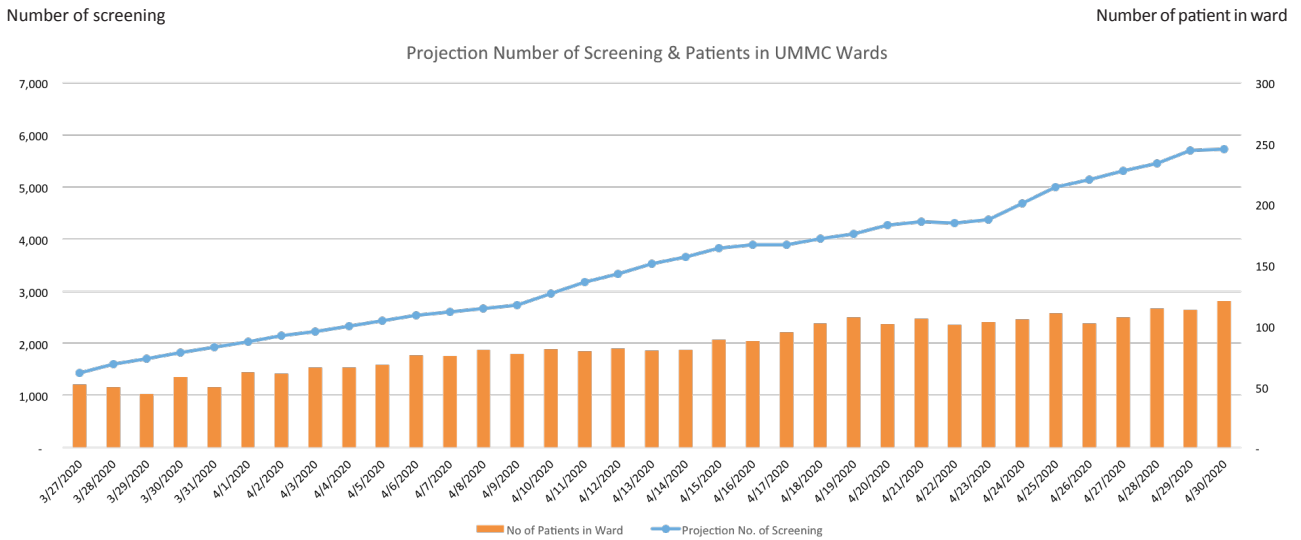


Figure 3: Projection of number of Covid-19 screening and number of patient admission at UMMC based on latest national projection from 27 March to 30 April 2020

Finally, the PPE utilization at the medical centre was estimated until the end of May 2020. It was projected that, more than 100,000 plastic aprons and almost 80,000 sterile and non-sterile isolation gowns, more than 40,000 masks N95 and face shields, approximately 30,000 gloves and nearly 17,000 bottles of hand sanitizer are needed by the healthcare workers from the various departments to treat the estimated number of patients. The details of the PPE and the quantities needed are presented in Table 1.

Table 1: Prediction of PPE requirements at UMMC in April and May 2020

NO	ITEM	Unit of Measurement	April 2020	May 2020	April and May 2020
1	MASK (N95)	PEACES (PCS)	18,128	27,191	45,319
2	GOWN ISOLATION STERILE	PCS	3,251	4,876	8,127
3	ISOLATION GOWN NON STERILE	PCS	26,814	40,221	67,035
4	TUDUNG CAP	PCS	6,567	9,850	16,417
5	SHOE COVER	PAIR	12,215	18,322	30,537
6	FACE SHIELD DISPOSABLE	PCS	16,174	24,261	40,435
7	FACE SHIELD REUSABLE	PCS	51	77	129

Table 1: Prediction of PPE requirements at UMMC in April and May 2020 (continued)

NO	ITEM	Unit of Measurement	April 2020	May 2020	April and May 2020
8	SURGICAL FACE MASK	BOX	8,812	13,219	22,031
9	LATEX GLOVE EXAMINATION	BOX	11,107	16,661	27,769
10	COVERALL SUIT	PCS	224	336	561
11	PLASTIC APRON	PCS	47,168	70,752	117,920
12	BOOT COVER	PAIR	161	241	402
13	HAND SANITIZER	BOTTLE	6,790	10,184	16,974

Discussion

Mathematical approaches using simple calculations and algorithms are one of the useful tools for hospital management to predict resource consumptions. Previous studies have shown that the application of mathematics in healthcare help to manage hospital inventory and ensure the supply and demand chain is in equilibrium (9, 10). The approach helps to inform the effective allocation of resources and could facilitate decision making for appropriate preparation plan particularly during outbreak seasons (11).

Recently, the Centre for Disease Control and Prevention (CDC) has introduced the PPE 'burn rate calculator' that could assist healthcare facilities to optimize the use of PPE during the pandemic of Covid-19 (11). The calculator records the number of PPE stocks available, daily PPE consumptions and estimates how long the remaining supply of PPE will last, based on the average consumption rate. Although the calculator is helpful to monitor the current hospital inventory, it does not inform the future quantities of PPE required. Therefore, the present study has taken one step further by forecasting the number of required PPEs based on the projection of patients in care at UMMC as part of hospital preparedness to ensure adequate access of PPE supplies to the patients and healthcare workers at the centre.

Simple predictive analytics using mathematical approaches could also help the hospital management to take timely actions to address PPE shortages. Several contingency strategies could be planned to help mitigate the PPE shortages, such as to negotiate with international suppliers to reduce the price for bulk purchases, to purchase supplies of PPE within the hospital networks, to engage with known suppliers and distributors, to communicate regularly with higher authorities to backfill shortages and to partner with neighbouring private or public hospitals specifically to share resources for any product that may be in limited supply (12). Some of the strategies mentioned have been initiated at UMMC to ensure an adequate supply of PPE.

Data visualization through predictive analysis could also produce actionable insight to optimize the use of PPE. Beyond the strategies to obtain new supplies, hospital management is also required to control the usage of PPE by conserving resources. This is done through deferring non-emergency and non-urgent procedures and operations, to encourage using PPE for extended periods without compromising on safety and reuse some of PPE components if possible. In addition, creating our own supply through local production of sewn hospital gowns and head covers. Priorities are given for the use of PPE at high-risk situations without compromising the safety of healthcare workers (1, 2, 12).

Nevertheless, through this predictive analysis we might face with events of undersupply or oversupply of the resources especially if the actual numbers are not in accordance to the projected numbers. In view of that, models that allow for regular updating as new data are released are important (4-6). In addition, as more knowledge on Covid-19 epidemic trajectories become available, this can help us to understand the new pandemic better.

Even though there are several limitations in this model, the use of simple predictive analytics using mathematical approaches could help to tweak hospital policy on how to manage supplies effectively, thus elevating critical shortages of the PPE as might occur during the Covid-19 pandemic.

Conclusion

In conclusion, a simple and easily calculated mathematical algorithm is a helpful tool to manage hospital resources like PPE during the critical periods in a pandemic. Successful implementation of PPE optimization relies on predicted information so that appropriate and timely decisions can be implemented by the hospital management.

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Competing interests

The authors declare that they have no conflict of interests.

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