ORIGINAL ARTICLE

Impact of COVID-19 on acute isolation bed capacity and nursing workforce requirements: A retrospective review

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Abstract

Aim: To understand the impact of COVID-19 on isolation bed capacity requirements, nursing workforce requirements and nurse:patient ratios.

Background: COVID-19 created an increased demand for isolation beds and nursing workforce globally.

Methods: This was a retrospective review of bed capacity, bed occupancy and nursing workforce data from the isolation units of a tertiary hospital in Singapore from 23 January 2020 to 31 May 2020. R v4.0.1 and Tidyverse 1.3.0 library were used for data cleaning and plotly 4.9.2.1 library for data visualization.

Results: In January to March 2020, isolation bed capacity was low (=<203 beds). A sharp increase in bed capacity was seen from 195 to 487 beds during 25 March to 29 April 2020, after which it plateaued. Bed occupancy remained lower than bed capacity throughout January to May 2020. After 16 April 2020, we experienced a shortage of 1.1 to 70.2 nurses in isolation wards. Due to low occupancy rates, nurse:patient ratio remained acceptable (minimum nurse:patient ratio = 0.26).

Conclusion: COVID-19 caused drastic changes in isolation bed capacity and nursing workforce requirements.

Implications for Nursing Management: Building a model to predict nursing workforce requirements during pandemic surges may be helpful for planning and adequate staffing.

KEYWORDS

bed capacity, COVID-19, nursing management, nursing workforce, workforce planning

1 | BACKGROUND

As the COVID-19 pandemic spread across the globe, its novelty and highly infectious nature have resulted in an unprecedented demand for health care services (Maben & Bridges, 2020). Countries urgently established care facilities in order to cater to the increased health care demand. In Wuhan, China, buildings were converted to temporary hospitals, providing over 10,000 beds for COVID-19 patients (CGTN, 2020). Similar strategies were seen in other countries. In Iran, plans were made to transform exhibition halls and stadiums to temporary hospitals (CGTN, 2020). In the United States of America, a field hospital was built in Manhattan's Central Park (Channel News Asia, 2020). Together with the expansion in care facilities, the demand for health care workers rose on the already insufficient workforce (Maben & Bridges, 2020).

TABLE 1 Classification of Isolation (ISO) units

Classifications of units created for COVID-19	Patients admitted to the unit
Isolation	Patients who have been tested positive for COVID-19 meet the criteria of being a suspect for COVID-19: Signs and symptoms suggestive of community-acquired pneumonia **OR** Person with an acute respiratory illness of any degree of severity (e.g. symptoms of cough, sore throat, runny nose, anosmia), with or without fever, who, within 14 days before onset of illness had: a. Travelled abroad (outside Singapore); OR b. Close contact with a case of COVID-19 infection; OR c. Stayed in a foreign worker dormitory; OR d. Worked in occupations or environments with higher risk of exposure to COVID-19 cases **OR** Person with prolonged febrile acute respiratory infection symptoms of 4 days or more, and not recovering AND who had not undergone prior swabbing for ARI symptoms in the same episode of illness. (The definitions changed over time in response to the COVID situation and known clusters of the nation.)
Acute respiratory infection (ARI)	Patients with symptoms of acute respiratory infection but do not meet the criteria to be considered a suspect for COVID-19

The first case in Singapore was tested COVID-19 positive on 23 January 2020 (Yong, 2020). The following days saw a slow rise of cases, with a total of only 13 COVID-19 cases by 30 January, all of which were infected overseas (Yong, 2020). On 4 February 2020, the first cluster with local transmission emerged (Yong Thai Hang Medical Hall) (Yong, 2020). Cases continued to rise with both cases from overseas and from local transmissions. Late March 2020, two foreign worker dormitories were reported as clusters (Yong, 2020), and this led to an exponential wave of COVID-19 cases. The highest number of cases which tested positive for COVID-19 in a day went as high as 1,426 on 20 April 2020 (Statista, 2020), with majority being linked to migrant worker dormitories (Cai & Lai, 2020). The quick increase in numbers could partially be attributed to active screening of the migrant workers in the dormitories.

For the period 1 March 2020 to May 2020, the demand for isolation beds as well as staffing rose. Nationwide initiatives were taken to rapidly create care facilities for COVID-19 patients. For instance, D'Resort NTUC chalet in Pasir Ris and Singapore EXPO convention and exhibition centre were repurposed as community isolation facilities to house COVID-19 patients who were clinically well with mild symptoms. In a bid to raise the manpower to serve these patients, the Ministry of Health (MOH) called for medical professionals from the private sector, those who had retired and those who were medically trained but no longer practising to sign up as volunteers to fight the pandemic (Cheow, 2020). MOH also redeployed manpower from other industries that were affected by COVID-19 to the health care sector (Cheow, 2020). For example, cabin crew from Singapore Airlines were redeployed as care ambassadors in some public health care institutions (Cheow, 2020). This demonstrates the extent to which the bed capacity and workforce requirements were stretched during the pandemic.

We aimed to understand the real and potential impact of COVID-19 on isolation bed capacity requirements, demand on the nursing workforce and nurse:patient ratios in the largest tertiary hospital in Singapore using simulation modelling. The usual nurse:patient ratio in a general ward would be 6 during the day and 7 during

the night. We hypothesize that as isolation capacity increased over time, there would be a point where the nursing workforce would be unable to meet the required staffing for isolation wards.

2 | METHODS

2.1 | Context/study site

This study took place at an acute tertiary hospital in Singapore. Major changes to the bed and staff allocation were made by the hospital as a response to the COVID-19 pandemic. Originally, the hospital was equipped with two isolation units, with a total of 43 single rooms with bedside monitors (11 of which were positive pressure rooms and the rest were negative pressure), 16 negative pressure cohort beds with bedside monitors and 16 cohort beds of normal pressure with no bedside monitor. In these two units, there were a total of 107 nurses.

In preparation for COVID-19, wards were converted to isolation or acute respiratory infection (ARI) units to house confirmed or suspected COVID-19 cases. ARI units were created as a response to COVID-19. There were no ARI units prior to this pandemic. The classifications of patients admitted to isolation/ARI units are described in Table 1. For purpose of clarity in the paper, both isolation and ARI units will be referred to collectively as isolation units.

The conversion of wards to isolation units took place over the course of the pandemic as the need for bed capacity increased. Within the isolation units, bed capacity also changed over time. During the initial period, the cohort rooms (originally able to accommodate five patients) were converted to nurse only one patient per room. Subsequently, when bed capacity demand soared, the capacity for each cohort room increased to hold three then four, and subsequently, five COVID-19-positive patients from the same cluster (these patients were likely to have contracted the disease from being in close contact with each other). The single rooms were then used to nurse those with URTI symptoms and suspected for COVID-19, pending swab results.

In addition to the conversion of wards to isolation units, there were also wards that moved their patients to a newly built community hospital (meant for rehabilitation) in order to create more isolation beds. With these changes in bed capacity, the nursing workforce had to be adjusted in order to operationalize this expanded capacity.

2.2 | Study design

This was a retrospective review of the bed capacity, bed occupancy and nursing manpower data of the isolation units in the hospital from 23 January 2020 (when the first COVID-19 case was reported in Singapore) to 31 May 2020.

2.3 | Data collection and analysis

Data on bed capacity (isolation and ARI beds) and bed occupancy (number of isolation and ARI beds occupied by patients) of the isolation units were retrieved via the hospital database.

The formulae used in calculating the nursing workforce required for an isolation unit is shown in Figure 1. Replacement factor ensured at least two days off per week and rest on public holidays, and the leave factor considered any sick leave/sick days. In order to evaluate any shortfall between required headcount (estimated number of nurses required based on bed capacity taking into consideration sick leave and rest days) and actual nursing workforce available, data were also retrieved via nursing rostering systems. Number of nurses physically on duty (number of nurses who were present in the isolation + ARI units) in the isolation units on a particular shift and day was manually counted from the nursing shift rosters during this period.

Data on the isolation bed capacity, actual nursing workforce and projected workforce were presented on a graph over time for a clear depiction of the situation. R 4.0.1 and Tidyverse 1.3.0 library was used for data cleaning, and plotly 4.9.2.1 library was subsequently used for data visualization.

2.4 | Ethical consideration

The study protocol was not required for review by the Centralized Institutional Review Board as it was a service evaluation project to advise policy through whole systems modelling with existing data and novel modelling methods leading to measured policy responses using deidentified data.

3 | RESULTS

3.1 | Bed capacity and occupancy

From January to March 2020, isolation bed capacity was relatively low (=<203 beds). A sudden increase in bed capacity occurred from late March and continued through April 2020. On 25 March 2020, the bed capacity was 195 beds. This quickly increased to 487 beds on 29 April 2020. Bed capacity plateaued subsequently. Refer to Figure 2 for a graph of the isolation bed capacity over time. Bed occupancy fluctuated but remained lower than bed capacity throughout January to May 2020. There was an excess of bed capacity of up to 265 beds on 10 May 2020. Refer to Figure 3 for a graph of isolation bed capacity and occupancy over time.

3.2 | Nursing workforce

The required headcount was calculated based on the isolation bed capacity. Hence, the required headcount increased in the same trend as the isolation bed capacity. For further observation of the actual workforce during the pandemic, the number of nurses required based on capacity was calculated as well. The number of nurses required based on capacity is the estimated number of nurses required based on bed capacity without taking into consideration sick leave/sick days and rest days. This is the estimated number of nurses needed to be at work per day. The difference between these two values is also illustrated in Figure 4.

Number of nurses required each shift= (Bed Capacity ÷ Patient to Nurse Ratio)

Required headcount= Number of nurses required per day* Replacement Factor* Leave factor

Patient to Nurse Ratio		
Morning Shift	Afternoon Shift	Night Shift
6	6	7

Replacement factor= 7/4.8
Leave factor= 1.04

FIGURE 1 Formulae for calculation of the required headcount of an isolation unit [Colour figure can be viewed at wileyonlinelibrary.com]
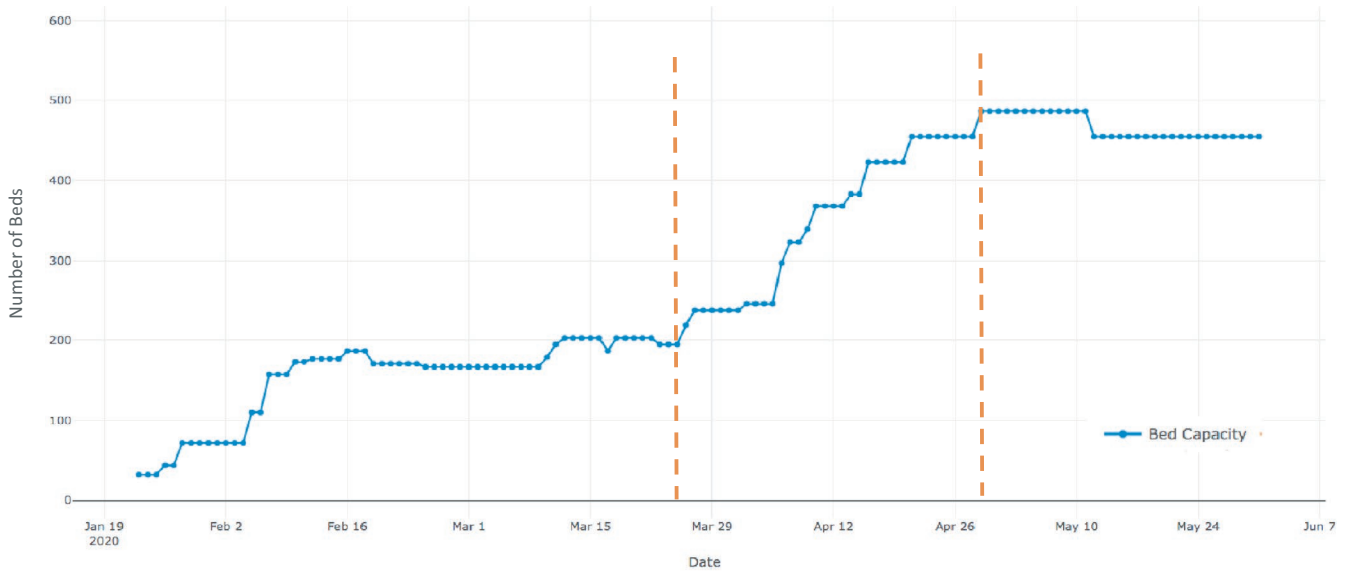
Isolation Bed Capacity Over Time

FIGURE 2 Graph of isolation bed capacity over time. The graph is divided into three portions. The first portion, from January 2020 till 25 March 2020, shows the relatively low isolation bed capacity during the initial period of the COVID-19 pandemic in Singapore. The middle portion, from 25 March 2020 to 29 April 2020, shows a steep increase in the isolation bed capacity. The last portion of the graph shows a plateau in the isolation bed capacity after 29 April 2020 [Colour figure can be viewed at wileyonlinelibrary.com]

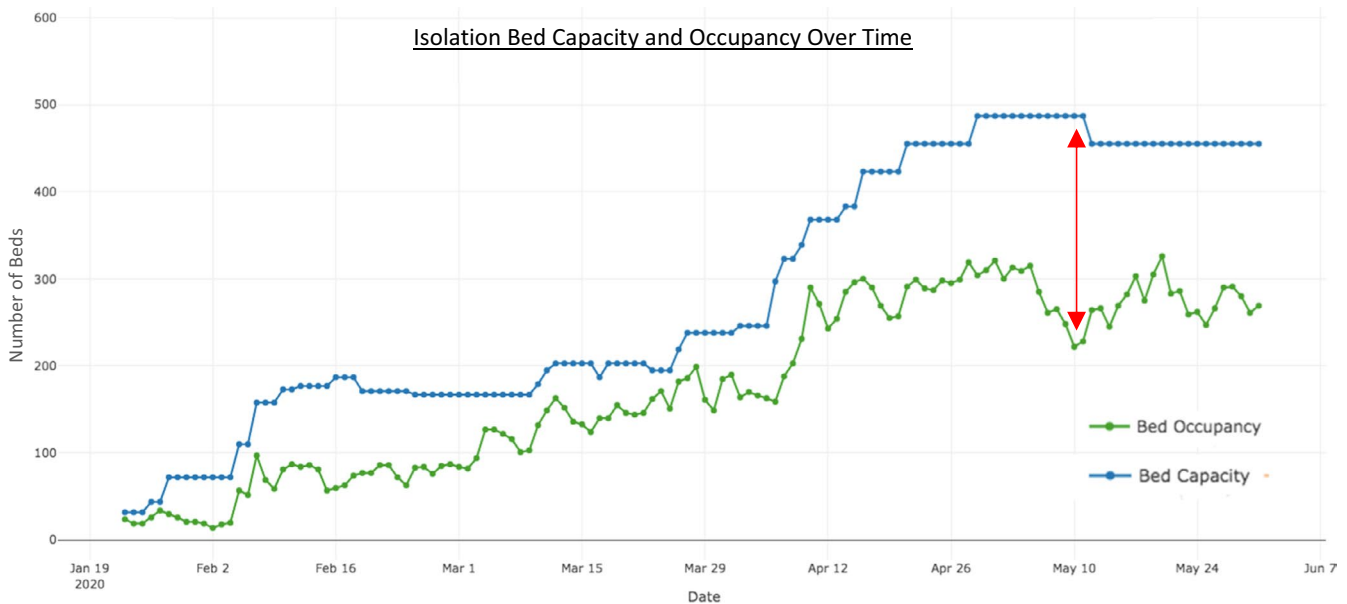## Isolation Bed Capacity and Occupancy Over Time

FIGURE 3 Graph of ISO/ARI bed capacity and occupancy over time. The arrow in the graph illustrates the day with greatest excess of isolation beds [Colour figure can be viewed at wileyonlinelibrary.com]

Comparing the number of nurses required based on capacity and the number of nurses physically on duty, total nursing workforce deployed to isolation wards only kept up with the number of nurses required up to 16 April 2020. Following that, the number of nurses required was not matched by the number of deployed nurses. A shortage of a minimum of 1.1 nurses (on 20 April 2020), to a maximum of 70.2 nurses (on 10 May 2020), was observed. Refer to Figure 5 for the graph comparing the number of nurses required based on capacity with the number of nurses physically on duty.

The nurse:patient ratio was also observed over time. The nurse:patient ratio peaked in the month of February 2020, with the highest nurse:patient ratio being 1.57. This ratio decreased in the subsequent months with nurse:patient ratio of less than 0.6 in April and May 2020. Refer to Figure 6 for the trend of the nurse:patient ratio over time.

Despite not meeting the number of nurses required based on capacity, the nurse:patient ratios were not adversely affected from January to May 2020. The minimum nurse:patient ratio was 0.26 for
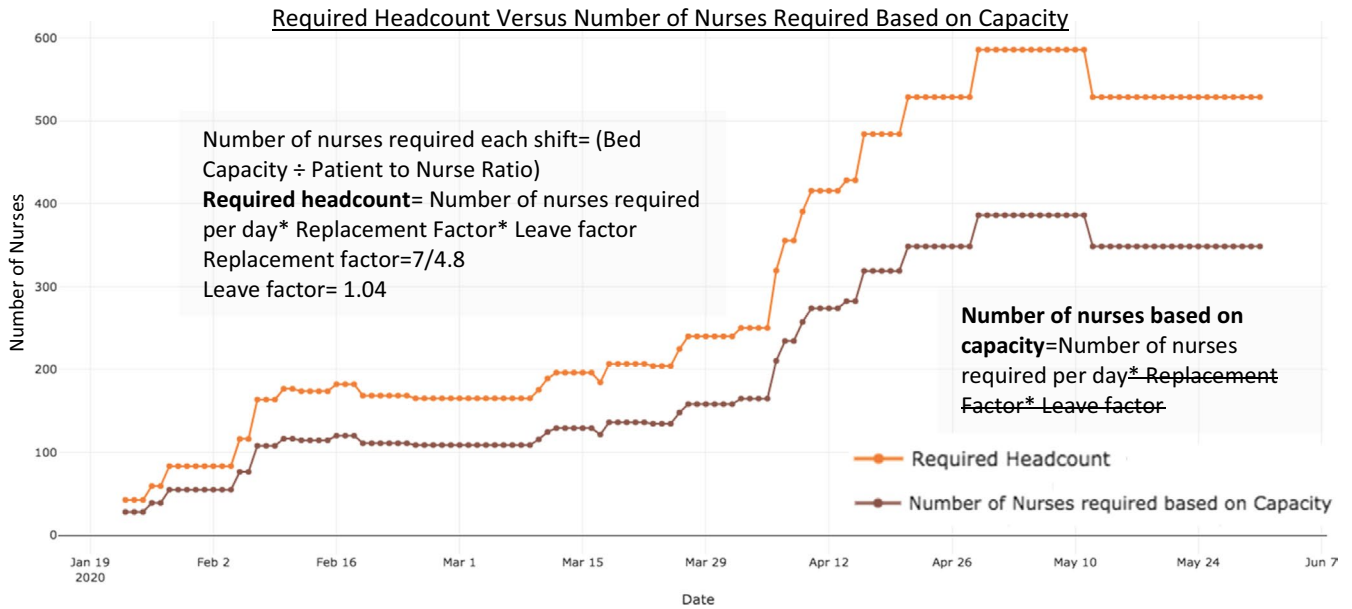
FIGURE 4 Required headcount versus number of nurses required based on capacity [Colour figure can be viewed at wileyonlinelibrary.com]
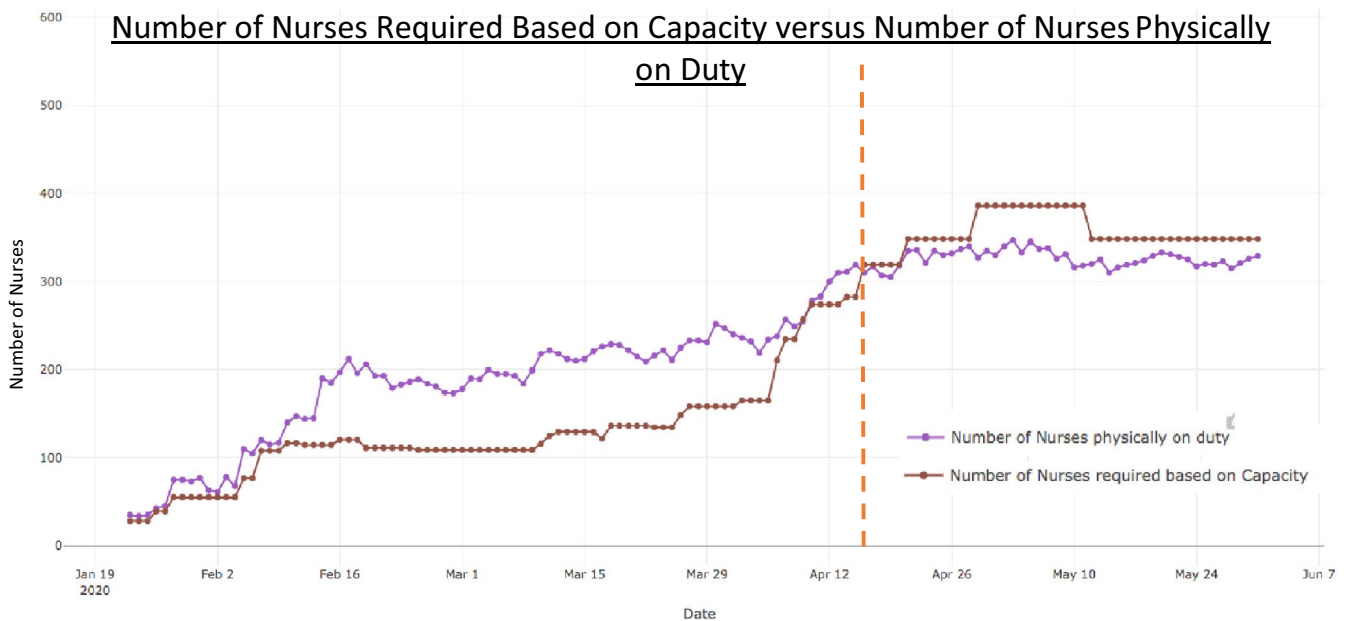

FIGURE 5 Number of nurses required based on capacity versus number of nurses physically on duty. The dotted line on the graph illustrates the point at which the nursing workforce was unable to meet the number of nurses required based on capacity in the isolation wards [Colour figure can be viewed at wileyonlinelibrary.com]

a night shift in January. This is related to the low occupancy rates of the isolation units.

4 | DISCUSSION

During the pandemic, one challenge faced was the inability to accurately plan ahead. Since news of the outbreak in China in December 2019, the hospital had plans on the potential conversion of wards to isolation units as well as the nursing workforce required should those changes take place. However, those plans were not closely followed. The reason was that there were too many uncertainties resulting from the novelty of the disease. The mode of transmission, its contagiousness, the morbidity and mortality rates of the disease, etc., was unknown at the time. Therefore, this resulted in a day-to-day reaction to the number of isolation admissions.

In this study, we found a rapid change in isolation bed capacity over the few months in response to COVID-19. The trend of bed capacity is reflective of the number of COVID-19 cases in Singapore.
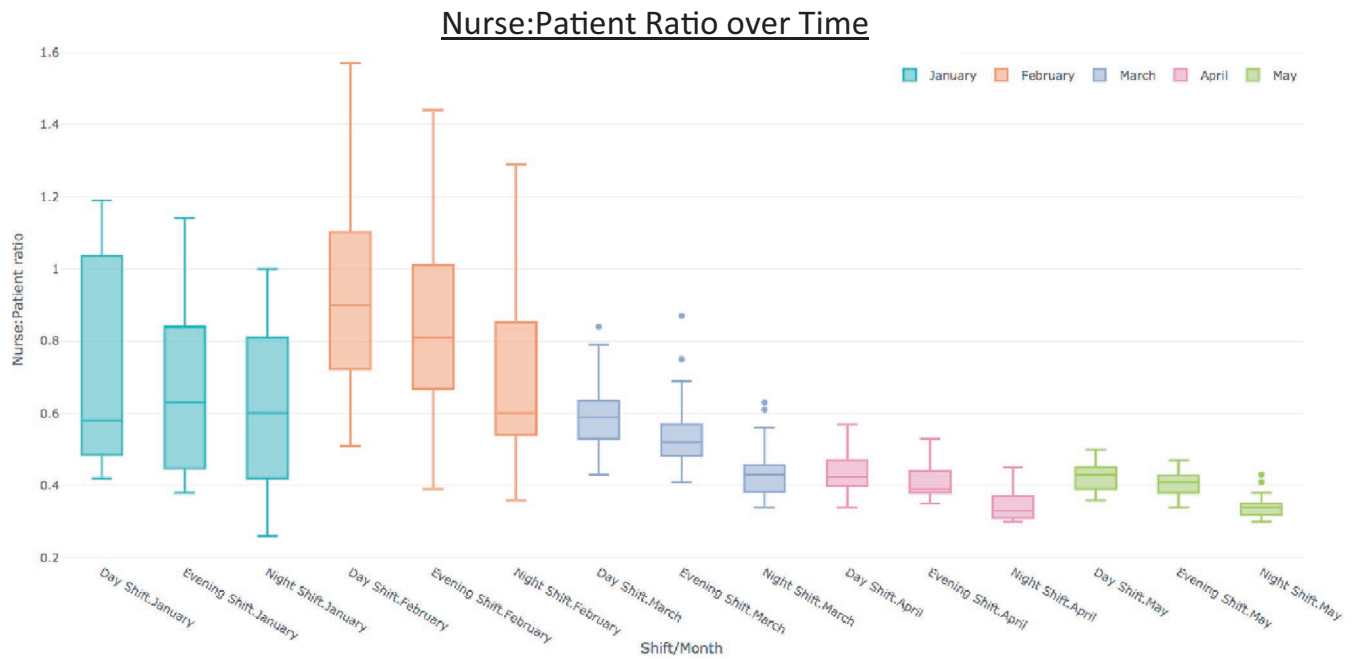
Nurse:Patient Ratio over Time

FIGURE 6 Nurse:patient ratio over time. This is a box plot of the nurse:patient ratio over time. Each month is represented by a colour. Within each month, the nurse:patient ratios for each of the three shifts are shown [Colour figure can be viewed at wileyonlinelibrary.com]

Isolation bed capacity remained low (=<203 beds) for the first two months as community spread was within control and demand was low. The number of COVID-19 cases in Singapore only began to rise sharply after the emergence of clusters in foreign worker dormitories in April 2020 (Yong, 2020). The sharp increase late March and through April (from 195 to 487 beds) reflected the hospital's response in preparation to receive increasing numbers COVID-19 cases.

However, despite the huge increase in isolation bed capacity, the occupancy rates did not reach the isolation capacity of the hospital from January to May 2020. Reasons for low occupancy rates could be due to efforts to minimize admissions to acute hospitals. Medical teams were sent to foreign worker dormitories to triage workers who were tested positive for COVID-19. After assessment by the doctors, those who were deemed sufficiently stable were sent directly to community isolation facilities (CIF) eliminating the need for admission to an acute hospital. The hospital also set up a fever screening area. Persons with fever were sent for COVID-19 screening. If the swab results were positive, those who were stable were sent to a CIF. For those who were admitted to the hospital for monitoring, once their condition stabilized, discharge to CIF was facilitated. The setting up of CIF was effective in keeping bed occupancy rates low, ensuring sufficient capacity for those who required closer monitoring (Boggs, 2020).

The low occupancy rates in the acute hospitals may also be attributed to relatively low rates of COVID-19 patients turning severely ill in Singapore. On 31 May 2020, there were 12,841 COVID-19-positive patients in care facilities (Ministry of Health, 2020). Of these patients, only eight were in intensive care units and 313 in acute hospitals (Ministry of Health, 2020). The total number of

deaths as of 31 May 2020 was 23 (Ministry of Health, 2020). If there were a larger proportion of patients who were severely ill, the patient occupancy rates may have been higher.

Changes in bed allocation and capacity in response to an outbreak have been seen previously. During the severe acute respiratory syndrome (SARS) outbreak in 2003, closure of a hospital to be designated for SARs cases occurred (Gopalakrishna et al., 2004). However, the SARS outbreak latest only from March to May 2003, with only 238 probable SARS cases in Singapore (Communicable Disease Surveillance in Singapore, 2003). Compared with SARS in Singapore, the extent to which the isolation bed capacity has expanded during COVID-19 is unprecedented.

As changes took place in the isolation bed capacity; the nursing workforce inevitably had to be reallocated. The actual nursing workforce at isolation units kept up with the number of nurses required till 16 April 2020. Additional workforce was mobilized as a result of closure of elective surgeries, discontinuation of specialist nurse services and discontinuation of education and research activities. The nurses from these departments were deployed to isolation wards. After 16 April 2020, the actual nursing workforce plateaued and fell below the number of nurses required. This shows the point at which the nursing workforce was stretched and unable to continue meeting former nurse:patient ratios shown in Figure 1. The hospital faced a shortfall of a minimum of 1.1 nurses on 20 April 2020, to maximum of 70.2 nurses on 10 May 2020.

One initiative taken by the hospital in attempt to improve the workflow of the nurses in times of the shortage of nursing workforce was the use of technology. Vital sign wearables were deployed to one isolation ward (Fan et al., 2020). Once it was attached to the patient, nurses could remotely monitor the patient via a mobile

application and have those readings directly transmitted to the electronic medical records (Fan et al., 2020). Mobile tablets were also provided for the patients in some isolation wards (Fan et al., 2020). Through it, patients could make simple requests or type messages to the nurses. The nurses can then view the request from the nurse station rather than entering the patients' rooms, and they will also be able to reply the patient's messages from the nurse station. Apart from time savings, personal protective equipment was saved from the reduced direct contact with a COVID-19-positive patient, and staff exposure to the virus was also minimized (Fan et al., 2020).

Fortunately, bed occupancy was low, the COVID-19 patient acuity was low, and most COVID-19 patients were well enough to perform activities of daily living independently. Thus, even though the actual nursing workforce was unable to meet the theoretically required numbers, the nurse:patient ratio was not adversely affected. The minimum nurse:patient ratio was 0.26, which is not lower than usual norms.

This was not seen in other parts of the globe where supply of health care workers was drastically insufficient. Vincenzo Defilippis, director of the local health authority of Bari, in southern Italy cited the scarcity of doctors and nurses to be the biggest challenge faced there (Amaro, 2020). A contributing factor could be the difference in the rate of COVID-19 among health professionals. In Singapore, the rate of COVID-19 cases among health care workers was low. Eighty-eight health care workers (out of 5,050 cases) were tested positive for COVID-19 as of 17 April 2020 (Wong et al., 2020). There were no cases of fatality among these health care workers (Wong et al., 2020). For those with a known source of infection, only five were ever exposed to an infected patient (Wong et al., 2020). In contrast, 60 health care professionals in Italy died from COVID-19 and more than 12,000 were infected in Spain by April 2020 (Amaro, 2020). In Portugal, it was reported that those who were not under quarantine had to do consecutive shifts in order to make up for the lack of workforce (Amaro, 2020).

4.1 | Limitations

This study discussed the bed capacity and nursing workforce situation among isolation units without evaluating the impact of COVID-19 on non-isolation wards. Some non-isolation units were relocated to increase isolation capacity. Moreover, the nursing workforce of these non-isolation wards was reduced due to the deployment of nurses to isolation units. Moreover, this study did not distinguish the general ward and intensive care unit bed capacity and nursing workforce within the isolation units. Nonetheless, this study provides a good overview of the impact of COVID-19 of the isolation bed capacity and workforce in this acute hospital.

5 | CONCLUSION

COVID-19 caused drastic changes in bed capacity and nursing workforce requirements worldwide. Our hypothesis that the isolation capacity increased over time in response to the COVID-19 situation in

Singapore to a point where the nursing workforce would be unable to meet the required headcount for the isolation wards was shown to be true. Fortunately, due to low occupancy rates, the nurse:patient ratio was not adversely affected.

6 | IMPLICATION FOR NURSING MANAGEMENT

The task of responding appropriately to the drastic changes to bed capacity and nursing workforce requirements described in this paper was a challenging one for nurse leaders. In preparation for future outbreaks and pandemics, data from this study could further develop a model using systems dynamic modelling to plan and predict bed capacity and nursing workforce needs during a pandemic. For example, by entering some details of the outbreak, such as the mode of transmission (contact, droplet, airborne), the severity of the disease (cases that may require ICU care), infectious period and also the number of cases in the nation, the model should be able to predict the bed capacity and nursing workforce requirements of the hospital. The model should also be able to inform management at which point in time the nurse:patient ratio needs to be adjusted due to inability to cope with demand.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

ETHICAL APPROVAL
Ethical approval was not required for this study.

DATA AVAILABILITY STATEMENT
Research data are not shared.

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