

Establishing a New Normal for Hospital Care: A Whole of Hospital Approach to COVID-19

Brandon X. Lum¹, Eugene H. Liu^{2,3}, Sophia Archuleta^{2,4}, Jyoti Somani^{2,4}, Natasha Bagdasarian^{2,4}, Catherine S. Koh⁵, Clara S. Sin⁶, Mushan Wong⁶, Swee Chye Quek^{2,7} and Dale A. Fisher^{2,4}

1. Corporate Planning & Development Department, National University Hospital, National University Health System, Singapore.
2. Yong Loo Lin School of Medicine, National University of Singapore, Singapore
3. Department of Anaesthesia, National University Hospital, National University Health System, Singapore.
4. Division of Infectious Diseases, Department of Medicine, National University Hospital, National University Health System, Singapore.
5. Department of Nursing, National University Hospital, National University Health System, Singapore.
6. Operations Center, National University Hospital, National University Health System, Singapore.
7. Department of Pediatrics, National University Hospital, National University Health System, Singapore.

Corresponding author:

Brandon Lum

Email: brandon_lum@nuhs.edu.sg

Phone Number: (65)-9185 5911

Corporate Planning & Development Department, National University Hospital,
National University Health System, Singapore.

Summary: Singapore's National University Hospital (NUH) shares measures taken to manage surge caused by COVID-19, while maintaining essential clinical service and staff safety and morale. As massive case numbers recede the hospital is establishing hospital practices for the new normal.

Accepted Manuscript

Abstract

Singapore's hospitals had prepared operations to receive patients (potentially) infected with SARS-CoV-2, planning various scenarios and levels of surge with a policy of isolating all confirmed cases as inpatients. The National University Hospital, adopted a whole of hospital approach to COVID-19 with three primary goals: zero hospital-acquired COVID-19, all patients receive timely necessary care, and maintenance of staff morale. These goals to date have been met. A large influx of COVID-19 cases emerged requiring a significant transformation of clinical and operational processes. Isolation room numbers almost tripled and dedicated COVID-19 cohort wards were established, elective care was postponed and Intensive Care Units were augmented with equipment and manpower. In the wake of the surge establishing a new normal for hospital care requires a considered balance of maintaining vigilance to detect endemic COVID-19, establishing contingency plans to ramp up in case of another surge, while returning to business as usual.

Keywords: Whole of hospital; COVID-19; Surge Capacity; Academic Medical Center; Establishing a New Normal

Accepted Manuscript

Abbreviations: NUH, National University Hospital; MoH, Ministry of Health; ID, Infectious Diseases Division; IPC: Infection Prevention and Control; PCR; Polymerase Chain Reaction; ED, Emergency Department; ICU, Intensive Care Units; PPE, Personal Protective Equipment; ARI, Acute Respiratory Infection; CIF, Community Isolation Facilities; MICU, Medical Intensive Care Units; HD, High Dependency; PAPR, Powered Air Purifying Respirators; OHC, Occupational Health Clinic; ECMO, Extra Corporeal Membrane Oxygenation; OR, Operating Room; PTSD, Post-Traumatic Stress Disorder; SARS, Severe Acute Respiratory Syndrome

Accepted Manuscript

As populations around the globe struggle to adapt to life with COVID-19, maintaining the integrity of hospitals is paramount. The National University Hospital (NUH), Singapore, a 1200-bed public sector hospital, adopted a whole of hospital approach to COVID-19 in early January 2020 with three primary goals: zero hospital acquired COVID-19 cases, all patients to receive timely necessary care, and maintenance of staff morale. This paper outlines how clinical and operational capacity was adapted in a preemptive manner to cope with the complex and constantly changing situation over the first months of COVID-19. Up to 31 July 2020, the hospital had cared for over 1000 COVID-19 patients. Here we describe chronologically how the goals were met and the considerations of how hospitals will need to adjust to the long term presence of COVID-19.

Preparing for the First Case

The National University Hospital is an academic medical center providing a full range of secondary and tertiary care. It is part of the National University Health System (NUHS), which provides healthcare services for a population of approximately 1,400,000 in Western Singapore. During the pandemic, an inter-ministry Joint Task Force and the Ministry of Health (MoH) coordinated the country's response. Consistency was deemed core to staff buy-in and confidence; and great care was taken to ensure NUH strategies and processes were aligned to national policies and guidelines, and well-coordinated with other hospitals.

NUH has an Operations Center, activated to coordinate responses to external and internal incidents. The NUH COVID-19 Operations (COVID Ops) team was formed on 5 January 2020, shortly after notification of cases of viral pneumonia from China [1]. The Emergency Department (ED) had already enhanced pretriage to include specific questioning to patients regarding travel and contact history by 1 January 2020.

Within the COVID Ops team, senior hospital leadership guided organizational adaptation, empowered key stakeholders, ensured resourcing, and provided decisions and endorsements. The Infectious Diseases Division (ID) drove all workflow modifications to ensure screening and appropriate testing, safe inpatient care and Infection Prevention and Control (IPC).

The NUH Molecular Diagnostics Lab developed the capacity to perform SARS-CoV-2 Polymerase Chain Reaction (PCR) by 6 February 2020, reaching a capacity of 300 daily tests by 15 March 2020. Clinical and operations heads from all relevant departments developed a coordinated pre-emptive whole of hospital response (see Supplementary Figure 1).

Three overarching goals were enunciated. Firstly, the hospital aimed for “four IPC zeros”: zero patient-to-staff transmission, zero patient-to-patient transmission, zero staff-to-patient transmission, zero staff-to-staff transmission. Secondly, the hospital was to ensure the maintenance of essential services including emergency or urgent treatment for non-communicable diseases, oncology, cardiology, obstetrics, and trauma. Thirdly, staff morale was to be prioritized throughout the prolonged crisis, through strategic attention to staff safety and welfare.

Plans included clear communication to staff, through regular briefings, virtual meetings, and email updates at all levels; national, hospital and departmental. Key updates would include daily COVID-19 caseload, weekly “Ops Orders”, emerging diagnostic and treatment practices, and fortnightly updates on key new developments and learning points. Operations meetings included standing agenda items to ensure feedback from hospital staff.

Managing Early Cases Within Usual Capacities

The COVID-19 Ops team met regularly to enable timely discussions of new information, policies, and decisions. The command, feedback and learn approach emphasized ground feedback, facilitating swift changes and optimization of the hospital's response to the evolving global and local situation. The team monitored the caseload, bed occupancy daily, and supply status of Personal Protective Equipment (PPE) and lab test materials weekly.

Staff across the hospital formed self-contained teams within their departments as contingency against exposure and to minimize the effect of contacts being quarantined. The hospital's senior leaders had a group directly involved in COVID-19 operations, with a team kept in reserve. Clinical teams were segregated according to the most efficient way of working (e.g. COVID-19 versus non-COVID-19, etc.)

As case numbers increased in Singapore, pre-triage at the ED entrance evolved to include all acute respiratory infections (ARI). These patients were immediately sited in one of 12 negative pressure isolation rooms in the ED's self-contained isolation unit. The increasing numbers of suspected COVID-19 patients led to the creation of additional isolation capacity in a large tent on an unused adjacent open-air plot of land and in two unused clinics [2].

Patients with ARI requiring ward admission were isolated in negative or neutral pressure single rooms, while observing clinical progress and awaiting results. Detailed planning and rehearsals across clinical, nursing, security and housekeeping staff ensured the coordinated movement of suspect and confirmed COVID-19 patients within the hospital. This group of patients were moved, only using identified elevators and staircases, and were attended to by selected housekeeping and portering staff (trained in decontamination work and PPE usage). Suspect patients could be de-isolated upon two negative swab tests 24 hours apart. COVID-19 confirmed patients remained in isolation. Specialty specific protocols and workflows with dedicated sites for COVID-19 patients were prepared and rehearsed, including for surgery, obstetric care, and radiology investigations. Isolation of all suspect

patients enabled NUH to reduce the risk of nosocomial transmissions before patients' laboratory results were available.

Scenario-based planning and preparedness exercises facilitated an understanding of the potential needs. Additional "hot zone" capacity was created to increase isolation rooms, COVID-19 cohort wards, and COVID-19 ICU rooms. Alternative capacity with contact precautions was created for patients with multi-drug resistant organisms.

The hospital planned sequences with trigger points to activate more wards and ICUs for COVID-19 patients and dedicated teams in order to maintain team segregation. The phased plans, preparation work and activation were implemented by the Bed Management Unit and clinical teams (Figure 1).

The availability of PPE, and training in its use were priorities. Non-clinical staff from housekeeping, portering, security and administration, who do not normally use PPE, were also trained. Guidelines on PPE were updated and standardized nationally through MoH and its National IPC committee. There were detailed weekly updates on hospital PPE stockpiles. Clinical staff who would be involved in aerosol generating procedures in COVID-19 patients were further trained in the use of Powered Air Purifying Respirators (PAPR). Audits on correct infection control measures and PPE usage were stepped up by infection prevention representatives.

From 7 February 2020, all staff wore surgical masks in clinical areas and by early April masks were worn everywhere consistent with the national mandate of universal mask wearing. The aim was to protect patients and staff from staff with mild (or asymptomatic) disease and to protect staff from patients with unidentified mild or atypical disease. Staff were required to present to an expanded Occupational Health Clinic (OHC) upon the onset of any ARI symptoms or fever, where they would be tested. A workflow to guide staff who had possible occupational or community exposure was created, outlining the investigation

and actions needed. OHC monitored daily absentee numbers to allow early identification of possible clusters of infection within NUH as well as possible areas with morale issues. No routine testing was conducted for asymptomatic healthcare workers at NUH or any Singapore hospital.

To facilitate temperature screening of all visitors to NUH, the number of entry points into the hospital was reduced. Visitors to the wards were progressively limited and were not allowed in isolation and COVID-19 cohort wards, except on a case by case basis. All outpatients, and accompanying family and visitors were questioned. Patients with fever, ARI symptoms or high-risk travel histories were guided to designated clinic rooms, avoiding contact with other outpatients.

Procurement of key supplies was carried out as part of a national system, to minimize the risk of disruptions in the supply chain and to achieve economies of scale. Stockpiling and usage of critical medications, supplies and PPE at national and hospital levels were monitored and transparent. Stock level targets were set based on usage in worst case scenarios, with the aim of at least two weeks' supply of PPE on site, and two months' supply of critical drugs (e.g. sedatives, opioids and neuromuscular blockers). Additional ventilators, Extra Corporeal Membrane Oxygenation (ECMO) equipment and the associated consumable items were prepared to enable an increase of critical care capacity from 52 to 206 ventilated beds when necessary.

There was a substantial increase in the cleaning and decontamination work in the clinical areas, and the deployment of housekeeping staff was reprioritized to the "hot" zones. Additional hydrogen peroxide vapor machines were procured to enable a faster turnover of patients in the isolation wards.

Departments reviewed and prioritized clinic appointments for those needing in person consultation for urgent problems, particularly cancer and cardiovascular illnesses, obstetric

care and trauma [4-6]. Overall, in-person outpatient consultations were reduced by 53% in May 2020 (Figure 2). The use of teleconsultations enabled patients with stable conditions to be evaluated remotely [7-9]. Teleconsultations increased from 1% in March to 5% of all clinic appointments by May 2020. Home deliveries of medication were encouraged especially for patients whose appointments were deferred.

The movement of healthcare workers between hospitals was minimized, by stopping cross-hospital training rotations for residents. Medical and nursing students were not placed in high risk situations [10-12].

Research efforts were reprioritized to COVID-19 related research, including partnerships with biomedical engineering, material science, health service and public health researchers.

Building Capacity to Manage Surge

The 60 additional single occupancy isolation rooms in three wards were progressively mobilized as the number of COVID-19 patients exceeded the 42 available, although most of these additional rooms did not have negative pressure ventilation.

By May, NUH had the capacity to perform 1600 PCR tests per day, running 16 hours per day, with a turnaround of 6-8 hours. Swift turnaround times for the COVID-19 swab tests enabled transfer of patients to cohort wards (COVID-positive patients) or for de-isolation (COVID-negative patients).

Three naturally ventilated general wards were progressively activated as COVID-19 cohort wards for confirmed patients, creating a total capacity of 115 patients. Pediatric patients were housed with their COVID positive caregiver once confirmed. Prior to opening the cohort wards, drills and rehearsals were also carried out to cover safe clinical workflows, fire, and security emergencies. As these wards filled up, one of the hospital's covered carparks was prepared to create capacity for a further 57 positive cohort beds. As MoH established

national Community Isolation Facilities (CIFs), demand for hospital based isolation fell so that the majority of patients with mild COVID-19 disease could be transferred to CIFs while still infectious. These CIFs substantially reduced the need for hospital admission of COVID-19 patients, while enabling early detection of deterioration, provision of care, and transfer to hospital. NUH was tasked to provide clinical care at one such 1700-bed CIF, which meant diverting manpower (doctors, nurses, pharmacists) and infection control expertise for offsite support.

During March to May, non-urgent elective surgical procedures and outpatient clinic appointments were progressively reduced (Figure 2). Ambulatory surgeries and endoscopy procedures were postponed and the ambulatory surgery ward was modified to enable overnight inpatient stay. Reprioritization of elective work ensured that the hospital could still provide essential care in addition to COVID-19 work.

A major redeployment of staff naturally ensued, with doctors and nurses from clinics and surgical departments with reduced work supporting the increased workload in the ED, isolation wards, ICUs, epidemiology unit and off campus in the migrant worker dormitories and CIFs. Adequate training was provided for the staff before deployment (Table 2). Regular refresher training in the use of PPE and PAPR enhanced staff preparedness and the ability to respond swiftly and safely.

NUH has seven specialty based adult ICU and high dependency (HD) units with a total of 115 beds. The Medical ICU (MICU) was designated to be the main ICU for COVID-19 patients needing intensive care, with a planned sequence of ICUs to activate for anticipated escalation of needs. NUH is one of two public sector referral centers for ECMO treatment, pulling the most severe COVID-19 patients from other hospitals. Additional ICU and HD capacity for COVID-19 and non-COVID-19 patients was created in general wards.

The epidemiological team undertook tracing of contacts of patients upon the confirmation of COVID-19, and within two hours of diagnosis the team was required to submit a detailed activity map for each confirmed COVID-19 patient to MoH.

To help staff cope emotionally during the COVID-19 surge, NUH provided a mental wellness mobile app and counselling support. Leave was permitted so that staff could rest, but overseas travel was not allowed.

Assessing the Hospital Response

Zero hospital-acquired COVID-19:

Easy availability and a low threshold to testing revealed only two patient-facing staff with COVID-19. Root Cause Analysis (RCA) and contact tracing, demonstrated that the cases were community acquired. No onward spread was ensured by necessary quarantining of contacts and confirmed by testing. All patients developing hospital onset respiratory symptoms were swabbed for COVID-19 and none were positive.

Unpublished serology data results from staff working in the ED fever facility were all negative.

All patients receive timely necessary care:

Routine hospital data confirmed the effectiveness of the policies (Figure 2). Emergency care continued to be provided in a timely manner for all patients entering the ED, though there was also a drop in general ED visits to NUH, a trend that has been reported world-wide [13,14]. There was no significant reduction in emergency admissions and surgeries. There was no delay for patients needing elective care (e.g. cancer, cardiovascular disease, obstetrics or trauma). There was a substantial reduction of surgical work by up to 55% in May.

Maintenance of staff morale:

Qualitatively, reports from all department heads at operations meetings described high levels of staff morale. Senior leadership walk arounds also supported this. NUH saw a reduction of the rates of medical leave and resignation of staff by 4% and 0.25% respectively, compared to the same period in 2019. In a Pulse Survey conducted online with voluntary participation, in April 2020, 500 staff across various job groups responded that they felt well supported and that there was adequate communication.

In responses to staffs' feedback received as part of the Pulse Survey, staff working in the "hot" zones of ED, isolation wards, cohort wards and ICU were provided free meals when on duty, and scrubs that were laundered by the hospital. Alternative accommodation was provided to staff who had concerns about infecting vulnerable family members.

Moving Out of Surge; Staged Return to Business as Usual with a Difference

As the surge of COVID-19 inpatients abated, wards and rooms were reconverted for non-COVID-19 related care, after comprehensive cleaning. The hospital ring-fenced 80 beds (10% adult general care capacity beds) in isolation rooms and cohort wards, and 16 ICU rooms, for COVID-19 suspect or confirmed patients. This enables rapid response to any new wave of infections. In addition, staff who worked at the CIF will be on standby, with supplies and equipment stockpiled at the CIF site, allowing for swift reactivation.

Phased resumption of surgical services occurred as well as routine clinic work including more teleconsultations. As elective surgery resumed, PPE guidance for OR work was adapted, with N-95 masks required for dental procedures, procedures involving airways or with high risks of aerosolization. The numbers of staff present in the OR during airway management at induction and reversal of anesthesia have been reduced. With the lower community rates and even lower rates of unlinked community cases, pre-operative testing of COVID-19 for surgical patients is currently based on risk assessment.

The restrictions on training have affected the clinical and procedural experience that residents/students require for completion of training and certification of competency. These will need to be addressed in the future.

A New Normal for Hospital Care

The COVID-19 pandemic will eventually end, but the disease will likely remain endemic. We need to design future care processes on a premise that a vaccine or treatment will not deliver a complete solution. It is unlikely that a vaccine will be available soon, be fully effective especially in the elderly, or be accepted universally. Treatments may give a survival advantage but a consistent cure is also unlikely. Thus, many of the clinical and administrative measures instituted by hospitals will be required in the long term. There will continue to be forward triage at the ED, where patients with ARI are directed to isolation wards and subjected to COVID-19 testing, ideally with a sensitive saliva test. All patients admitted with ARI will likely be isolated until assessed to be non-infectious for COVID-19 given the risk of exposure to vulnerable and immune suppressed hospital inpatients. Furthermore, the risks in dentistry, surgical procedures and workflows in the ICUs have created a new paradigm of protocols and PPE [15,16].

A key factor of NUH's success was the creation of additional isolation capabilities for suspect and confirmed cases, to prevent nosocomial transmission (Table 1). Across Singapore's acute public hospitals there were similar expectations in terms of safety and surge capacity but each hospital had to consider the specific implementation challenges.

Hospitals must remain cautious about the risk of COVID-19 infection reintroduction. In the moderate term, hospitals need to be able to rapidly respond to surges in community transmission. This includes maintaining ward and ICU capacity specifically for COVID-19 patients, laboratory capacity, and adequate PPE, drugs and equipment. Compulsory mask-wearing by staff will be needed for the foreseeable future. The hospital must also prepare for

work “upstream” to augment or provide care in the community to preserve the hospital’s capacity.

The assessment of a hospital’s response includes consideration of leadership and coordination, communication and engagement of staff, hospital acquired infection rates, surge capacity created, maintenance of PPE and other supplies, and maintenance of usual health services [17].

This report summarizes the whole of hospital approach in NUH’s response to the COVID-19 pandemic and preparation for the new normal (Table 2). The hospital planned for both the ramp up and down of efforts, while reserve manpower that was created enabled the hospital to contribute extensively to COVID-19 work outside of the hospital. Clear prioritization of staff well-being and safety, with transparent communication, enabled a consistent and sustainable response to the prolonged crisis. With sound structures and an engaged workforce, zero hospital acquired infections and demonstrable maintenance of essential services, this report describes a successful hospital level response to-date.

Accepted Manuscript

NOTES

Authors' Contributions

BXL, EHL, QSC and DAF wrote the manuscript with input and guidance from all co-authors. All authors contributed to the activities described and writing of the manuscript, and approved the final version for publication.

Acknowledgements

We would like to thank our colleagues from Management Information Systems, Ambulatory Services, Emergency Department, Inpatient Operations, NUH Operations Centre and NUHS Operations for the provision of data for this paper. NUH's efforts to combat COVID-19 and subsequently return to normal would not have been possible without the support of all NUH staff. We would also like to extend our gratitude to all our colleagues, both clinical and support staff, in the National University Health System.

Funding:

Not Applicable

Competing interests:

We declare no competing interests.

References:

1. Timeline of WHO's response to COVID-19. Available at: <https://www.who.int/news-room/detail/29-06-2020-covidtimeline>. Accessed 7 August 2020.
2. Bagdasarian N, Mathews I, Alexander NJ, *et al*. A Safe and Efficient, Naturally Ventilated Structure for COVID-19 Surge Capacity in Singapore. *Infect Control Hosp Epidemiol*, **2020**; 1-3.
3. Archuleta S, Cross G, Somani J, *et al*. Responding to COVID-19: how an academic infectious diseases division mobilized in Singapore. *BMC Med*, **2020**; 18: 1-9.
4. World Health Organization. Maintaining essential health services: operational guidance for the COVID-19 context: interim guidance, 1 June 2020. Available at: <https://apps.who.int/iris/rest/bitstreams/1279080/retrieve>. Accessed 7 August 2020.
5. Cosentino N, Assanelli E, Merlino L, Mazza M, Bartorelli AL, Marenzi G. An in-hospital pathway for acute coronary syndrome patients during the COVID-19 outbreak: initial experience under real-world suboptimal conditions. *Can J Cardiol*, **2020**; 36: 961-964.
6. Leira EC, Russman AN, Biller J, *et al*. Preserving stroke care during the COVID-19 pandemic: potential issues and solutions. *Neurology*, **2020**; 95: 124-133.
7. Hollander JE, Carr BG. Virtually perfect? Telemedicine for COVID-19. *New Engl J Med*, **2020**; 382: 1679-1681.
8. Portnoy J, Waller M, Elliott T. Telemedicine in the Era of COVID-19. *J Allergy Clin Immunol Pract*, **2020**; 8: 1489-1491.
9. Elkbuli A, Ehrlich H, McKenney M. The effective use of telemedicine to save lives and maintain structure in a healthcare system: Current response to COVID-19. *Am J Emerg Med*, **2020**. doi: 10.1016/j.ajem.2020.04.003. [Epub ahead of print].
10. Wang S, Dai M. Status and situation of postgraduate medical students in China under the influence of COVID-19. *Postgrad Med J*, **2020**. doi: 10.1136/postgradmedj-2020-137763. [Epub ahead of print].

11. Almarzooq Z, Lopes M, Kochar A. Virtual learning during the COVID-19 pandemic: a disruptive technology in graduate medical education. *J Am Coll Cardiol*, **2020**; 75: 2635-2638.
12. Gill D, Whitehead C, Wondimagegn D. Challenges to medical education at a time of physical distancing. *Lancet*, **2020**; 396: 77-79. doi: 10.1016/S0140-6736(20)31368-4 [Epub ahead of print].
13. Jeffery MM, D'Onofrio G, Paek H, *et al.* Trends in Emergency Department Visits and Hospital Admissions in Health Care Systems in 5 States in the First Months of the CoViD-19 Pandemic in the US. *JAMA Intern Med*, **2020**. doi: 10.1001/jamainternmed.2020.3288. [Epub ahead of print].
14. Hartnett KP, Kite-Powell A, DeVies J, *et al.* Impact of the COVID-19 Pandemic on Emergency Department Visits — United States, January 1, 2019–May 30, 2020. *MMWR Morb Mortal Wkly Rep*, **2020**; 69: 699–704. DOI: <http://dx.doi.org/10.15585/mmwr.mm6923e1> external icon.
15. Wong J, Goh QY, Tan Z, *et al.* Preparing for a COVID-19 pandemic: a review of operating room outbreak response measures in a large tertiary hospital in Singapore. *Can J Anesth*, **2020**; 67: 732-745.
16. Phua J, Weng L, Ling L, *et al.* Intensive care management of coronavirus disease 2019 (COVID-19): challenges and recommendations. *Lancet Respir Med*, **2020**; 8: 506-517.
17. Fisher D, Teo YY, Nabarro D. Assessing national performance in response to COVID-19. *Lancet*, **2020**. S0140-6736(20)31601-31609. doi: 10.1016/S0140-6736(20)31601-9. [Epub ahead of print].

Table 1. Key Learning Points to Reduce Nosocomial Transmissions

Key Learning Points	Description
All suspect patients to be placed in isolation rooms	To reduce contact and possible transmission. Ability to create addition isolation capacity was key.
Ensuring sufficient supplies of pandemic stores	Stockpiling and usage of critical medications, supplies and PPE at national and hospital levels.
Stringent contact tracing upon identification of COVID-19 positive staff	To enforce stay-home-notices and quarantine measures where possible exposure was recognized.
To adhere to evidence-based guidelines for safety	Ensuring all staff entering Hot Zones are trained and equipped with adequate PPE.
	All Staff to adhere to governmental guidelines (e.g. compulsory use of masks). Regular audits to ensure compliance to guidelines

Accepted Manuscript

Table 2. NUH's COVID-19 Measures

Domain	COVID-19 Measures	The New Normal
Operations Center	<p>Set up of Ops Center in January 2020 with two full time staff. Augmented by staff to coordinate whole of hospital approach (see Supplementary Figure 1).</p> <p>Meetings held twice weekly</p> <p>Ops orders to be sent to all hospital staff upon updates in instructions</p> <p>Infectious Disease Division Consultants made available for departments to consult</p>	<p>Ops Center to remain in operation</p> <p>New Standard Operating Procedures to be drawn up to facilitate future pandemic responses</p> <p>Regular meetings to continue less frequently</p>
Inpatient Wards	<p>Decanting patients in existing isolation wards to other dedicated wards</p> <p>Mobilising three wards of single rooms to serve as isolation rooms</p> <p>Identified three wards to cohort COVID-19 patients</p> <p>Conversion of Day Surgery ward to house inpatients</p> <p>Patients with airborne transmissible diseases including tuberculosis and chickenpox were still housed in isolation wards.</p>	<p>To ring-fence 80 general ward beds, approximately 10% of the hospital's adult general ward beds</p>
Outpatient Clinics	<p>Reduction of non-urgent clinic visits (up to 53%)</p> <p>No new patients from overseas</p> <p>Increased use of teleconsultations</p> <p>Measures to reduce crowding implemented across common waiting areas in the hospital.</p>	<p>To scale up clinic visits to 90%, maintaining safe distancing measures across facilities</p> <p>Scale up tele consultations to 10% of total clinic consultations</p>
Emergency Department	<p>Creation of separate flow for suspected COVID-19</p>	<p>To maintain separate flow for suspect</p>

	patients, placed into fever facility.	COVID-19 patients and ARI patients
	Creation of additional isolation capacity via expansion of Extended Fever Facility (25 beds) and conversion of two unused clinics (43 beds)	
Intensive Care Units and High Dependency	Conversion of a HD unit to house ICU patients Conversion of a short stay surgical ward to house HD patients	16 ICU rooms (~10% of ICU and HD capacity – total 192) to be reserved for COVID-19 patients
Operating Rooms	Two operating rooms and a delivery room were prepared and reserved for COVID-19 patients Reduction of elective surgical procedures (up to 55%)	Maintain COVID-19 prepared operating rooms and delivery rooms Scale up of elective surgical procedures (up to 90% of usual load)
Logistics	Stockpile of at least two weeks of PPE and two months of critical drugs Procurement of additional ventilators and ECMO	Maintain healthy stockpiles on site of PPE, critical drugs and additional equipment
Manpower	Training of redeployed doctors via online learning and e-lectures More than 200 nurses trained in two-week long critical care crash courses, including ICU and ED attachments	Short attachments for nurses to ED, isolation wards and ICUs to maintain their ability to be deployed in these areas
Staff Management	All staff were to wear surgical masks at all times Staff to report temperature, twice daily Instituting team segregation in all hospital departments Implementation of telecommuting. Transition to electronic approvals in procurement and administrative processes. Frequency communications to staff & presence of hospital leadership	To maintain all COVID-19 safety measures To adopt telecommuting as the norm
Housekeeping	Redeployment of housekeeping staff to 'hot zones'	Redistribution of housekeeping staff across the hospital

Security	Implementation of screening at all hospital entry points Limiting number of visitors for non-COVID-19 patients	To maintain COVID-19 measures
Education and Research	Shift of essential trainings and teachings online Stop cross-hospital trainings Non-COVID-19 research was paused	Further explore using online methods for trainings To progressively increase non-COVID-19 research
Laboratory	Increase scale of laboratory testing Laboratory manpower was reorganized and augmented by research staff from the affiliated medical school	Maintain COVID-19 levels of laboratory testing with multiple teams

Accepted Manuscript

Figure Legends

Figure 1. NUH COVID-19 admissions to isolation wards from February to July 2020. *a*: Opening of ED Extended Fever Facility. *b*: Opening of first COVID-19 Cohort Ward. *c*: Singapore enters nationwide lockdown (Circuit Breaker), opening of 2nd COVID-19 cohort ward, conversion of unused clinics for ED patients. *d*: Opening of 3rd COVID-19 cohort ward. *e*: Conversion of Short Stay Ward to clean HD ward, equipping surgical HD ward to be ICU capable. *f*: Temporary Pandemic Ward in carpark on standby, NUH set up Tuas Community Care Facility – first CIF in the West of Singapore. *g*: Singapore exits nationwide lockdown (Circuit Breaker). Abbreviations: ED, Emergency Department; ICU, Intensive Care Unit; HD, High Dependency; CIF, Community Isolation Facilities

Figure 2. Comparison of hospital services in 2019 and 2020. A: Hospital Inpatient Admissions. B: Outpatient Clinic Attendances. C: Emergency and Elective Surgeries. Wilcoxon Signed Ranked Test was used to compare workload between the period February to July in 2019 and February to July 2020. * $P < 0.05$. Abbreviations: EM, Emergency; EL, Elective

Figure 1

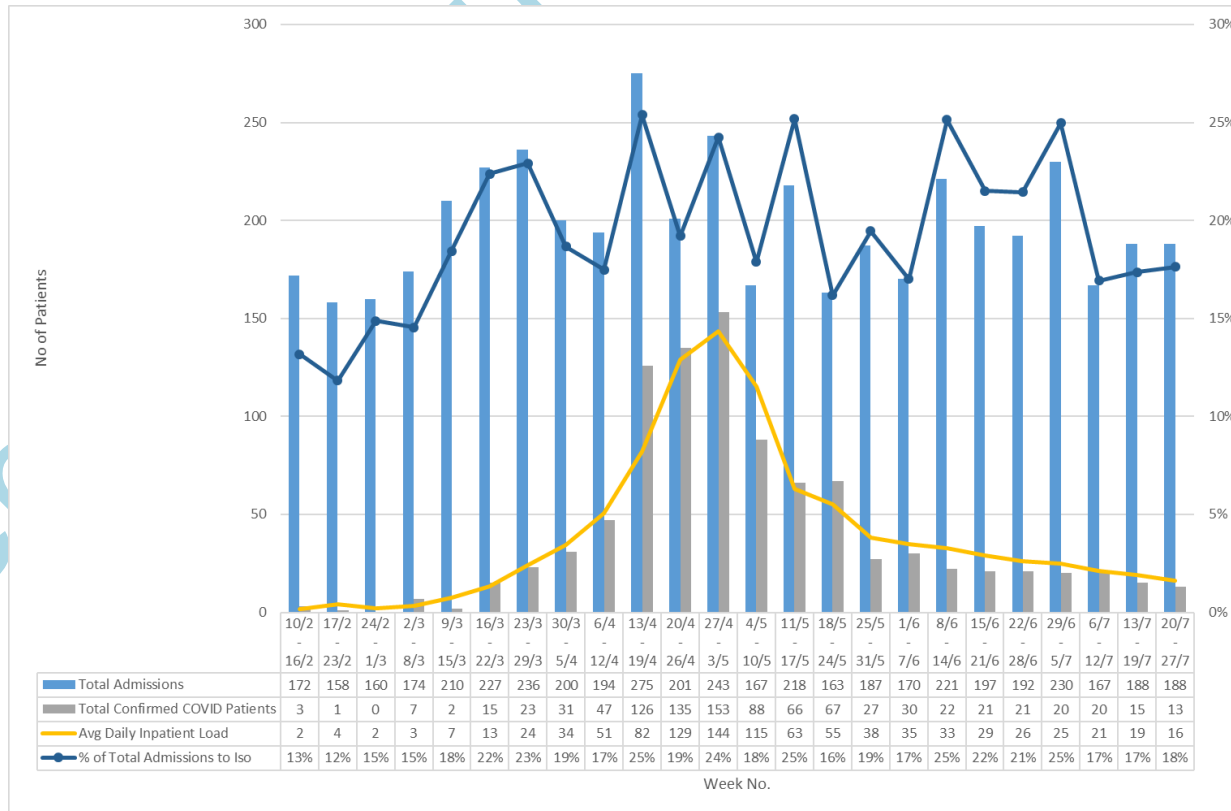


Figure 2

