

CONCEPTS

Infectious Disease

Dynamic emergency department response to the evolving COVID-19 pandemic: the experience of a tertiary hospital in Singapore

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Abstract

The coronavirus disease 2019 (COVID-19) pandemic has placed large stressors on emergency departments (EDs) worldwide. As the pandemic progressed, EDs faced changing patient epidemiology and numbers. Our ED needed to rapidly transform to deal with the risk of COVID-19. Having limited floor space, we opted for a phased, dynamic response that allowed us to adapt the ED multiple times as the epidemiology of the pandemic evolved. The principles behind our response include guiding ED operations with data, enhancing infection control practices, and being prepared to transform areas of the ED to care for different groups of patients. Our experience can serve to guide other EDs in planning their response to surge capacity and ED operations during such pandemics.

KEYWORDS

COVID-19, Emergency department, Operation, SARS-CoV-2

1 | INTRODUCTION

During the coronavirus disease 2019 (COVID-19) pandemic, emergency departments are at the forefront of hospitals' responses to the ongoing outbreak. Singapore, a Southeast Asian city-state with close travel links to mainland China, was one of the first few coun-

tries in the world to detect cases of COVID-19 outside of China, reporting its first imported COVID-19 case on January 23, 2020.¹ By April 2020, cases rapidly accelerated with an ongoing outbreak centered on crowded migrant worker dormitories.² As of July 2020, >50,000 cases of COVID-19 had been reported, one of the highest rates recorded in Southeast Asia. Given ongoing community transmission, EDs at public hospitals in Singapore had to ensure the sustainability and adaptability of their approaches to the containment of

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COVID-19. Given that even a single patient in a crowded ED can potentially ignite a nosocomial outbreak of a novel respiratory pathogen,³ with devastating consequences and the prospect of ED closure,^{3,4} it is crucial to ensure that hospital EDs can continue to operate safely throughout the COVID-19 pandemic, without becoming hotbeds for disease transmission.

Singapore General Hospital is Singapore's oldest and largest hospital with a total of 1735 beds, and the current ED was built in 1977. Over the years, the daily ED patient load has increased from roughly 175 to 350 a day, but spatial constraints have limited the physical expansion of the department.⁵ The first case of COVID-19 in Singapore was diagnosed on presentation to our ED on January 23, 2020 and picked up because of increased vigilance.⁶ Over the next few months, our ED rapidly developed and implemented a response plan that maximized the limited physical space and allowed our ED to appropriately manage patients with different risk profiles for COVID-19, while simultaneously maintaining adequate protection for other patients and staff. In this paper, we describe this response, with a focus on phased adaptations to deal with successive waves of COVID-19 cases and evolving epidemiology. We also describe the challenges faced in rapidly converting various patient areas to support higher-acuity care. As of the time of writing, although multiple studies have described their institution's ED response to COVID-19 at various timepoints,^{4,6-8} to the best of our knowledge, an overall multiphased ED response guided by evolving COVID-19 epidemiology has yet to be described in the peer-reviewed literature.

We believe this description can serve as a potential planning model for other EDs, especially those facing similar space constraints, as EDs start preparing for the "new normal" and successive waves of COVID-19.

2 | PHASES OF COVID-19 PANDEMIC AND RESPONSE IN SINGAPORE

To date, Singapore has faced several waves of COVID-19 patients, each with distinct epidemiology.^{1,2} During the first wave of cases from mid-March to early April 2020, "imported cases," comprising travelers and returning Singaporeans, predominated. From March 18, 2020 onwards, the Singaporean government barred inbound travel; from June 17, 2020, travel curbs were lifted, but all travelers were required to serve a 14-day stay-home-notice period and undergo COVID-19 testing.⁹ In the second wave, patients deemed to have caught COVID-19 in the local community, termed "community cases," predominated. The number of community cases rose at the end of March, peaked in mid-April and have been declining up to the time of writing (July 2020). In the third and largest wave, cases among migrant workers staying in purpose-built dormitories ("dormitory cases") predominated, with a significant number of asymptomatic cases.² A significant spike occurred in mid-April, with a daily maximum of 1397 patients diagnosed on April 24, 2020 (Figure 1). In response to the spike in cases, a nationwide "circuit breaker" period was declared from April 7, 2020 to June 1, 2020. During this partial lockdown period, all non-essential

services and schools were closed and public gatherings were prohibited.⁹ To cope with the significant rise in "dormitory cases," the Singapore government pre-positioned medical teams at dormitories to manage patients with mild symptoms.² This greatly reduced the number of patients presenting to hospital EDs and smoothed out the expected peak in ED attendances despite a huge spike in detected COVID-19 cases. (Figure 1).

3 | HOSPITAL SETTING AND ED LAYOUT PRIOR TO COVID-19 PANDEMIC

Having experienced a previous outbreak of severe acute respiratory syndrome in 2003, our hospital's ED has since been divided into "clean" and "dirty" zones, with provision for isolation facilities in the "dirty" zone.¹⁰ (Figure 2):

1. The "dirty" zone, otherwise termed as a "fever area,"¹¹ is a space in the department with separate access to the ambulance drop-off area. It is designed to manage ambulatory and non-ambulatory patients at risk of communicable diseases. This area is equipped with its own 11-bed negative-pressure isolation area, its own triage room, X-ray suite, toilets, and registration counter. All effluent air is HEPA (high-efficiency particulate air) filtered and ventilation is separate from the rest of the ED. Outside of outbreak scenarios, this area is utilized for cases suspected of having infectious pathogens requiring isolation, such as tuberculosis and measles.
2. The "clean" zone, which typically handles the bulk of patients, consists of 8 consultation rooms, a critical care area (CCA) for non-ambulatory patients requiring stretcher beds, and an observation ward. The beds in the observation ward are meant for patients admitted to the observation unit or those awaiting transfer to the ward.
3. Our resuscitation room consists of 6 bays. Should there be a need, 4 bays can be sealed off with sliding doors to create negative pressure rooms. Essentially, the resuscitation room can accommodate both "clean" and "dirty" patients.

4 | GUIDING PRINCIPLES DURING COVID-19 OUTBREAK RESPONSE

During any crisis response, medical care can be delivered at 3 levels: conventional care, contingency care, and crisis care¹² (Figure 3). Departments and health systems aim to remain at the conventional and contingency phases of the response to ensure that patient care is not compromised. To achieve this, our ED adopted the following guiding principles during the ongoing COVID-19 outbreak:

1. Phased, dynamic response: The ED response plan was continuously adapted to meet changing needs as the crisis unfolded, with repurposing of patient areas in response to changing trends in patient numbers and epidemiology.

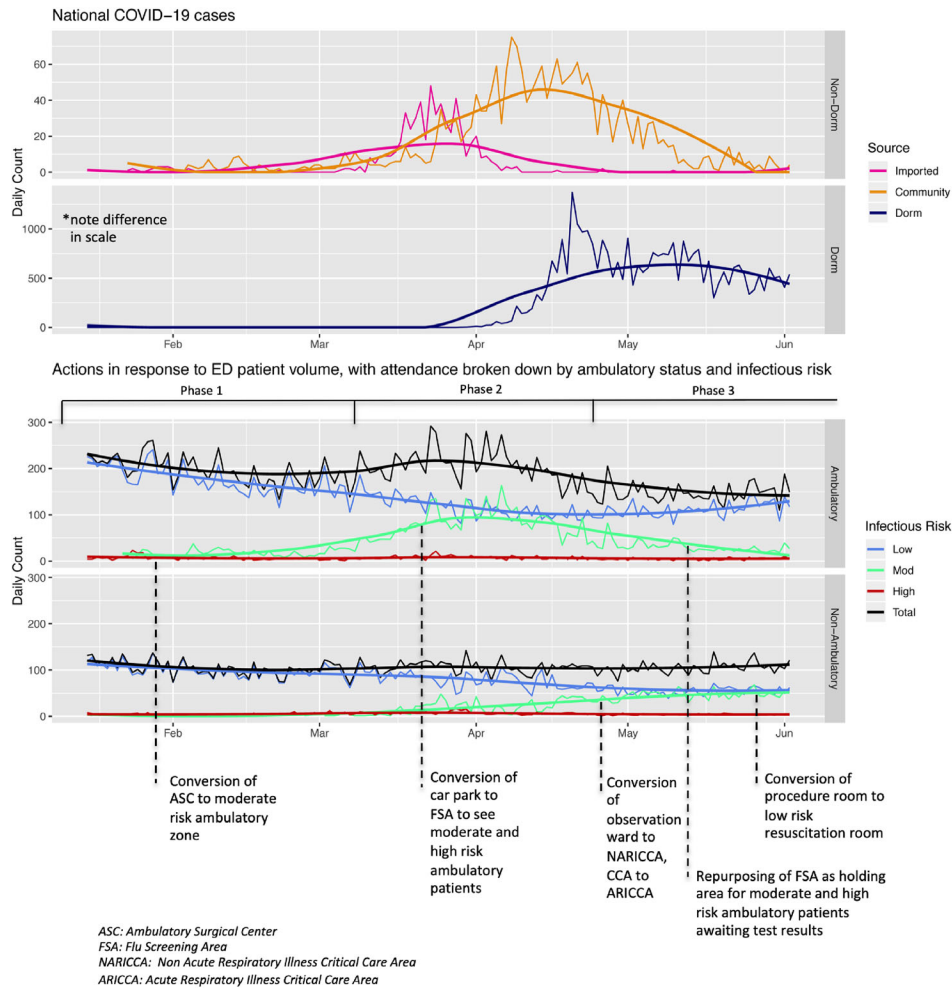


FIGURE 1 Phases of COVID-19 outbreak in Singapore over a 6-month period and corresponding response plans at the emergency department of an acute tertiary hospital

2. ED-wide adoption of enhanced infection control measures: Given ongoing community transmission, to mitigate the small potential risk of an unsuspected COVID-19 case presenting outside of containment, enhanced infection control measures were adopted ED-wide, including enhanced personal protective equipment, safe-distancing measures, and staff surveillance measures.
3. Early segregation of suspect COVID-19 cases: Patients were triaged into high, intermediate, or low risk for COVID-19 at the point of entry to the ED, based on screening criteria (Figure 4), which included both clinical syndromes as well as epidemiology. Our institution adopted a broader set of screening criteria compared to official case definitions for suspect COVID-19 cases, in order to achieve higher pickup of cases.⁶ Separate patient areas were created to segregate patients of different COVID-19 risk profiles, with specific areas for patients requiring ambulatory, non-ambulatory, and resuscitation level care.

5 | MANAGING CHANGING PATIENT EPIDEMIOLOGY IN PHASES

We break down our response into 3 broad phases. These phases reflect our response to national-level directives, evolving risk profile, and trends in patient distribution. The details of the changes in floor space can be visualized in Figure 2.

5.1 | Management of ambulatory patients: expansion of capacity

In the first 2 phases of the COVID-19 outbreak, our ED experienced pressure on ambulatory care, given the large number of intermediate-risk COVID-19 suspect cases among returning travelers as well as migrant workers from dormitories. These ambulatory patients were generally more stable and we opted to deal with fluctuating numbers by creating temporary clinical areas.

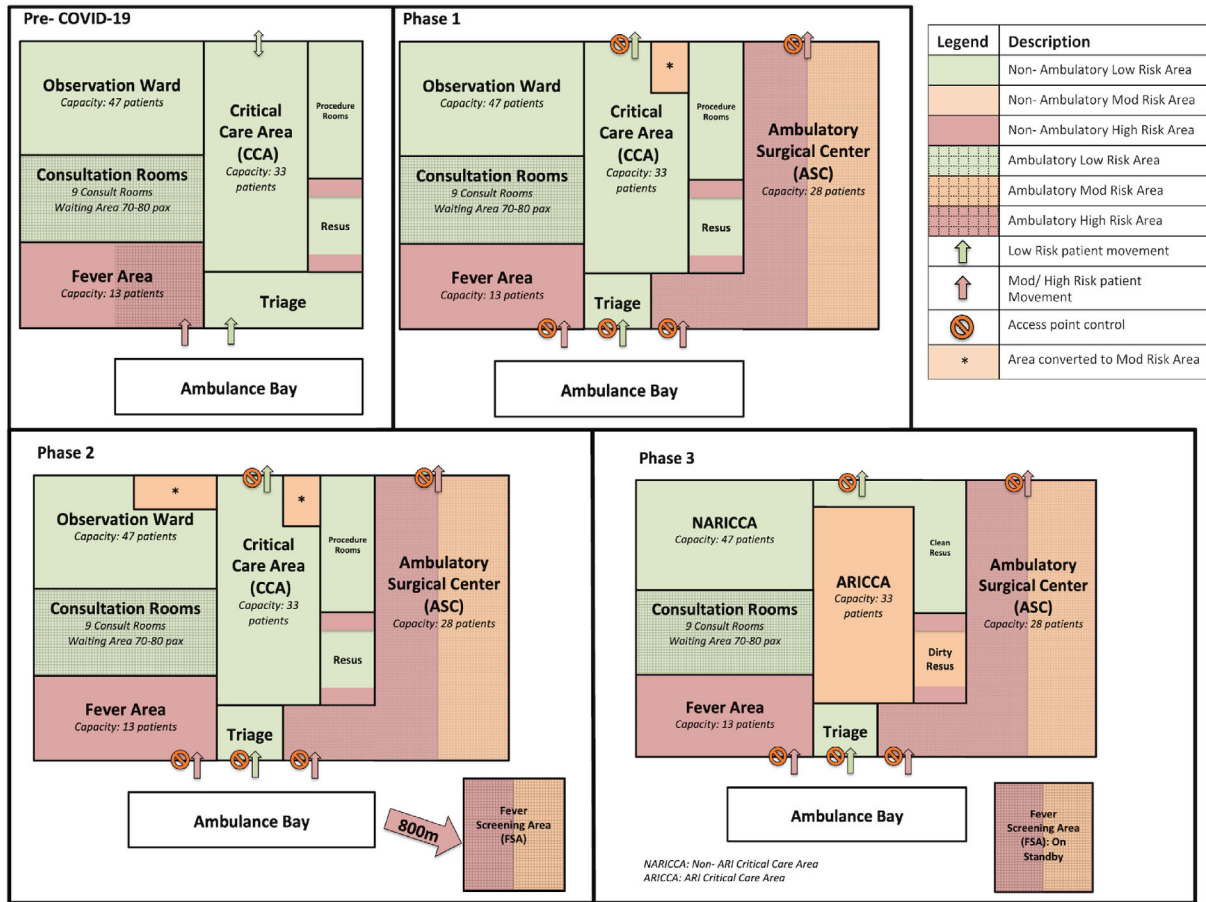


FIGURE 2 Alterations to layout of emergency department during different phases of COVID-19 outbreak, at an acute tertiary hospital in Singapore

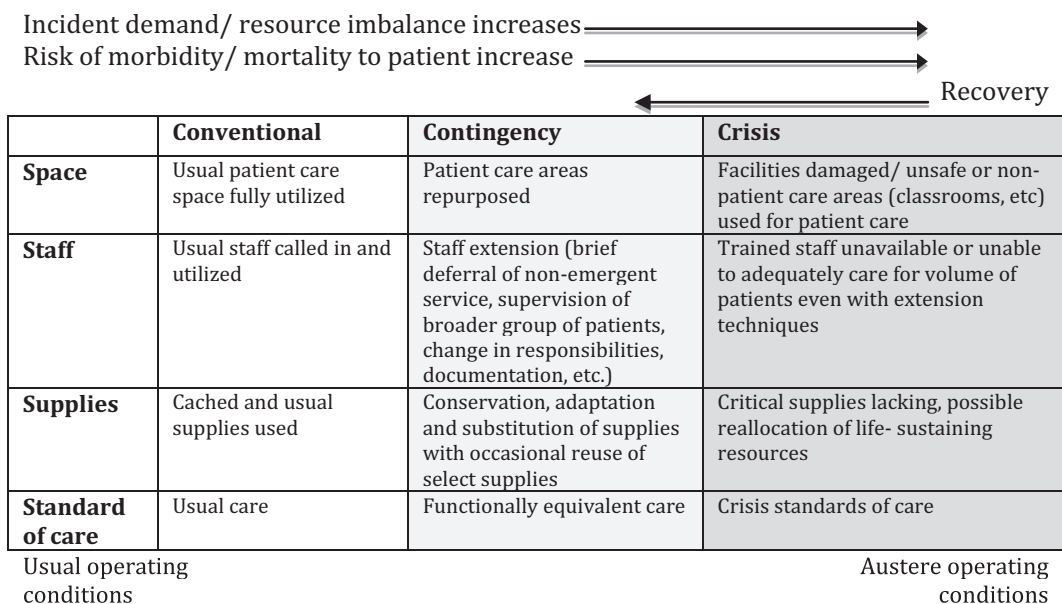


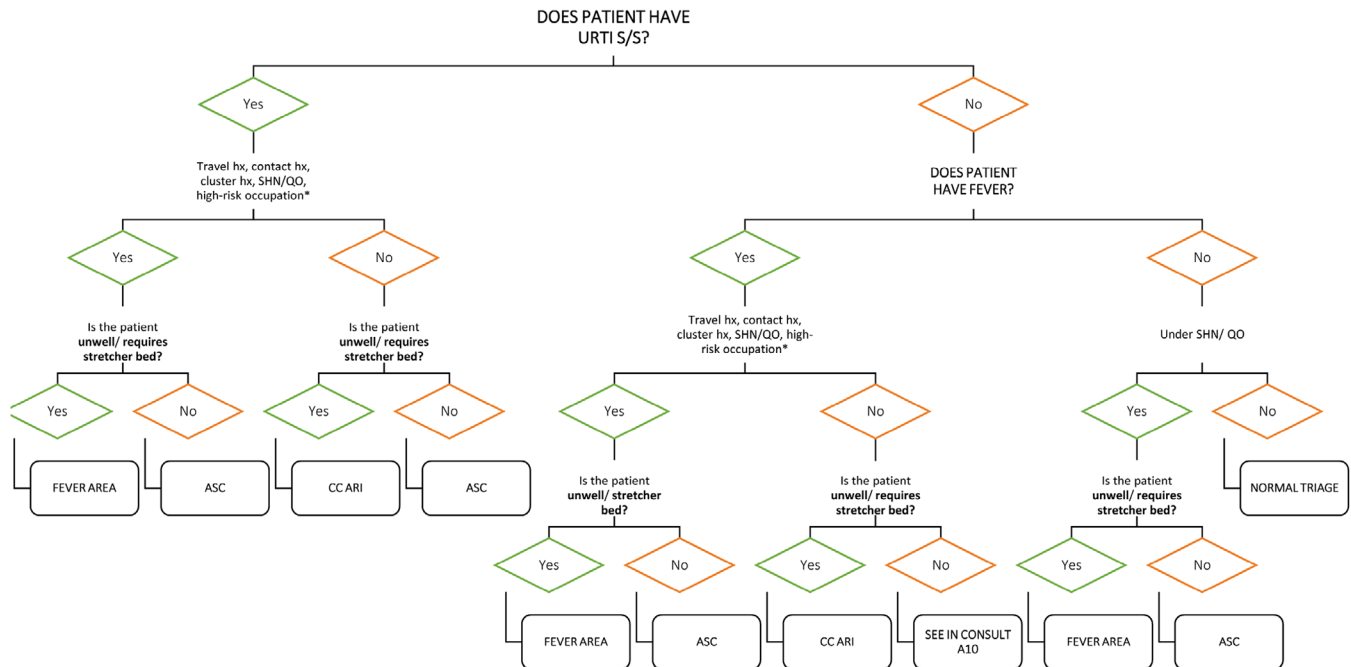
FIGURE 3 Continuum of incident care and implications for standards of care. Adapted with permission from Institute of Medicine – Guidance for Establishing Crisis Standards of Care in Disaster Situations¹²

EXCEPTIONS:

ALL patients REFERRED FOR PNEUMONIA → see in ASC (if well) or ARI CCA (if unwell)

ALL COVID-positive → see in *Fever Observation*

ALL FOREIGN WORKERS who are CURRENTLY OR PREVIOUSLY STAYING IN DORM (regardless of whether decanted or not) → see in ASC (if well) or *Fever CC* (if unwell)



URTI: Cough, runny/ blocked nose, sore throat/ phlegm, loss of smell/ taste

SHN: Stay Home Notice

QO: Quarantine Order

***HIGH-RISK OCCUPATION:** (1) Any staff currently working in a healthcare setting e.g. primary/ acute care, dormitory operations, isolation facilities, ambulance staff (2) Close contact with foreign workers e.g. construction supervisors (3) Essential workers i.e. NOT working from home

SGH DEM Triage Decision Tree v6.2 (08/05/20)

FIGURE 4 ED triage criteria for suspected COVID-19 cases, based on compatible clinical syndromes, epidemiological risk, and patient status

5.1.1 | Phase 1

To prepare for the anticipated surge in ambulatory cases from returning travellers, we took over the adjacent ambulatory surgery center (ASC) to create an additional unit capable of caring for patients in individually partitioned cubicles (Figure 2). An adjacent link way was converted to serve as an additional waiting area for patients. This area could hold up to 12 stable patients who were waiting for general laboratory and diagnostic imaging results and were expected to be discharged after.

5.1.2 | Phase 2

On March 20, 2020, as part of the national containment response, our hospital was tasked with receiving COVID-19 suspect cases referred from primary care and transported by a dedicated ambulance service. Before this, these cases were received at the National Centre for Infectious Diseases (NCID), a purpose-built facility that had been designated to lead the national response.^{7,13} At that point in time, NCID was screening 100–200 patients a day with the numbers steadily increasing. Plans were thus made for our ED to accommodate the diverted

patient flow, which approximated 30–40 patients a day. A multistory car park 800 meters from the hospital ED was thus converted at short notice to receive these patients, the bulk of whom were envisaged to require only ambulatory care.¹⁴ This converted car park was termed the fever screening area (FSA) and was managed by the ED, with supplementation of manpower from the rest of the hospital. Due to the distance from the main ED and limited resuscitation capabilities, there were strict triage criteria for diversion to the FSA, including stable vital signs, age ≤ 65 years old, and having only symptoms of acute respiratory illness (ARI). Patients were triaged by dedicated ED nurses at the 2 receiving areas, namely the FSA (for those transported via the dedicated ambulance service), and the drop-off point of the main ED. Patients who did not meet triage criteria for the FSA were managed in the “fever areas” (eg, converted ASC) of the main ED.

5.1.3 | Phase 3

In mid-May, because of the diminishing number of patients being received at the FSA, the patient consultation service at FSA was stopped, as the “fever areas” in the main ED were sufficient to handle the numbers of suspected COVID-19 cases requiring ambulatory care.

However, the FSA was held in a state of standby readiness, should there be a resurgence of ambulatory suspect cases.

5.2 | Management of non-ambulatory patients: flexibility with existing spaces

During the second and third phases of the pandemic, our ED saw a rising number of COVID-19 suspects who required non-ambulatory care. Non-ambulatory patients were generally less stable and needed to be managed in the main ED to deal with possible deterioration, instead of being managed off-site. Rather than expanding ED capacity for these patients, our ED adapted its existing spaces to changing epidemiologic risk.

5.2.1 | Phase 1

In general, patients requiring non-ambulatory care in the first phase of our response were at low risk of COVID-19, given that imported cases formed the majority of cases and were generally ambulant. However, to minimize ED congestion, which could increase the risk of coming into contact with an unsuspected case of COVID-19 in the ED, our department closed down its observation unit. Patients previously planned for observation were now either admitted or discharged with advice. The observation ward was then used as a transit area for patients awaiting movement to the inpatient ward. To accommodate the increased number of admissions arising from closure of the observation unit, inpatient beds were freed up from cancelled surgical electives in close partnership with the hospital management. In this phase, our ED took the precaution of separating out non-ambulatory patients with ARI, designating a separate zone in the CCA to house these patients.

5.2.2 | Phase 2

On March 19, 2020, our hospital's ED was tasked to receive 50% of the daily national ambulance load that was diverted away from Tan Tock Seng Hospital (TTSH), the second-largest tertiary hospital co-located with the NCID. TTSH had now reached maximum occupancy because of the pressure on admissions and could no longer freely accept cases through its ED. At the same time, our ED was also experiencing an increase in non-ambulatory suspect COVID-19 cases, given the older age profile of patients presenting during this phase. To manage this surge, our ED expanded the capacity for non-ambulatory patients by converting a room in the observation ward to handle non-ambulatory patients with ARI.

5.2.3 | Phase 3

As the number of imported cases and dormitory cases was dwindling, our ED prepared for a surge in community cases, especially after the lifting of social restrictions. Taking into account our rapidly aging population, we expected a higher proportion of COVID-19 suspects to be non-ambulatory. Recognizing the diminishing value of epidemio-

logical risk factors such as travel and contact history in distinguishing COVID-19 cases, all patients with compatible clinical syndromes were deemed potential COVID-19 suspects. Furthermore, patients could also be minimally symptomatic or even asymptomatic.^{15,16} Our ED thus converted the entire observation ward into a "clean zone," and the entire CCA to a "dirty zone" for handling of non-ambulatory cases. We termed these zones ARICCA (ARI critical care area) and NARICCA (non-ARI critical care area). Our ED also reinforced emphasis on enhanced infection control measures, given the increased risk of an unsuspected COVID-19 case presenting outside of containment because of the decreased value of epidemiological risk factors for triage.

5.3 | Management of patients requiring resuscitation: creating a new resuscitation room

As the pandemic progressed, it became apparent that preexisting resuscitation rooms were not ideal. These facilities had multiple patients of different COVID-19 risk profiles in fairly close proximity and had a high number of aerosolizing procedures being done. We opted to convert a procedure room into a new resuscitation area.

5.3.1 | Phase 1/Phase 2

Initially, all patients requiring isolation were concurrently managed in our resuscitation room, which has built-in isolation capabilities. However, there were difficulties in properly segregating the patients of different risk profiles, as the facility was built for isolating up to 4 patients. This meant that the medical team had to ensure a rapid throughput to be able to cope with the increasing numbers of critically ill patients with moderate to high COVID-19 risk. As this often proved to be challenging, our ED started planning for further measures in Phase 3.

5.3.2 | Phase 3

To further minimize the risk of cross-contamination in high-risk areas where aerosol-generating procedures (eg, intubations) were frequently performed, we converted 2 procedure rooms into resuscitation rooms meant for patients with low COVID-19 risk. These were cases with strictly no contact history, travel history, or ARI symptoms. Cases with unclear risk profile were still seen in the usual resuscitation area, now used for patients with moderate/high risk for COVID-19. The repurposed resuscitation area was termed "clean resus." We chose to convert 2 procedure rooms to the new "clean resus" because of their large size, availability of oxygen and air wall outlets, and close proximity to the existing resuscitation area. With the addition of 4 cubicles outside the procedure room as a monitoring area (with postresuscitation monitoring capabilities but unable to support airway management), the clean resus was able to manage up to 6 critically ill patients. Conversion of the "clean resus" area took 5 weeks, as approval had to be obtained from hospital infection control and

the National Environmental Agency, for the airflow and the radiation shielding capability, respectively.

Because of the limited time available to familiarize our entire department with the “clean resus” area, it was paramount that the setup be intuitive. The layout of our usual resuscitation area (henceforth termed “dirty resus”) was replicated in the “Clean Resus” area, with all equipment and drugs contained in specially designed, mobile “resus trolleys” that were laid out in the exact same configuration as the airway, circulation, and monitoring panels of the dirty resus. This modular design also had a secondary advantage – it allowed us to recreate a resuscitation area anywhere in the department by simply wheeling the “resus trolleys” to the designated location should the need arise. Simulation sessions were also held to stress test the workflow and familiarize staff with the set up.

6 | ENHANCED INFECTION CONTROL MEASURES: PROTECTING OUR STAFF AND PATIENTS

Prior to COVID-19, the department has always had a compulsory surgical mask policy for all medical staff. Since the start of Phase 1, donning an N95 respirator was made compulsory for medical staff in all areas of the department.⁶ When dealing with patients at risk of COVID-19, medical staff donned goggles, disposable gowns, and gloves in addition to their N95 masks. When performing aerosolizing procedures, staff wore powered air purifying respirators. All staff working in the ED underwent twice-daily temperature monitoring, with results entered into an electronic surveillance system; staff who had fever or ARI symptoms were required to report to the Singapore General Hospital staff clinic during office hours and to the ED after hours, and COVID-19 testing was performed for symptomatic staff.¹⁷ Staff would be placed on medical leave until results of COVID-19 testing were known.

Measures were taken to protect our patients as well. Knowing that some patients with COVID-19 might present atypically, the wearing of surgical masks by all patients and visitors was made compulsory. Physical distancing measures were also implemented in patient waiting areas and staff rest areas.¹⁸ Lastly, as the physical structure of the department did not allow for completely separate routes of patient transport (to the ward, for example), arrangements were made for the transport route of any potential COVID-19 patient to be cordoned off by security personnel prior to movement. Given that the added ED capacity posed a challenge for timely contact tracing over multiple sites, our ED leveraged on technology to deploy a real-time location tracking system using radiofrequency identification tags, enabling the specific location and movement of individual patients to be rapidly retrieved for epidemiological investigations.

7 | VOLUME OF SUSPECTED AND CONFIRMED COVID-19 CASES MANAGED IN THE ED OVER A 6-MONTH PERIOD

From January 15 to June 2, 2020, our ED handled a total of 10,234 suspected cases of COVID-19. Roughly two thirds of patients

(65.7%, 6722/10234) were seen in ambulatory areas, whereas the remainder were seen in non-ambulatory areas. Of the ambulatory patients, the majority (69.3%, 4661/6722) were managed in the “fever areas” of the main ED (existing “fever area,” and “fever area extension” created by converting the adjacent ASC), and the remaining cases (30.7%, 2061/6722) were managed off-site at the FSA. Out of the $\geq 10,000$ suspect cases handled in the ED, a total of 1257 cases (12.2%, 1257/10234) eventually tested positive for COVID-19. Despite extensive epidemiologic investigations, no evidence of healthcare-associated transmission of COVID-19 was detected at the ED level, and $< 1\%$ of COVID-19 cases (0.23%, 3/1257) were managed outside of the designated “fever areas” in the ED, likely because of the broad criteria used to identify suspected COVID-19 cases.⁶ Despite intensive ongoing staff surveillance and wide availability of COVID-19 testing for staff, only one non-clinical staff working in the ED tested positive for COVID-19, likely attributed to community acquisition.¹⁹ Enhanced infection control precautions likely limited further intra-hospital transmission; despite testing of all staff close contacts, no additional cases were detected.

8 | DISCUSSION AND LESSONS LEARNED

A dynamic ED response during evolving phases of the COVID-19 pandemic allowed for containment of COVID-19 at the ED level without compromising patient care. No healthcare-associated transmission of COVID-19 was detected over a 6-month period at the ED level; the ED remained in operation throughout the COVID-19 outbreak without being overwhelmed by patient numbers,⁴ and continuity of care was achieved for both patients of all COVID-19 risk groups.

During the COVID-19 outbreak, the ED saw a $\sim 20\%$ decrease in patient volumes compared to the corresponding period a year earlier,²⁰ similar to experiences reported from other countries.²¹ However, enhanced distancing required our ED to be decongested further, which posed significant challenges given limited floor space. Although our ED did not see a huge spike in severely ill patients that some hospitals did,²² we saw increasing numbers of patients with potential COVID-19 risk. As part of the phased response, our ED opened up new areas and converted existing spaces to provide additional capacity to handle this surge. Waiting times for the sickest category of ED admissions (P1 patients) did not increase during the ongoing COVID-19 outbreak,²⁰ an indicator that patient care was not compromised. The appropriate and accurate triage of suspected COVID-19 cases in the ED, with $< 1\%$ of COVID-19 cases being managed outside of the ED’s designated “fever areas,” also translated into appropriate disposition of high-risk COVID-19 suspects into inpatient isolation wards, with the vast majority of COVID-19 cases being managed in isolation from the beginning of their patient journey.²³ To-date (July 2020), despite having handled ≥ 1200 cases of COVID-19 over 5 months, our hospital has not reported any patient-to-healthcare worker transmission of COVID-19.²⁴ This demonstrates the key role of the hospital ED in containing nosocomial transmission of a novel respiratory pathogen through accurate triage and risk-stratification.⁶

This dynamic ED response was made possible through the contribution of multiple factors. First, close surveillance of patient numbers as well as evolving screening criteria allowed our ED to preempt patient surges by repurposing physical spaces ahead of time. The physical space of the ED could thus be adapted to the changing patient numbers, optimizing the usage of our ED's limited floor space. Second, advance planning allowed for valuable lead time needed to convert existing areas to manage high-acuity care. Although the physical transformation was quick, approval from the relevant authorities was needed to ensure the safety of staff and patients being seen in the repurposed areas. As this can take time, EDs should consider having preapproval for some of these plans so that such plans can be implemented expeditiously. Conversion of our institution's multistory car park to an FSA as part of pandemic preparedness plans had been initiated as early as 2013, and preapproval from the relevant stakeholders had already been obtained prior to the COVID-19 outbreak.¹⁴ This allowed the seamless execution of conversion plans during the COVID-19 pandemic and mitigated the need for erection of temporary tent structures to provide additional ED capacity,⁸ which may be less durable, especially in Singapore's tropical climate. Finally, a close working relationship between the ED and the whole-of-hospital is essential to guide the ED's dynamic response. During the outbreak, our ED worked closely with the infectious diseases and infection control departments, in order to obtain key assessments of epidemiological trends that were invaluable in guiding the ED's workflow for COVID-19 suspect cases and ensure that the converted patient care areas were safe from the infection control standpoint. Coordination with the occupational health department and centralized reporting of ED staff to staff clinic also allowed for early detection of potential staff clusters.²⁵

9 | FUTURE CHALLENGES: ANTICIPATING THE NEW NORMAL

On June 2, 2020, Singapore lifted its circuit breaker, entering the first phase of a multiphased recovery where restrictions are gradually loosened. There continues to be a small number of new community COVID-19 patients daily. We anticipate possible repeated waves of infection likely to happen 10–14 days after the lifting of social restrictions, and have thus opted to continue with essentially 3 different COVID-19 risk categories of patients with corresponding high, medium, and low acuity areas for each group. We anticipate the possibility of reopening resources such as FSA, readjusting our floor space again or further repurposing clinical areas.

Given the resumption of elective procedures that may create increased demand for inpatient beds and increase ED wait-times, as well as an anticipated increase in permitted visitors (from one companion to two), increased crowding in the ED may pose an infection control issue. This may require the reopening of overflow areas to recreate the increased capacity needed for enhanced physical distancing.

Lastly, the department workforce was augmented with additional doctors and nurses from other departments during this period. With

the return of day-to-day work in the hospital, the additional personnel will be reduced. This will decrease our ability to have separate doctors managing all the newly created areas and cross-coverage will be required. We hope to mitigate the infection control risks by allocating cross-coverage within similar risk zones.

In conclusion, a phased, dynamic ED response to the evolving COVID-19 pandemic allowed for containment of COVID-19 at the ED level without compromising patient care. As our department awaits the completion of a brand-new ED in the next few years, we will take these lessons and apply them as we prepare for a new environment. Similarly, we believe that other EDs might benefit from our experiences managing COVID-19 with limited physical space.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest

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