

Radiology Preparedness in the Ongoing Battle against COVID-19: Experience from Large to Small Singapore Public Hospitals

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Summary Statement

A summary of the preparations made by the radiology departments in 6 Singapore Public

Hospitals to battle the COVID-19 pandemic.

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ABSTRACT

The coronavirus disease 2019 (COVID-19) pandemic presents an unprecedented challenge to the healthcare systems of the world. In Singapore, the Radiology community's early experience on managing this pandemic was shaped by lessons learnt from the earlier SARS outbreak in 2003. This article surveys the operational responses of radiology departments from 6 public hospitals in Singapore.

INTRODUCTION

The integral role of Radiology in the early diagnosis and subsequent management of an infectious disease outbreak has been well described and is epitomized by the Severe Acute Respiratory Syndrome (SARS) epidemic of 2003 (1). China, Hong Kong, Vietnam and Singapore were countries most severely affected by the infection with 238 cases and 33 deaths resulting from SARS in Singapore. The experience of dealing with the epidemic was a pivotal moment in the development of our nation's healthcare system, which was stressed and tested to its limits. Radiology departments within hospitals were challenged for reconfiguring their setup and work processes in response to the needs of frontline imaging services, thereby aiding rapid diagnosis. One radiology department in Singapore was also a site of cross-infection, an incident which highlighted the importance of protecting and securing imaging resources during an outbreak (2).

In Singapore, the healthcare system is organized into 3 clusters, each helmed by a tertiary level hospital and supported by several regional hospitals and primary care polyclinics (3). There are also national institutes, such as the new purpose-built National Centre for Infectious Disease (NCID), which provides national level infectious disease surveillance and coordination, and the Kangar Kerbau Women's and Children's Hospital (KKWCH) dedicated for pediatric patients (**Table 1**). For the coronavirus disease 2019 (COVID-19) outbreak (4), the infectious disease teams and isolation facilities within each hospital allow it to manage their own suspect and confirmed COVID-19 patients as they present. NCID manages all non-hospital referrals whereas pediatric referrals are directed to KKWCH (5). Each of these hospitals has an organic radiology department with a full suite of general diagnostic imaging capabilities and varying levels of subspecialty, nuclear medicine and interventional radiology capabilities.

With the lessons learned from SARS, most radiology departments in Singapore have, where possible, incorporated outbreak preparedness into their work processes and protocols (6). To this end, newer facilities including NCID have been designed and equipped with imaging services that are integrated with the institutions' overall infection control and outbreak containment strategies. Regular drills and tabletop exercises conducted by the various institutions' outbreak management teams all include and involve radiology departments.

Following the World Health Organization's (WHO) declaration of the COVID-19 virus epidemic as a Public Health Emergency of International Concern on 30 Jan 2020, the outbreak continued to unfold and on 11 Mar 2020, it was classified as a pandemic by the WHO (7). Singapore diagnosed its first COVID-19 case on 23 Jan 2020 and has since treated 1000 cases as of 1 Apr 2020. Both imported cases and local transmission of COVID-19 are ongoing in Singapore as we continue to screen for and manage these cases (8). Singapore's overall strategy in dealing with the outbreak aims at flattening the epidemic curve (Figure 1) (9) such that hospitals do not get overwhelmed by a surge of cases. This is achieved via isolation of confirmed cases, contact tracing and physical distancing in order to break the chain of transmission (10).

Unlike SARS in 2003, when Tan Tock Seng Hospital was designated a 'SARS hospital', all hospitals in Singapore now collaborate in managing COVID-19 patients. This article surveys and details the wide-ranging operational responses of the radiology departments in 6 public hospitals that are treating COVID-19 in Singapore as they geared up to meet this challenge (Table 2).

Immediate Response – Protect

In the earliest phase of the outbreak, all contingency plans were reviewed and an effort made to conserve, secure, and protect all available manpower and resources. In one of the hospitals, a small taskforce comprising key appointment holders were constituted to coordinate the outbreak response. In the initial phase, the task force met daily to review manpower status, information update, operational plans, equipment status, training and safety plans. Key members were also emplaced into the hospital outbreak response team and infectious disease (ID) teams to obtain firsthand information and coordinate measures in response to the rapidly changing situation.

Personal Protective Equipment (PPE) and Infection Control Measures

Hospital PPE stockpiles were immediately released and made available to all frontline staff. With global stocks in short supply, a few sites rationed their surgical masks to non-clinical staff. Guidance on PPE usage was provided by the Ministry of Health of Singapore, which took a risk-based approach in developing the guidelines. Usage of the different PPE types is dependent on: first, the national framework for disease response or Disease Outbreak Response System Condition (DORSCON) level; second, the infection risk areas within the hospital; and last, the type of procedures performed (11). Each hospital's infection control committee issued a local set of PPE recommendations based on these guidelines. The full set of PPE consists of cap, goggles or face shield, n95 mask, and gown, which are worn by frontline staff when interacting with suspect or confirmed cases of COVID-19. Wearing a surgical mask is a basic requirement when one is working in a clinical area.

The use of powered air purifier respirator (PAPR) is not mandatory in most instances. If available, it is often reserved for aerosol generating procedures or in situations where prolonged n95 mask use cannot be tolerated. Following the experience of SARS, our

hospitals carry out regular mask fitting exercises for all staff and have made instructional videos on donning and doffing of PPE available online. Already a feature in all institutions, the importance of hand hygiene was re-emphasized and frequent reminders sent out in an effort to improve on compliance. Sanitizing hand-rubs were also made widely available throughout the department. In some hospitals, portable high-efficiency particulate air (HEPA) filters have also been placed at staff areas to minimize potential transmission. Other measures include a 'mask-up' policy within both the clinical and non-clinical areas.

It is vital from the outset to have departmental infection prevention liaison officers (IPLO) working closely with ID physicians or members of the hospital's infection control team to provide clarity on what constitutes adequate and appropriate PPE. Within one hospital, there is even a daily safety walkabout by departmental IPLO and senior staff to follow up on infection control policies.

Staff Segregation and a New Work Environment

In order to avoid disruption in manpower should cross-transmission occur, the policy of staff segregation or cohorting was implemented throughout all hospitals. Each professional group was divided into fully functioning units taking into account the need to create an optimal mix of available subspecialty expertise. These units were then either separated by time or location within the department or hospital (12). For example, in a particular tertiary hospital, the diagnostic radiology department was segregated into 3 cohort teams (Table 3) with main subspecialties divided and distributed into these cohorts. It takes into account the physical limitations and functional requirements at each location, such as number of workstations available or inpatient imaging support exclusively by a designated "hot" team. Residents were likewise distributed into each team taking into account their training plan. Smaller subspecialties such as breast radiology or neuro-interventionist may be divided into smaller

units nested within a cohort, but segregated from it. Each cohort team and nested team is duplicated and could therefore function independently if required. The small neuro-interventionist team is duplicated at the national level across several hospitals for business continuity due to their limited strength.

In another example, the interventional radiology department was segregated into 2 functional hybrid teams based on physical location of the interventional suites. Each team consists of members across the professional domains (e.g. doctors, nurses, radiographers etc.) capable of performing the full range of procedures.

To further enable physical segregation, most teams found it useful to have alternative radiology work areas or intra-hospital satellites with network ready access points installed for picture archiving and communication system (PACS) workstations. Unused offices were also converted into radiology workspaces in several instances. These newly installed or reconfigured workstations would be spaced at least 2 meters apart and users are advised to wipe down with disinfectant before and after each use. Remote reporting or teleradiology via virtual private network (VPN) access is a top drawer plan for most hospitals. When the need arose for some centers, the existing infrastructure facilitated rapid operationalization by hospital IT professionals. The challenges with teleradiology include the need to source for suitable high resolution reporting workstations and the presence of reliable and secure network connectivity.

In temporal segregation, the existing manpower is divided into two or more groups which will then work in shifts. The department's workload will then be reduced by postponing non-urgent cases to accommodate the reduced manpower. In smaller departments, physical segregation is deemed to be less onerous and hence more feasible when compared with a time-based shift system. To overcome limitations in staff numbers, one hospital utilized a staggered shift system which allows it to meet its commitment to around the clock

one-hour chest x-ray reporting turnaround time, while simultaneously minimizing fatigue and preventing staff burnout. Mixed temporal and physical segregation were employed in another hospital, where two teams worked weekly shifts, alternating between on-site clinical and procedural-based coverage followed by off-site or home-based reporting.

There has been a concerted nation-wide effort to consolidate our medical manpower at this crucial time. Prospective non-essential leave was cancelled *en bloc* with prior in-principle approved leave allowed only on a case-by-case basis. The number of staff members affected by the lockdown occurring in China was fortunately small, and they were able to return to work well after an enforced two weeks' leave of absence. As an established practice since SARS, all staff members are required to monitor their body temperatures twice daily and have them logged onto a national healthcare online database. Occupational health clinics are available for those who feel unwell, requiring further assessment and treatment.

In line with national policy directions, 'social distancing' is encouraged within and outside the workplace to minimize chances of cross infection taking place. It was a difficult policy to implement due to the busy and often crowded nature of typical radiology workspaces. Across all institutions, there have been deliberate efforts made to curtail non-essential meetings. Meeting agendas have also been shortened. When possible, technological adjuncts in the form of video conferencing using dedicated software (e.g. Zoom, Zoom Video Communications, Inc., San Jose, CA, USA; Webx, Cisco Systems, Santa Clara, CA, USA) are employed. The latter proved particularly useful in the conduct of residency teaching sessions, especially since residents from different institutions were prohibited to congregate. Lecture slide and teaching material have been made available online. In some hospitals, clinic-radiologic rounds have been exclusively conducted via Personal Data Protection Act (PDPA) compliant (13) video conferencing platforms (WebEx). For those hospitals where physical clinic-radiologic rounds continued, attendees must wear masks, and the rounds were

held in larger rooms with better ventilation and seats that are spaced further apart. In a similar fashion, social distancing measures have been also extended to the staff pantry in a few centers. Staff have been oriented to sit further apart during staggered lunch breaks and casual conversation is kept to a minimum. Pantry windows have also been opened for improved ventilation during meal times.

Protecting Patients

In a departure from what was practiced during SARS, patient screening is now mostly performed at main entrances of the hospitals instead of at the entrances of radiology departments (14). The key components of screening entail stringent temperature monitoring via thermal scanners, detailed travel history logs, and enforcement of access controls. Accompanying family members are discouraged from crowding in the waiting areas of the radiology departments. Where possible, start times for imaging scans have also been scheduled further apart to ensure temporal segregation. Physical segregation for patients is achieved by reconfiguring separate access routes for inpatients and outpatients. This serves to minimize potential cross infection between these groups of patients. Pre-appointment text messages are also sent to remind patients to reschedule their appointments if they are unwell.

Within the newest operational hospital, radiofrequency identification (RFID) tags used in staff identification passes and existing smart patient tracking technology have been put to use in access control for staff and maintaining visibility on unauthorized patient movements. With the availability of electronic data on staff and patients' location at any particular time, the process of contact tracing in the event of diagnosis of a positive COVID-19 case is expedited and done with increased precision.

Detect and Isolate

Equipment and Facilities

The use of CT scan as a screening tool is a novel approach and has been trialed during the COVID-19 outbreak in China, with a reported detection rate of 98% for initial CT scan vs 71% for first RT-PCR (15). However, this move was prompted partly by the lack of test kits during the early stages of the outbreak and also the fairly high false negative RT-PCR results. The use of routine screening CT for COVID-19 pneumonia is currently not endorsed by most radiology societies (16, 17).

The main imaging modality of choice in COVID-19 screening in Singapore remains conventional radiography, with CT scan used only as a problem-solving tool. The main reason we have continued to rely on conventional radiography as a screening tool lies in its ability to rapidly screen large numbers of patients accurately, without the prolonged downtime needed to clean the equipment and scanner room. Other important factors include the rapid availability of a radiology report and existing inventory of portable radiography machines. Radiography services are also ubiquitous in Emergency Departments and at the dedicated screening center at NCID.

The radiology departments within the larger and newer hospitals house imaging (MR, CT and US) and interventional radiology equipment, which are within negative pressure rooms. Adjoining anterooms have also been built to minimize air exchange with corridors, besides providing space for handwashing, donning and doffing of protective gowns, and storage of equipment.

Specific assets within the radiology facility have been assigned exclusively for suspect and confirmed cases of COVID-19. Clear boundaries are set for low traffic access routes and lift lobbies to be used. If a dedicated facility or equipment scanner cannot be assigned (e.g. highly specialized equipment that is not duplicated, such as that used in nuclear

imaging), isolation cases should be scanned at the end of the work day, not only to minimize cross contamination, but also to factor in time required for cleaning the room. Portable digital radiography equipment with wireless capabilities are useful, in that no additional handling of cassettes are required. The portable equipment is covered with single use disposable plastic sheets and wiped down meticulously according to a set protocol for disinfection. Portable digital radiography and ultrasound units also allow for rapid “on-time” upload of images to PACS for expedited reporting. Similarly, for CT and MRI scanners, there is standard cleaning followed by terminal cleaning (sodium hypochlorite 1000 ppm, ultraviolet treatment for CT), which is usually performed by a specialized team.

Radiology Reporting

To support the screening efforts along with management of critically ill patients in the intensive care units, hospitals have a 1-hour turnaround time policy for chest radiographs reports. Such ‘high alert’ studies are labeled for easy identification and are placed within a newly created worklist within the PACS. In order to meet this requirement for early reports, most departments have devoted additional manpower to it. In the initial stages of the outbreak, senior radiologists (especially those with experience during SARS) were tasked with reporting these radiographs. Junior radiologists were able to tap on the expertise of these ‘SARS veterans’ when they needed clarification and advice. Subsequently, with additional academic resources, such as journal references and teaching websites shared online, radiologists and residents alike have been able to familiarize themselves with typical diagnostic features and keep abreast of latest developments in case definitions and management of COVID-19. All staff were also made cognizant of the possibility of atypical presentations and to pay particular attention to incidental findings on imaging performed on non-suspect patients. A dedicated workflow to isolate and manage these patients with

incidental suspicious findings is critical. More recently, guidance on CT reporting has been also made available by the Radiological Society of North America, endorsed by the Society of Thoracic Radiology and the American College of Radiology (18).

Communication

To stay current with the ever-changing landscape, staff may rely on regular detailed daily updates by the Ministry of Health, which provides a bird's eye view of the situation and disseminates newly implemented policies (8). These updates are available online and are also comprehensively covered on traditional media channels. Communication channels between the hospitals' outbreak management team and staff, as well as within the department, take the form of daily email updates, regular recorded video messages, and via officially approved instant messaging applications (19).

Sustaining the effort

With the scale of this outbreak of pandemic proportions, the posture of a heightened state of vigilance must be maintained for some time. This, in addition to potential social isolation and disrupted work patterns, adds considerable stress to all health care workers. There is, therefore, a need for all to be aware of one's own mental health, to recognize a distressed colleague, and to provide support where possible. Our hospitals' senior management is aware of the importance of psychological health, and avenues have been made available to staff should psychological support be necessary. Inter-departmental mindfulness meditation sessions led by senior management continues to be a well-received activity in one of the hospitals.

Through collaborating with co-workers from other departments, some have experienced greater camaraderie and are energized by the experience. Messages of support

and encouragement, along with gift items from the public, help boosting the morale of all health care workers as well.

Given the fluid situation on the ground during an outbreak, significant disruption will continue to happen. While we may not anticipate all possibilities, it is important to remain flexible yet responsive to new challenges. With time, existing protocols will need reinforcement for compliance. New protocols may occasionally need to be crafted and work processes reviewed and refined along the way. Provision of healthcare to the uninfected patient population should as far as possible not be neglected, although compromises in the form of additional infection control measures and additional wait time can be unavoidable.

Most importantly, the outbreak will likely persist for a foreseeable period of time. It is therefore important to educate and manage staff expectations to new social norms, such as social distancing, heightened vigilance, and personal hygiene. It may also be timely to re-think and re-design workflows leveraging new technologies, such as video conferencing, text messaging, and mobile applications for scheduling, screening, and even clinical consultations, to minimize patient movement through the hospital. Lessons learnt should also be incorporated into the design and planning of future new radiology departments and facilities.

CONCLUSION

The COVID-19 pandemic is an unprecedented challenge to the world. The radiology community in Singapore has fortunately been able to harness the lessons learnt from SARS and the dress rehearsal from H1N1 to put in place a robust system supported by trained experience staff to manage, protect, detect, isolate and sustain our efforts.

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Table 1: Level of health care and bed capacity of the 6 hospitals in Singapore

Institution	Level of Healthcare	Bed Capacity
National Centre for Infectious Diseases	National Centre	330
Singapore General Hospital	Tertiary Centre	1700
Tan Tock Seng Hospital	Tertiary Centre	1500
National University Hospital	Tertiary Centre	1239
Sengkang General Hospital	Regional Centre	1000
Changi General Hospital	Regional Centre	1000
KK Women's and Children's Hospital	Tertiary Centre for Women and Children	830

Table 2: Checklist of Pandemic Response Measures for the Radiological Department

Protect
<i>PPE</i>
<ul style="list-style-type: none">· Ensure adequate stockpile and monitor consumption rate· Ensure all staff are N95 mask-fit tested and trained. Conduct refresher training· Develop and enforce PPE guideline for radiological procedures based on risk profile of patients
<i>Staff</i>
<ul style="list-style-type: none">· Segregate and cohort staff either by space or time, with consideration for expertise and functions each team can support in the event other teams are quarantined· Consider changes to workflow to minimize movement across teams or areas· Consider use of technology such as video conferencing tools to avoid large meetings or minimize human contact· Develop a system to regularly monitor the health of staff and detect possible clusters
<i>Patients</i>
<ul style="list-style-type: none">· Perimeter screening of unwell patients and workflow to isolate and manage these patients· A system to risk stratify patients and redesign workflow based on the risk profile of these patients· Consider scheduling changes to minimize crowding at waiting areas· A system to remind patients to defer or reschedule non-urgent appointments if unwell
Detect and Isolate
<i>Radiology Reporting</i>
<ul style="list-style-type: none">· Keep staff updated on the clinical developments such as epidemiology, radiological findings· Incorporate new knowledge into detection and screening workflows including screening for suspicious findings in non-suspect patients· Redeploy manpower and resource to prioritize work on essential services and curtail non-essential services
<i>Equipment and facilities</i>
<ul style="list-style-type: none">· Make use of negative pressure facilities or mobile units for high risk patients to minimize risk of exposure· Develop protection, cleaning and disinfecting protocols for equipment and infrastructure
<i>Communication</i>
<ul style="list-style-type: none">· Clear and regular communication channel with hospital outbreak management to respond to changes· Clear and regular communication channel with staff to update changes to workflows, guidelines and situation· Develop written guidelines and workflow where possible
Sustaining Effort
<ul style="list-style-type: none">· Implement social distancing measures· Provide psychological and mental support for staff· Continue effort to redesign workflows to leverage on new technology to reduce human contact and build resilience into work processes

Table 3: Sample Segregation Plan of a Diagnostic Radiology Department in a Tertiary Hospital

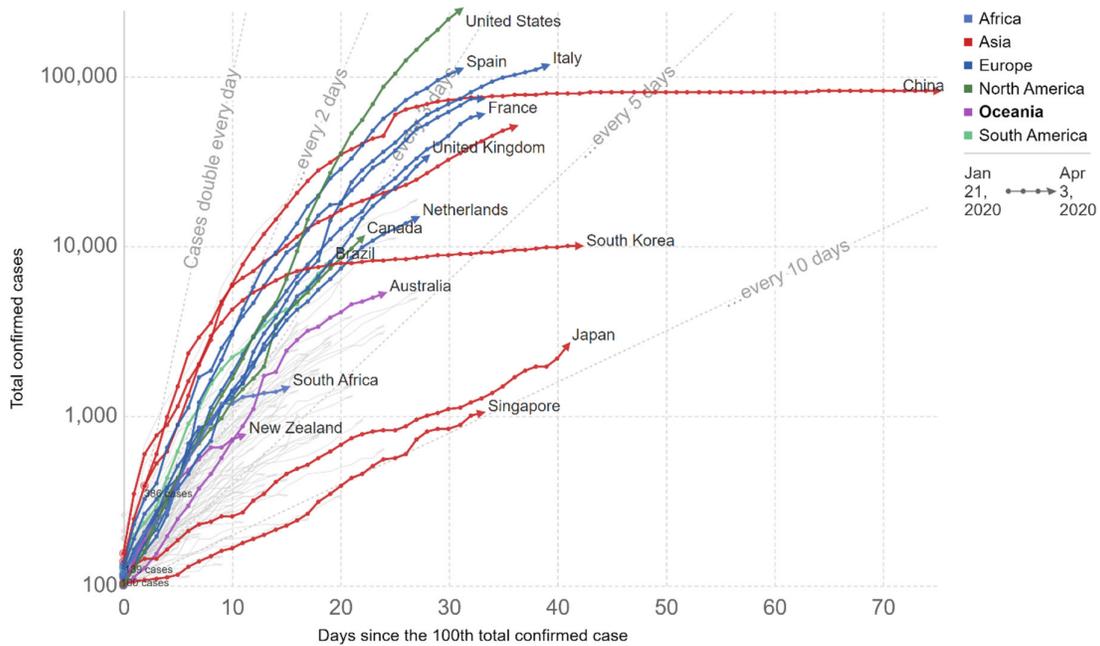
	Subspecialty Team	Radiologists	Residents
Cohort Team 1 (Inpatient)	Body	4	2
	MSR	2	
	NR	2	2
	NIR (Nested)	2	
	Total	8 + 2(Nested)	4
Cohort Team 2 (Main Department)	Body	6	5
	NR	4	4
	Gen/ Mammo 1 (Nested)	4	1
	Gen/ Mammo 2 (Nested)	4	2
	Total	10 + 8(Nested)	9 + 3(Nested)
Cohort Team 3 (Satellite Centres)	Body	6	3
	MSR 1 (Nested)	3	2
	MSR 2 (Nested)	4	2
	NR	2	2
	Total	8 + 7(Nested)	5 + 4(Nested)

Body – Body radiology; MSR – Musculoskeletal radiology; NR – Neuroradiology; NIR – Neurointerventional radiology; Gen – General radiology; Mammo – Breast radiology; Nested teams smaller teams which are generally physically separated from the rest of the cohort teams but are nested within a cohort for administrative convenience because they are within a same building or locality. In this sample, interventional radiology is a separate department and not featured within this plan.

Total confirmed cases of COVID-19

The number of confirmed cases is lower than the number of total cases. The main reason for this is limited testing.

Our World
in Data



Source: European CDC – Situation Update Worldwide – Last updated 3rd April, 11:30 (London time) OurWorldInData.org/coronavirus • CC BY

Figure 1: Epidemic curve of COVID-19 cases by country. (Image source: Max Roser, Hannah Ritchie and Esteban Ortiz-Ospina (2020) - “Coronavirus Disease (COVID-19) – Statistics and Research”. Published online at OurWorldInData.org. Retrieved unmodified from: ‘<https://ourworldindata.org/coronavirus>’ [Online Resource]. Accessed 4 April 2020. Use permitted under the Creative Commons Attribution License CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/deed.en_US).