Radiology: Cardiothoracic Imaging

SPECIAL REPORT

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

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The coronavirus disease 2019 (COVID-19) pandemic presents an unprecedented challenge to the health care systems of the world. In Singapore, early experiences of the radiology community on managing this pandemic was shaped by lessons learned from the severe acute respiratory syndrome outbreak in 2003. This article surveys the operational responses of radiology departments from six public hospitals in Singapore.

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 the most severely affected countries by SARS, and in Singapore, there were 238 cases and 33 deaths. The experience of dealing with the epidemic was a pivotal moment in the development of our nation's health care 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 that highlighted the importance of protecting and securing imaging resources during an outbreak (2).

In Singapore, the health care system is organized into three 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, which provides national-level infectious disease surveillance and coordination, and the Kandang Kerbau Women's and Children's Hospital dedicated for pediatric patients (Table 1). For the coronavirus 2019 (COVID-19) outbreak (4), the infectious disease teams and isolation facilities within each hospital help manage their own suspected and confirmed COVID-19 cases as patients present. The National Centre for Infectious Disease manages all nonhospital referrals, whereas pediatric referrals are directed to the Kandang Kerbau Women's and Children's Hospital (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 during the SARS outbreak, most radiology departments in Singapore have, where possible, incorporated outbreak preparedness into their work processes and protocols (6). To this end, newer facilities including the National Centre for Infectious Disease 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 epidemic as a Public Health Emergency of International Concern on January 30, 2020, the outbreak continued to unfold, and on March 11, 2020, it was classified as a pandemic by the WHO (7). Singapore had its first COVID-19 case diagnosed on January 23, 2020, and has since treated 1000 cases as of April 1, 2020. Both imported cases and local transmission of COVID-19 persist in Singapore as we continue to screen for and manage these cases (8). The overall strategy of Singapore in dealing with the outbreak aims at flattening the epidemic curve (Figure) (9) such that hospitals do not get overwhelmed by a surge of cases. This is achieved by isolation of confirmed cases, contact tracing, and physical distancing to break the chain of transmission (10).

Unlike during the SARS outbreak in 2003, when Tan Tock Seng Hospital was designated a "SARS hospital," all hospitals in Singapore now collaborate in managing patients with COVID-19. This article surveys and details the

Abbreviations

COVID-19 = coronavirus 2019, PPE = personal protective equipment, SARS = severe acute respiratory syndrome

Summary

This article provides a summary of the preparations made by the radiology departments in six public hospitals in Singapore to battle the COVID-19 pandemic.

wide-ranging operational responses of the radiology departments in six public hospitals that are treating patients with 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 was made to conserve, secure, and protect all available staff and resources. In one of the hospitals, a small task force comprising key appointment holders was constituted to coordinate the outbreak response. In the initial phase, the task force met daily to review staffing, information update, operational plans, equipment status, and training and safety plans. Key members were also emplaced into the hospital outbreak response team and infectious disease teams to obtain firsthand information and coordinate measures in response to the rapidly changing situation.

Personal Protective Equipment and Infection Control Measures

Hospital personal protective equipment (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 nonclinical 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 different PPE types is dependent on *(a)* the national framework for disease response or Disease Outbreak Response System Condition (DORSCON) level , *(b)* the infection risk areas within the hospital, and *(c)* the type of procedures performed (11). Each hospital's infection control committee issued a local set of PPE recommendations according to these guidelines. A full set of PPE consists of a cap, goggles or a face shield, an N95 mask, and a gown, which are worn by frontline staff when interacting with suspected 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 a powered air purifier respirator 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 were 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 filters were also placed at staff areas to minimize potential transmission. Other measures include a "mask-up" policy within both the clinical and nonclinical areas.

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

Staff Segregation and a New Work Environment

To avoid disruption in staffing, should cross-transmission occur, the policy of staff segregation or cohorting was implemented in all hospitals. Each professional group was divided into fully functioning units considering the need to create an optimal mix of available subspecialty expertise. These units were then separated by either time or location within the department or hospital (12). For example, in a particular tertiary hospital, the diagnostic radiology department was segregated into three cohort teams (Table 3) with main subspecialties divided and distributed into these cohorts. It considers the physical limitations and functional requirements in each location, such as the number of workstations available or inpatient imaging support exclusively by a designated "hot" team. Residents were similarly distributed into each team considering their training plan. Smaller subspecialties such as breast radiology or neurointerventional radiology 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 neurointerventional radiology team is duplicated at the national level across several hospitals for business continuity because of its limited strength.

In another example, the interventional radiology department was segregated into two functional hybrid teams depending on the physical location of the interventional suites. Each team consists of members across the professional domains (eg, 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 intrahospital satellites with network-ready access points installed for picture archiving and communication system 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 through virtual private network 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 staff is divided into two or more groups, which will then work in shifts. The

Table 1: Level of Health Care and Bed Capacity of the Six Hospitals in Singapore

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

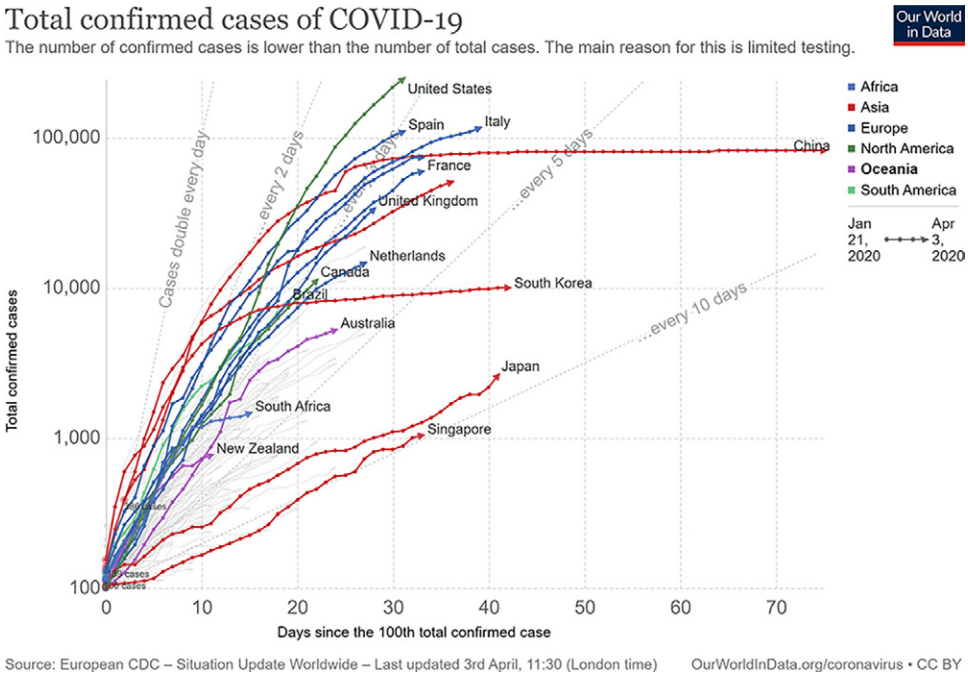

Figure: Epidemic curve of COVID-19 cases by country. (Reprinted under a CC BY 4.0 license from reference 9).

department's workload will then be reduced by postponing nonurgent cases to accommodate the reduced staff. 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 1-hour chest radiography reporting turnaround time, while simultaneously minimizing fatigue and preventing staff burnout. Mixed temporal and physical segregation policies were employed in another hospital, where two teams worked in weekly shifts, alternating between on-site clinical and procedural-based coverage followed by off-site or home-based reporting.

There has been a concerted nationwide effort to consolidate our medical staff at this crucial time. Prospective nonessential 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 2 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 health care 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. It was a difficult policy to implement because of the busy and often crowded nature of typical radiology workspaces. Across all institutions, deliberate efforts have been made to curtail nonessential meetings. Meeting agendas have also been shortened. When possible, technological adjuncts in the form of video conferencing using dedicated software (eg, Zoom; Zoom Video Communications, San Jose, Calif; WebEx; Cisco Systems, Santa Clara, Calif) are employed. The latter proved particularly useful in the conduct of residency teaching sessions, especially because residents from different institutions were prohibited to congregate. Lecture slides and teaching material have been made available online. In some hospitals, clinic-radiologic rounds have been exclusively conducted by using the Personal Data Protection Act–compliant (13) video conferencing platforms (eg, 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 also been 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 mealtimes.

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

Protect
PPE
• 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 radiologic procedures based on risk profile of patients
Staff
• 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
Patients
• 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 nonurgent appointments if unwell
Detect and Isolate
Radiology reporting
• Keep staff updated on the clinical developments such as epidemiology, radiologic findings
• Incorporate new knowledge into detection and screening workflows including screening for suspicious findings in nonsuspect patients
• Redeploy staff and resources to prioritize work on essential services and curtail nonessential services
Equipment and facilities
• 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
Communication
• 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 were possible
Sustaining Effort
• Implement social distancing measures
• Provide psychologic 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

Note.—PPE = personal protective equipment.

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. Preappointment text messages are also sent to remind patients to reschedule their appointments if they are unwell.

Within the newest operational hospital, radiofrequency identification 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 performed 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 versus 71% for the first reverse-transcription polymerase chain reaction test (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 number of false-negative reverse transcription

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

Cohort Team	Subspecialty Team	No. of Radiologists	No. of 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 centers)	Body	6	3
	MSR 1 (nested)	3	2
	MSR 2 (nested)	4	2
	NR	2	2
	Total	8 + 7 (nested)	5 + 4 (nested)

Note.—Nested teams are smaller teams that are generally physically separated from the rest of the cohort teams but are nested within a cohort for administrative convenience because they are within the same building or locality. In this sample, interventional radiology is a separate department and not featured within this plan. Body = body radiology, Gen = general radiology, Mammo = breast radiology, MSR = musculoskeletal radiology, NIR = neurointerventional radiology, NR = neuroradiology.

polymerase chain reaction 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 the National Centre for Infectious Disease.

The radiology departments within the larger and newer hospitals house imaging (MRI, 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 suspected 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 (eg, 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 is useful, in that no additional handling of cassettes is 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 US units also allow for rapid "on-time" upload of images to the picture archiving and communication system for expedited reporting. Similarly, for CT and MRI scanners, standard cleaning is 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 radiograph reports. Such "high alert" studies are labeled for easy identification and are placed within a newly created worklist within the picture archiving and communication system. To meet this requirement for early reports, most departments have devoted additional staff resources 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 into 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 in patients not suspected of having COVID-19. A dedicated workflow to isolate and manage these patients with incidental suspicious findings is critical. More recently, guidance on CT reporting has also been 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 e-mail updates, regular recorded video messages, and 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. Therefore, there is 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 psychologic health, and avenues have been made available to staff should psychologic support be necessary. Interdepartmental mindfulness meditation sessions led by the senior management continue to be a well-received activity in one of the hospitals.

Through collaborating with coworkers 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 boost 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 be reviewed and refined along the way. Provision of health care 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 rethink and redesign workflows leveraging new technologies, such as video conferencing, text messaging, and mobile applications for scheduling, screening, and even clinical consultations, to minimize patient movement within the hospital. Lessons learned should also be incorporated into the design and planning of new radiology departments and facilities in the future.

In 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 learned from SARS and the dress rehearsal from H1N1 infection to put in place a robust system supported by trained, experienced staff to manage, protect, detect, isolate, and sustain our efforts.

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