Operational Strategies to Prevent Coronavirus Disease 2019 (COVID-19) Spread in Radiology: Experience From a Singapore Radiology Department After Severe Acute Respiratory Syndrome

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Abstract

As coronavirus disease 2019 (COVID-19) infection spreads globally, the demand for chest imaging will inevitably rise with an accompanying increase in risk of disease transmission to frontline radiology staff. Radiology departments should implement strict infection control measures and robust operational plans to minimize disease transmission and mitigate potential impact of possible staff infection. In this article, the authors share several operational guidelines and strategies implemented in our practice to reduce spread of COVID-19 and maintain clinical and educational needs of a teaching hospital.

Key Words: COVID-19, operational strategies, radiology

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INTRODUCTION

The novel coronavirus disease 2019 (COVID-19) outbreak was declared a public health emergency of international concern by the World Health Organization on January 30, 2020 [1]. As of March 22, 2020, there were 306,893 reported cases worldwide with 13,026 deaths. COVID-19 spreads mainly via respiratory droplets and contact transmission [2,3], resulting in varying degrees of lower respiratory tract symptoms. Radiology hence plays a key role in the management of COVID-19 infection with the use of chest x-ray (CXR) and CT [4] in screening, diagnosis, and prognostication of disease [2,3,5-7].

As a new condition, a number of publications have been recently published [2-7] to familiarize radiologists with its imaging appearance, but few have dealt with the more practical operational challenges faced [8-11]. With an anticipated worldwide increase in COVID-19 cases, the demand for chest imaging will inevitably rise with an accompanying increase in exposure and risk of disease transmission to frontline radiology staff. Harnessing our experience and lessons from severe acute respiratory syndrome (SARS) outbreak in Singapore in 2003, the authors would like to share the operational guidelines and strategies implemented in our practice to reduce the risk of COVID-19 transmission (ie, patient to patient, patient to staff) and to mitigate the impact of possible intradepartment staff transmission. Although these strategies may not be directly applicable to all institutions due to inherent social, cultural, geographical, and economic differences, the authors believe the underlying principles and rationale of implemented strategies remain relevant and can be adopted or modified by

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other institutions for their practice in dealing with the current COVID-19 outbreak.

Broadly, the strategies can be divided into the following categories:

1. Equipment and manpower
2. Strict infection control practices
3. Team segregation
4. Limitation of staff interaction

STRATEGY 1—EQUIPMENT AND MANPOWER READINESS

Equipment: Portable CXR Machines and Dedicated CT Scanners

The demand for portable CXRs will rise tremendously. Our department experienced a 3-fold increase in portable CXR numbers from the emergency department (EMD) alone with at least 100 portable CXRs performed daily since the start of the outbreak. As such, our department has allocated half of the available portable x-ray machines to EMD to cope with the outbreak.

Similar to the SARS outbreak in 2003, hospital EMDs have set up outdoor extensions or tents (colloquially termed "fever facilities") with portable digital radiography services to effectively triage patients. The immediate priority is to identify patients with symptoms concerning for COVID19 with or without relevant contact or travel history, which is updated daily by local health authorities according to global situation, and manage them separately from low-risk patients to minimize disease transmission. A sample layout of the fever facility is shown in Figure 1.

For patients who require imaging depending on protocol or physician's discretion, portable CXRs are performed in these fever facilities to minimize patient transportation and

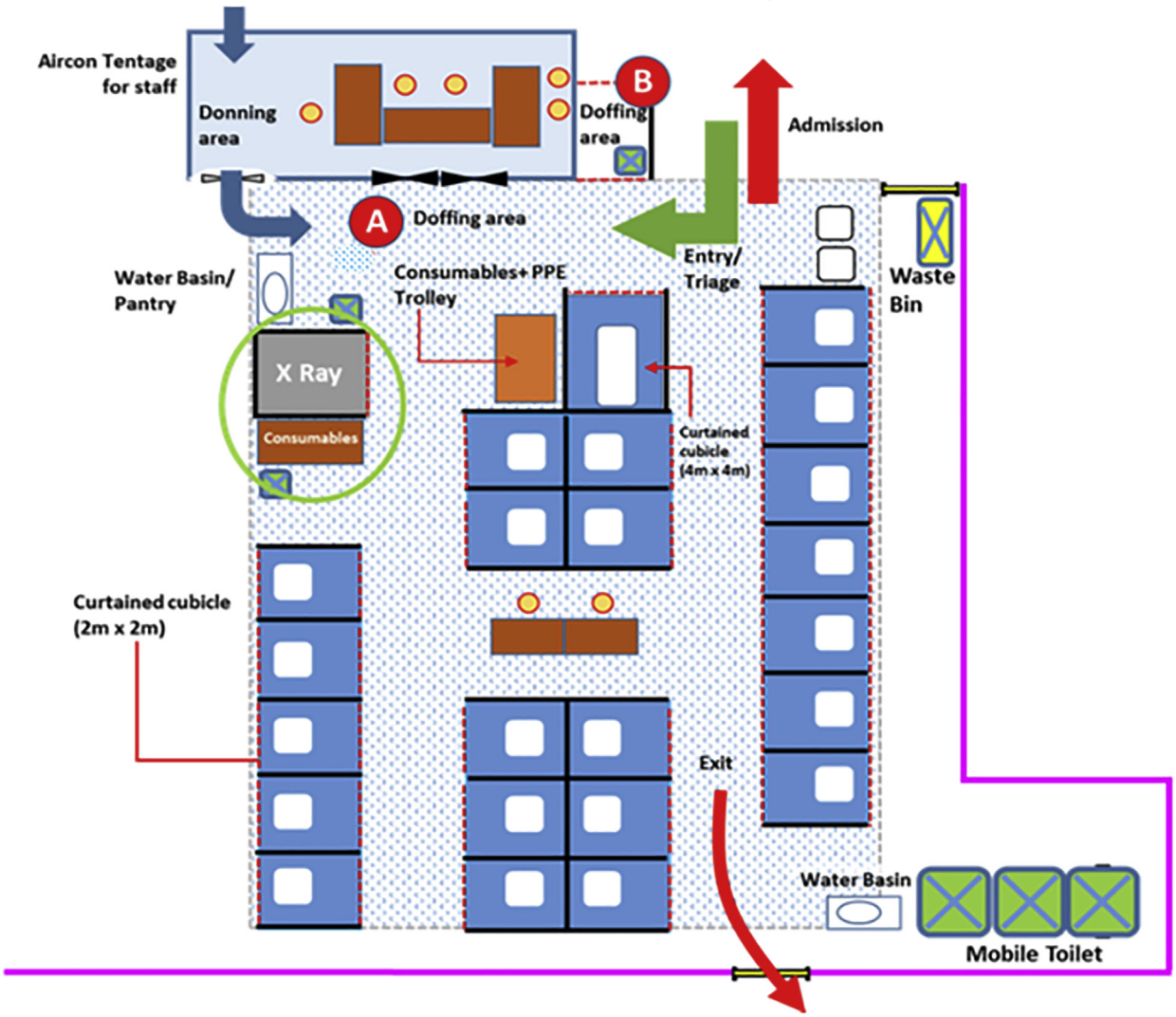

Fig 1. Schematic of the fever facility set up with a digital radiography portable x-ray system.

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risk of disease spread. In addition, dedicated portable x-ray machines with a separate set of cassettes are allocated for case suspects in isolation areas to reduce cross-contamination with other low-risk patients. Some other hospitals in Singapore had to pre-emptively rent additional portable x-ray units to handle the increased demand [8]. Hence, radiology departments should consider and assess the adequacy of existing portable facilities during this period.

For patients who require CT scans, portable CT scanners can be a potential solution but many institutions could face economic and logistical challenges (ie, space constraint) during implementation. As an alternative, our department designated a dedicated CT scanner with shortest distance to isolation wards for suspected case to prevent contamination to other CT scanners.

Manpower

We also experienced an increase in manpower demand due to a number of factors including: (1) increased workload in certain modalities (eg, portable CXRs) with necessary quick turn-around times, (2) increased time required to perform procedures for case suspects due to additional precautions required, and (3) limitation of staff cross-coverage due to team segregation strategies (see strategy 3).

Radiology departments should ensure manpower adequacy during this period as the situation may potentially worsen and manpower resources could also deplete exponentially if staff infection and quarantine occurs. As such, in Singapore, we have frozen nonessential overseas leave and conference leave for public health care workers [8] with financial reimbursements for leave cancellations. Local leave is still granted as staff can be recalled to work quickly if unforeseen circumstances arise.

Personal Protective Equipment

There is a huge demand for personal protective equipment (PPE) worldwide. Fortunately, we have learned from the SARS experience to stockpile PPE on a national and hospital level to ensure adequate supply for our frontline staff. This is in line with the pandemic response plan published in 2004 by Singapore Ministry of Health [12], which advised institutes to maintain a 3- to 6-month stockpile of PPE. Mask-fitting exercises have also been carried out on a regular (approximately three per year) basis to keep staff updated on their mask sizes. Within the department, equipment is distributed to staff daily at designated sites to ensure accountability and sustainability of PPE stock. Frontline staff (eg, radiographers) are also updated on the latest policies, via e-mails or e-learning hospital intranet modules, on handling droplet and contact precaution patients with instructions on the proper donning, use, and removal of PPE.

STRATEGY 2—STRICT INFECTION CONTROL

Strict Adherence to PPE Guidelines

All staff are required to wear surgical masks when on clinical duty. The use of PPE with fluid-resistant characteristics, disposable gloves with coverage over gown cuff, eye protection (including face shields or goggles), and fit-tested N95 or higher face mask is mandatory when handling suspected or confirmed COVID-19 patients [13]. Our department also advocates the double glove practice with the outermost layer of gloves changed between every patient. The inner layer of gloves are not removed when cleaning surfaces that had patient contact to minimize the risk of contact transmission [14].

CT and MRI Scan Protocols for High-Risk Patients

The following guidelines were implemented in our institute to reduce the risk of cross contamination for nonportable modalities, such as CT or MRI. Nonurgent scan requests were postponed until the confirmation of COVID-19 diagnosis. If a scan is deemed urgent, it is scheduled as the last case of the morning or afternoon session on a dedicated scanner to minimize disease transmission between patients and to allow abundant time for cleaning and airing of room before the next scan. A specific route of transportation is used between the isolation wards and the imaging department. Hospital security is engaged to clear human traffic along this route to minimize exposure or transmission between the patient and the public and staff.

Upon arrival at the scan room, the patient is attended to by two separate radiographers. The radiographer who has direct contact with the patient is designated the "dirty" radiographer ("dirty" being the colloquial term for "high risk for potential contamination or exposure to COVID-19"). The dirty radiographer performs hand hygiene and dons full PPE with double gloves and is responsible for (1) positioning patient for scan, (2) moving patient off scanner, and (3) cleaning of equipment after scan completion. The "clean" radiographer remains stationed in the scan room to operate the scanner. The separation of clean, dirty (or potentially contaminated), and changing areas is illustrated in Figure 2.

Heightened Levels of Hygiene and Cleaning

There had been constant efforts to improve hygiene awareness ever since the SARS outbreak in 2003. For example, departments are regularly assessed on hand hygiene standards by an infection control team, and results are used for department appraisals. The COVID-19 outbreak only served to heighten hygiene standards all around. In addition, temperature monitoring of staff has been instituted.

Thermometers were issued to staff so they can record their temperature readings daily. Staff who feel unwell are also advised against coming to work.

Rigorous measures have also been taken to clean and disinfect radiology equipment. Single-use disposable plastic sheets are used for lining of CT scan couches for case suspects. After disposal, the surfaces are wiped down with isopropyl alcohol 70%. Terminal cleaning of the scan room by housekeeping staff is also carried out by using diluted bleach solution (6 mg chlorine releasing disinfectant tablet to 1,000 mL water) to wipe down the machine, walls, and floor. Because we do not have a negative air pressure room for our CT scanner, the scan room is aired for at least 30 min to allow the cleaned surfaces to dry adequately before proceeding to scan another patient.

For portable x-ray machines, deep cleaning is performed twice a day using diluted bleach solution to wipe down the machine exteriorly. For parts of the machine that are delicate (eg, collimators, control console, exposure buttons), isopropyl alcohol 70% rather than bleach is used for cleaning after every patient. For detailed guidelines on equipment disinfection, staff should seek advice from their specific equipment vendors.

STRATEGY 3—TEAM SEGREGATION (PHYSICAL AND TEMPORAL)

Gaining experience from the SARS outbreak in 2003, local radiology departments have adopted team segregation strategies to (1) reduce risk of human-to-human transmission with team quarantine in the event of staff infection and (2) maintaining the capabilities to meet the hospital needs [8]. The department is hence split into independent teams, each comprising of selected individuals with different skill sets (ie, radiologists, radiographers, nurses) to serve the daily hospital needs. In our institution, we adopted a combination of temporal and physical segregation strategies.

Temporal Segregation

The rationale behind temporal segregation is due to the inherent incubation period of COVID-19. Asymptomatic infected staff may be a potential source of human-to-human transmission at work [15]. With reported potential incubation periods of up to 2 weeks [16] for COVID-19, trial runs of split teams in temporal "2 + 2" format have been suggested by the Chinese Society of Imaging Technology in an expert consensus article [9]. In this 2 + 2

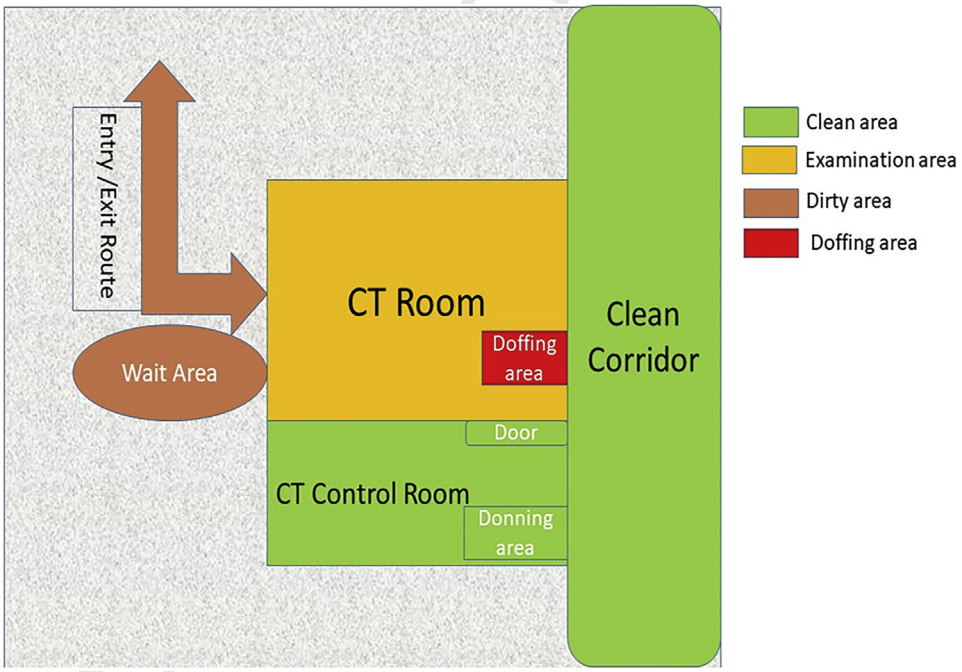

Fig 2. Separation of "clean" and "dirty" areas for CT scan. Scan protocol to be performed by two radiographers. The dirty radiographer dons full personal protective equipment (PPE) at the donning area before entering CT room. After positioning and preparation of the patient for the scan, the dirty radiographer then exits the scan room to a dedicated waiting area without removing the PPE (waiting area), and the clean radiographer remains stationed in the CT control room to complete the CT study. Upon scan completion, the dirty radiographer re-enters the scan room and assists in moving the patient off the scanner. The dirty radiographer would then remove the outer gloves and begins cleaning the equipment including the power injector. The dirty radiographer then removes the PPE in a dedicated changing area (doffing area) and performs hand hygiene before exiting the scan room.

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format, staff who are at high risk (eg, frontline radiographers, sonographers, interventional radiologists) are split into two groups. The first group works 2 weeks consecutively whereas the second group rests and self-quarantines at home. A swap happens at the end of the 2-week period.

However, this 2 + 2 format faces many potential challenges in our experience. Firstly, not all radiology departments can afford for many of its staff to be self-quarantined during this period of high manpower demand. Secondly, working in a high-risk environment and being constantly gowned in PPE for 14 days consecutively can be physically and mentally exhausting for staff. As the outbreak prolongs, this arrangement may not be sustainable or ideal for team morale and efficiency.

As such, we decided to adopt a more sustainable "1 + 1" variation, given that most symptoms show up within the first 6.4 days (95% confidence interval: 5.6-7.7 days) of infection [16]. In addition, staff are rotated to low-risk areas instead of home quarantine after their shift in the high-risk zones to minimize impact on manpower. An example of this would be an interventional radiologist on a 1-week shift of reporting diagnostic imaging studies with no patient contact, after a 1-week shift of performing interventional procedures with patient contact. Implementation of temporal strategies is cumbersome from the rotation planning perspective, but would be critically important if staff transmission truly occurs.

Physical Segregation

On a national level, physical segregation involves prohibiting staff from working in different hospitals except in critical subspecialties with limited expertise (eg, neurointervention). Staff are now restricted to working in a single defined hospital to reduce the risk of interhospital virus transmission. The same principle applies to radiology resident rotations between hospitals. Adjustments to training have been made to allow residents to continue at their respective hospitals. These strategies are not expected to cause major issues due to the vast improvements in technology since the SARS outbreak in 2003. For example, radiologists can now report scans remotely from other locations with the use of electronic medical records, radiology information systems, and PACS.

Within the radiology department, further physical segregation can be performed. Unlike radiographers and nurses who have to be on site, radiologists can potentially report from home via teleradiology. However, this may not be feasible for many centers to perform on a large scale due to inherent differences in technical and economic support. In Singapore, health care institutions face a unique situation of "Internet separation." The option of teleradiology is nonfeasible locally as the Singapore government has terminated direct access to the Internet from the hospital's internal systems due to previous cyber-attacks [17].

Hence, our department has implemented physical segregation by dividing reporting areas into dirty (ie, high risk) and clean (ie, low risk) areas. Reporting rooms that are close to areas with high patient flow and contact (eg, ultrasound, fluoroscopy, inpatient CT scanners) are classified as dirty, with the remaining rooms classified as clean. Radiologists reporting in the dirty rooms would be isolated within the rooms during working hours, with no interaction with colleagues in the clean rooms. This is achievable in part due to Singapore's experience with SARS, from which we have learned to segregate outpatient and inpatient areas by building separate out- and inpatient wings in the same hospital to minimize cross contamination. Hence, the department is distributed over several satellite reporting areas, rather than a single central reporting area. By adopting these strategies, the extent of team or group quarantine could be further minimized in the event of staff infection. It is also easier to take necessary actions including disinfection of workplace and equipment that had contact with the identified staff.

Potential challenges could arise in radiology departments with unique architecture layout in which inhibition of human traffic may impair workflow patterns. To overcome these issues, departments can consider the use of technology in the form of hospital-endorsed online meeting platforms to disseminate information. One example would be to alert radiology staff to the location and timing of radiology scans for confirmed or suspected cases of COVID-19 in the department.

Combination Strategies

Implementation of both temporal and physical segregation policies may seem excessive. However, departments can adopt variations of the temporal or physical segregation strategies to best suit their needs. Ultimately, the segregation strategy implemented aims to achieve a balance between (1) meeting clinical demands, (2) maintaining team spirit r morale, (3) and reducing extent of disease spread should it occur and (4) not compromising the safety of patients and staff.

STRATEGY 4—LIMITATION OF STAFF INTERACTIONS

Staff-to-Staff Interactions

Although physical segregation of radiology staff serves to limit intradepartment staff interactions, additional steps can be implemented to limit interdepartmental staff

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interactions. These interdepartmental interactions may be unscheduled interactions, such as doctors coming to the department for urgent scans request or discussion, or scheduled interactions, such as multidisciplinary meetings. These interdepartmental interactions increase the risk of disease transmission and hence should be limited.

Our department has now restricted access of doctors from other departments, apart from urgent reasons such as accompanying unstable patients for imaging studies or procedures. Face-to-face scan requests or discussions are now replaced by telephone discussion or text messages through a secured network. Scheduled interactions, such as multidisciplinary meetings, are performed through third-party video-conferencing applications (eg, Zoom) to facilitate complex patient care discussions, while maintaining physical segregation.

On a social level, lunch meetings and after-office-hours social gatherings between colleagues are discouraged during this period, as is attendance at professional conferences and seminars. This is to minimize congregation of health care workers from different institutions or different countries.

Staff, Student, Resident, and Fellow Interactions

Our radiology department is heavily involved in undergraduate and postgraduate radiology education for domestic and international students and radiologists. With the COVID-19 outbreak, medical students have been barred from hospitals to minimize staff-to-student and student-to-patient interactions.

To continue delivery of radiology education, large-group lectures have been converted to online modules with either a prerecorded voiceover or a real-time online teaching session, whereby students can dial in to participate in a live question-and-answer session. To supplement online lectures, materials have also been uploaded for students to review. In addition, our overseas medical student elective program has been put on hold due to the current worldwide outbreak.

The training of residents and overseas fellows have been similarly affected. All large group teachings and lectures and small-group sessions are also conducted online. Trainees might face difficulties in their education during this period of uncertainty. Hence, the department should emphasize open-channel communication if residents or fellows require any assistance.

In conclusion, the COVID-19 outbreak has created chaos and disrupted many routines globally. Radiology, as one of the important assessment tools, is similarly affected. Although some issues may be unique to individual departments, the majority of challenges faced by radiology departments globally are similar. By sharing our experience, we hope that worldwide institutions may benefit from the practical experiences and strategies implemented in our department.

TAKE-HOME POINTS

- Radiology departments should ensure adequate portable imaging capabilities, manpower demands, and PPE stock in this time of outbreak.
- Strict infection control practices, heightened levels of hygiene, and rigorous cleaning are essential in reducing spread of COVID-19.
- Physical and temporal staff segregations with deliberate limitation of staff-to-staff interactions play a role in reducing disease spread and maintaining hospital services.

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