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Preparing IR for COVID-19: The Singapore Experience

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ABSTRACT

This paper describes country-wide special measures undertaken for interventional radiology (IR) staff during the current coronavirus disease 2019 (COVID-19) pandemic. Although each IR service around the world faces unique challenges, the principles outlined in this paper will be useful when designing or strengthening individual practices and integrating them within wider hospital and national measures. Moving beyond the current outbreak, these measures will be useful for any future infectious diseases which are likely to arise.

ABBREVIATIONS

BCP = business continuity planning, DORSCON = disease outbreak response system condition, HCW = health care workers, MOH = Ministry of Health, PAPR = powered air-purifying respirator, PPE = personal protective equipment, SARS = severe acute respiratory syndrome

Novel coronavirus disease 2019 (COVID-19) has now spread around the world since the first reports only a few months ago (1,2) and was officially declared a pandemic by the World

Health Organization on March 11, 2020 (3). Unlike prior pandemics, unprecedented containment measures have been imposed for COVID-19 infection, which unfortunately have

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failed to halt its spread. Alarming, up to 14% of cases developed severe symptoms, and 5% required intensive care unit support for critical illnesses (eg, respiratory failure, septic shock, and multiorgan failure) (4). Medical systems in several countries have been severely tested to the point of near collapse, nosocomial and community transmission are well recognized, and many patients (4–7) and health care workers (HCW) have tragically succumbed to the infection (8,9).

Interventional radiology (IR) provides advanced image-guided treatments of a range of patient conditions, from the well to the vulnerable and from elective outpatients to critically ill intensive care unit patients. IR services are essential to hospital operations and to multidisciplinary management of patients even during the current crisis. In this position, IR faces challenges from many aspects. Our patients and our staff must be protected from nosocomial infections above all else, and we must remain prepared to provide sustainable high-quality services despite potentially austere conditions (10).

As a country, we have learned much from our unfortunate experience with the severe acute respiratory syndrome (SARS) pandemic in 2003, which was a severe challenge for our medical and IR services (11,12). At that time, there were inadvertent staff and patient cross-infections, resulting even in mortality. Experts recognize that the current outbreak is very different from that of SARS, despite sharing novel beta-coronavirus causes (13). Nevertheless, many of the processes described in this paper that were developed and refined to avoid recurrence of such disastrous outcomes remain applicable in the current outbreak. The National Center for Infectious Diseases has been in operation since September 2019. This is a 330-bed (expandable to 500-bed) dedicated, stand-alone facility designed to manage large outbreaks. Additionally, all hospitals have been built or retrofitted with specialized isolation rooms (capable of high-efficiency particle filtration, negative pressure ventilation, and an attached anteroom) (14,15). Similarly, several operating rooms and procedure and endoscopy rooms have been built or retrofitted to incorporate negative-pressure ventilation, high-efficiency particulate-absorbing (HEPA) filtration, and an anteroom.

The authors' national response measures follow those of the color-coded Disease Outbreak Response System Condition (DORSCON) system (16), which guides a calibrated response to the threat level. Currently, the nation is at the "Orange level," which allows legally enforceable home quarantines, visitor screening, and travel restrictions. At a higher level, social distancing measures such as school closures, work from home orders, and avoidance of large public gatherings may be mandated. This paper has distilled the combined expertise of the authors' country's major IR departments from the public and private sectors. Represented in this article are small and large IR services, albeit within a single country. The information contained herein will be useful for the global IR community.

PRINCIPAL CONSIDERATIONS

The following broad categories are applicable across all services, large and small, although the details vary by practice size and risk levels:

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PROTECTING PATIENTS

Active Screening

These measures include temperature measurements using thermal or hand-held temperature probes at all points of entry of the hospital and self-declaration of risk factors which include travel history to countries with COVID-19 cases, acute respiratory symptoms, and contact with COVID-19 patients (with legal penalties for false declaration). This applies to all hospital staff and visitors including patients, companions, product vendors, and others.

Service Segregation

Separation can occur by physical location or by time. Inpatient and outpatient cases are performed in different parts of larger departments or at separate times (morning vs afternoon, and alternate days) in smaller centers. Procedures are performed in an outpatient setting as far as possible as this reduces patient risk for potential nosocomial infection. Procedures requiring overnight hospital stay are redesigned to allow patients to come from home just prior to the procedure and then be admitted for overnight stay (compared to the previous practice of hospital admission 1 day prior to the procedure for laboratory workup). Measures taken by various departments are summarized in [Tables 1 to 5](#).

PROTECTING STAFF

Personal Protective Equipment

Wearing a surgical mask is mandatory for all staff in clinical areas where there is direct interaction with patients (eg, procedure rooms, clinics, patient waiting rooms, and other areas) because of recognized viral shedding by minimally symptomatic and even asymptomatic individuals (17). Enhanced personal protection equipment (PPE) is calibrated to the risk level. Recommended PPE measures are outlined in [Table 5](#). All staff are fit-tested for N95 masks. Hands-on training and on-line videos on proper donning and doffing of PPE are available to all staff. Visual reminders are posted in strategic areas (eg, designated PPE donning/doffing zones and isolation ward anterooms). A "buddy system" is used to ensure proper use of PPE and to prevent inadvertent missed steps. During aerosol-generating procedures (18), full PPE (cap, goggles or face shield for eye protection, N95 mask, full gown, and gloves) for HCW is required for all patients regardless of COVID-19 status and powered air-purifying respirators (PAPR) are required in COVID-19 patients

Table 1. IR Team Set-ups

Category	Resources	Doctors	Nurses	Techs	Coverage
Outpatient IR	2 rooms: Fluoro, US Level 1	6 (2 senior IRs, 2 junior IRs, 2 trainees)	2 per room per shift × 2 shifts = 8	1 per room per shift × 2 = 4	Clinics, remote cases
Inpatient IR	4 rooms: Fluoro, CT, US Level 2	12 (4 senior IRs, 4 junior IRs, 4 trainees)	2 per room per shift × 2 shifts = 32	1 per room per shift × 2 = 8	On-call cases, portable/infectious cases
On-call	Any appropriate room	3 (1 senior, 1 junior, 1 trainee)	4	2	Weekdays after 6 pm, weekends, and public holidays
Admin	NA	1 or 2	2	1	Management
Diagnostic	NA	1	-	-	

Note—The table illustrates set ups in a large team with 10 procedure rooms located on 2 floors. Some procedure rooms remained closed to maintain surge capacity.

Admin = administration; fluoro = XXX; NA = XXX.

Attire

All staff are issued hospital scrubs appropriate for various locations, and movement between locations without change of attire is prohibited. For example, dedicated isolation ward attire is issued, all staff must change into this attire upon entry into the isolation ward and, conversely, must shower and change into appropriate new attire before leaving the ward.

Staffing

Adequate staff availability helps to lighten individual workload. Since the initial stages of the outbreak, all nonessential leave has been frozen, allowing the full department resource to be available at all times for patient care. This allows greater time for attention to detail, proper use of PPE, and adequate time for rest and recovery.

Education

Refresher courses dealing with hospital protocols for contact and droplet and airborne precautions are given and are available online for personal review. Frequent interprofessional education is conducted to update staff on warning signs of disease, imaging appearances, and status of current measures. At least 1 case was detected by a vigilant radiology resident who noticed suspicious lung changes on an abdominal computed tomography (CT) scan.

Hygiene Measures

Hand hygiene is a mandatory competency which all staff are required to demonstrate by completion of online self-directed training modules, followed by MCQ assessment. Successful demonstration of competency is tied to monetary incentives. Educational posters such as the “WHO five moments of hand hygiene” (19) are prominently displayed around campus in strategic locations (eg,

Table 2. Team Set-up in a Large Center Supporting Dedicated IR Facilities

Category	Resources	Coverage
COVID-19 positive and suspected cases	3 rooms: 1 angio suite with high-end C-arm, 1 CT, 1 hybrid OT	All COVID-19 suspected and confirmed cases
Regular inpatients and outpatients	9 rooms: 2 angio suite, 1 US, 2 hybrid OT, 2 CT, 2 fluoro	All non-COVID-19 inpatients and outpatients
Rostering	Total of 12 IRs divided into 2 teams in physically separate locations. One team on angio-suite duty, one team covering CT guided procedures.	
On-call staffing	Two independent teams allow for simultaneous activation and/ or handling of infectious and non-infectious cases.	

Angio = XXX; fluoro = XXX; OT = XXX.

*As provided in the National Centre for Infectious Diseases.

lift cabins, lift lobbies, carparks, notice boards, and so forth). Hand sanitizers are widely available for staff and visitors in high-touch areas. Surprise audits are regularly conducted to monitor compliance and results presented to senior hospital management. These measures have proven effective in inculcating the discipline of hand hygiene for prevention of nosocomial infections among all health care workers.

PREVENTING CROSS INFECTION

Dedicated Workflows

Patients with confirmed COVID-19 infection are housed in purposely built negative-pressure airborne infection-isolation rooms with attached anterooms (20). Patients who are suspected of harboring infections are held in

Table 3. Segregation in a Small-Team Set-up with 2 Procedure Rooms Located on the Same Floor

Category	Resources	Doctors	Coverage
Outpatient	1 room, Level B1	3 (1 senior, 1 junior, 1 trainee)	Clinics, remote cases
Inpatient	1 room, Level B1	3 (1 senior, 1 junior, 1 trainee)	On-call cases
Both of the teams in level B1 minimize interaction between themselves to less than 30 min. They always wear face masks and observe interpersonal separation.			
Diagnostic Reporting area, Level 4			

Q16 Level B1 = XXX; Level 4 = XXX.

designated locations away from staff and other patients while awaiting test results. Dedicated workflows (C.W. Too et al, unpublished data) are in place for performing IR procedures in this group of patients. Broadly, separate workflows are available for portable ultrasonography-guided procedures, fluoroscopic procedures that can be performed with a C-arm in a designated remote location (usually a “hot” operating theatre for COVID-19), and fluoroscopic procedures which require patients to come to the IR department (eg, for procedures which require CT guidance, biplane fluoroscopy, or advanced fluoroscopic capability).

Portable Procedures

Movement of infected patients through hospital corridors and lifts is potentially hazardous, and hence procedures are performed at the patient’s bedside (in situ) as far as possible. Q7 During portable procedures, strict adherence to protocols (eg, donning PPE), and doffing steps in the corridor, anteroom, and in-patient room are reinforced and checked. Contaminated items (eg, consent forms) should not leave the patient’s room. Clean items (eg, patient charts) should not enter the anteroom or patient’s room. Protection of imaging equipment and decontamination after a procedure is mandatory. In larger hospitals, a dedicated high-end ultrasonography machine remains parked in the isolation ward at all times.

Patient Movement and Coordination

When in situ procedures are not possible, patients are directed to an IR suite through a dedicated corridor which bypasses areas with high foot traffic and patient contact. Q8 In departments with multiple procedure rooms, 1 room is dedicated as a “hot room,” ideally a room with the most direct access to inpatient transfer. All consumables in this room (eg, catheters, wires, balloons, and so forth) are kept in mobile shelving units where possible and are moved out of the room prior to the patient’s entry. Fixed equipment is covered with plastic sheets. Traffic control during patient movement with a preidentified controller is vital to prevent unnecessary holdups along the way (eg, waiting for the

Table 4. Segregation by Time in A Small-Team Set Up with 2 Co-Located Rooms and 2 Doctors

	Monday	Tuesday	Wednesday	Thursday	Friday
AM	Inpatient	Inpatient	Outpatient	Outpatient	Inpatient
PM	Inpatient	Thyroid FNA	Inpatient	Inpatient	Inpatient
Daytime hours	Two independent teams consisting of 1 IR, 4 nurses, and 2 technologists each. Work hours and break hours were staggered: 8 am to 5 pm and 12:30 pm to 9:30 pm.				
On-call	Independent team consisting of 1 IR, 2 nurses, and 1 technologist who was on-call for an entire week and alternated weekly with the second team. An additional stand-by team of 2 nurses and 1 IR was on-call daily in case of positive COVID-19 case.				

FNA = XXX; IR = interventional radiologist.

*If physical segregation is not possible, temporal segregation is used.

elevator, waiting for room availability, and so forth), which could increase risk to bystanders. After the procedure, patients recover in the procedure room and are then returned directly to their isolation room without the usual step-down period in the IR recovery bay. Terminal cleaning is instituted before commencement of the next case.

Cleaners Wear Approved PPE During Cleaning

All plastic coverings are removed carefully to avoid accidental aerosolization of particles, and then placed in biohazard bags. Any unused consumables within the room must be discarded; hence, only essential items are to be brought into the procedure room. At the end of the procedure, all involved staff are required to shower and change into new attire. Coordination with multiple responsible staff (eg, anesthesia, infectious diseases, security, and cleaning services) is, hence, essential, and operations are rehearsed to prevent breaches in protection.

Prior to operationalization, the planning team walked the designated routes to demarcate clean and infected zones. Engineers measured room air pressure and air dissipation to identify clean corridors. All protocols were developed in consultation with hospital infectious disease specialists. Finally, such procedures were performed preferentially as Q9 the last case of the day to allow at least 1.5 hours of room airing time after the case.

Workload Optimization

IR room capacity for elective cases was reduced by half to allow spare capacity for urgent, infected cases. Due to the requirement for enhanced infection control measures, procedure time for suspected and confirmed cases is dramatically longer than usual. This workload planning requires new waiting time norms for elective and urgent procedures, careful vetting of requests, and patient assessment through hospital rounds and IR clinics. A senior duty IR is assigned

Table 5. PPE Recommendations

Scenario	PPE	Remarks
Confirmed or suspected COVID-19 patients	Full PPE at all times: cap, eye protection (goggles or face shield), N95 mask, full gown, gloves	Surgical mask for the patient
Patients with pneumonia or acute respiratory symptoms	Full PPE when performing IR procedures. Surgical mask for contact with nonprocedure patient	Surgical mask for the patient
Patients under quarantine due to close contact with confirmed COVID-19 patients	Full PPE when performing IR procedures. Surgical mask for contact with nonprocedure patient	Surgical mask for the patient
Patients from a general ward and outpatients with no risk factors for COVID-19	Surgical mask	
Aerosol-generating procedures	Full PPE plus PAPR for confirmed or suspected COVID-19 patients. Full PPE for all other patients	Examples of AGP: intubation, positive pressure ventilation, nasogastric tube insertion, oral/airway suctioning, CPR Lung biopsy per se is not an AGP, but there is risk of aerosolization due to intraprocedural hemoptysis inciting violent coughing in some patients; hence this is categorized as an AGP

AGP = aerosol-generating procedures; CPR = cardiopulmonary resuscitation; PAPR = powered air purifying respirator; PPE = personal protection equipment.

every day to vet requests and optimize procedure planning based on clinical needs and operational capability. Nonurgent procedures in patients suspected of infection or patients with confirmed COVID-19 infection are deferred until patients can be deisolated (21). Personal contact between clinical teams and IR teams is reduced. For example, where personal consultations for procedures and imaging interpretations were previously common, these contacts have been converted to phone consultations as far as possible. Nonurgent cases such as embolization of arteriovenous malformations and angiomyolipoma, fallopian tube

recanalization, uterine fibroid, and benign prostatic hypertrophy embolization have been postponed by 1 or 2 months. Urgent cases and oncology-related treatments are given priority.

Staff Monitoring

All hospital staff are issued personal thermometers to measure body temperature twice daily. This information is logged into a national electronic data base known as a staff surveillance system (S3). This procedure serves as an early warning system to detect fever among clusters of hospital staff which could indicate HCW disease transmission. Travel to at-risk countries is prohibited, and measures are in place for home isolation of staff returning from overseas. Staff are also required to report any personal contact with suspected or confirmed cases outside of work.

ROLE OF IR IN COVID-19 PATIENTS

Potential roles for IR directly related to patients with COVID-19 infection include vascular access (central venous lines, distal perfusion catheters for extracorporeal membrane oxygenation) and drainage of pleural or peritoneal fluid collections. However, virtually any interventional procedure may be required incidentally in an infected or suspected patient. Potentially acute situations may arise during the procedure (eg, collapse during embolization of acute bleeds requiring cardiopulmonary resuscitation). It is important to anticipate these and plan dedicated protocols for various scenarios. During cardiopulmonary resuscitation, there is potential for aerosol generation during chest compressions; hence, the use of PAPRs is recommended. It is suggested that such acute cases be considered for general anesthesia by elective endotracheal intubation for airway management.

Fortunately, the numbers of IR procedures that have been required so far in COVID-19 patients are low. These procedures included a few portable pleural drains, venous access procedures, 1 mesenteric angiogram in a hybrid operating room, a change of percutaneous nephrostomy tube, a bronchial artery embolization in the angiography suite, and 2 cerebral angiograms performed for stroke. Although the numbers are currently relatively small, IR interventions in such cases will increase over time as the cases continue to rise in our country (22).

BUSINESS CONTINUITY PLANNING

Distancing Regimens

Staff are further segregated into smaller functional teams with minimal cross-contact. All staff are required to wear face masks at all times, except at meal times. Meal times are further staggered, and staff are asked to sit in small groups or individually and to minimize social interaction. In the unfortunate event of intrahospital transmission to a health care worker, this plan should allow minimal risk of cross-transmission. This is to allow continuation of essential

services in the event of intrahospital staff transmission, which could require multiple individuals to be quarantined.

Staff and Workplace Segregation

Previously, IR staff were scheduled to cover several hospitals within a hospital network to allow optimal allocation of expertise to patients regardless of the patient's physical location. However, with enhanced infection control measures, staff are segregated to remain within 1 designated hospital. Under DORSCON Orange, cross-institutional movement of staff is tightly controlled to minimize risk of cross-infection, and approval from the Ministry of Health is required for any cross-movement. For neurointervention, the present existing practice provided on-call coverage on a city-wide basis from a pool of 5 credentialed neuro-interventionists for all public hospitals in Singapore. This practice had to be altered, and the 3 public hospitals providing neurointervention are now exclusively serving their own hospitals. As this entails high on-call frequency for the neurointerventionists, they are given some relief from their day time service work whenever feasible.

Technology

Physical meetings have been replaced to a large extent by online platforms. Institutional licenses for CISCO (San Jose, California), WebEx (Milpitas, California), and Zoom (San Jose, California) are in place to facilitate multidisciplinary meetings, tumor boards, educational, and research meetings. The meeting is hosted by an administrator who sends the login details to all relevant parties. For clinical meetings, a list of patients and issues to be addressed are sent out in advance of the meeting. Participants log in remotely through personal devices, and attendance is logged for records and continuing medical education points. Multidisciplinary meeting decisions are entered into the patient's electronic medical record immediately by a scribe. Patient confidentiality is ensured by institutional agreements, software encryption, password protection, and curation of meeting participants.

Contact Tracing

The names and designation of all staff involved in every IR procedure are captured in the radiological information system (RIS) picture archiving and communication system (PACS) (Healthcare BPO, Princeton, New Jersey). Staff rosters are updated daily and archived. This is to facilitate contact tracing in the event that the COVID-19 infection is unexpectedly diagnosed in a patient or staff member. In one of the newer hospitals, a real-time locating system (RTLS) is in place. Radiofrequency identification tags are provided to all staff and patients, which log their physical locations at all times. This requires extensive investment in infrastructure but is by far the most robust method for contact tracing. Close contacts of confirmed cases (eg, those expected to have been within 2 m of the individual for at least 30 minutes and without appropriate PPE) are placed on home quarantine for 14 days with twice daily temperature and

symptom surveillance. Those with appropriate PPE at the point of contact are allowed to continue working if the hospital infection control team has assessed the risk of transmission to be small. This risk assessment is necessary because otherwise large numbers of HCW could be quarantined for exposure to an undiagnosed COVID-19 patient who subsequently tested positive for the virus. This is also the reason why all hospital staff must wear surgical masks in all areas where patients are encountered.

COMMUNICATIONS, COMMAND, AND CONTROL

Communication

The situation in hospitals has been fluid, calling for rapid dissemination of essential information to all relevant staff. Singapore is fortunate to have high mobile phone penetration and widespread availability of fast mobile internet. Web-based platforms are heavily used for rapid dissemination of information. WhatsApp (Menlo Park, California) has proven popular and is widely used for informal and nonconfidential information sharing. Various chat groups are set up for relevant information sharing. For confidential material (eg, patient-specific data), an encrypted messaging platform (TigerConnect, Santa Monica, California) is used. Workplace (Facebook) has also been adopted as a rapid communication and support tool between management and staff. Timely, transparent and accurate reporting in an evolving epidemic has been shown to alleviate much anxiety (23).

Command and Control

Individual providers are restricted to certain places of practice (eg, certain hospitals, or outpatient vs inpatient services). Urgent cases are discussed and handed over to colleagues when the original IR is not scheduled to be in a particular service area. Overseas travel is restricted, and individual leave is curtailed to allow adequate availability of human resources. Time norms for listing of cases based on urgency have been instituted to maintain capacity. Although these measures restrict some individual liberties, they are necessary for the greater good of patients and IR service.

STAFF MORALE, WELFARE, AND PSYCHOLOGICAL SUPPORT SYSTEMS

Infectious disease outbreaks with potential for significant morbidity and mortality are well known to instill significant fear in the community (24). A range of responses is expected during these stressful times. Staff have reported feeling worried for personal and family safety, particularly with transmission to vulnerable family members. At least 1 IR fellow elected to terminate the fellowship due to family concerns about his safety. Some have demanded routine use of "excessive PPE," beyond hospital recommendations due to personal concerns, thus potentially

685 alarming colleagues. On the other end of the spectrum are
686 members who seem excessively unconcerned about the
687 risk. Potentially, they may not fully comply with recom-
688 mended precautions thus placing themselves and co-
689 workers at undue risk. Staff have reported low morale
690 due to heightened measures, restriction of overseas travel,
691 and “PPE-fatigue.” Morale-boosting activities, tokens of
692 support from the community, and words of appreciation
693 from senior management have been very helpful.
694 Furthermore, regular timely information is provided by
695 management through the above-mentioned channels to
696 keep everyone updated and to combat speculation and
697 fake news, which have unfortunately been increasing
698 steadily. Staff who have seen the extensive precautions
699 taken have reported feeling reassured.

700 SUMMARY

701 The protocols described in this paper may appear stringent;
702 some may even be perceived as draconian (4), but multiple
703 lines of defense are needed to prevent uncontrolled intra-
704 hospital transmission. The combination of large patient
705 numbers and compromised staff can quickly combine to
706 overwhelm health care services. Vigilance and adherence to
707 enhanced protocols is vital for the sake of our patients and
708 our families.

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