

Interventional Radiology Procedures for COVID-19 Patients: How we Do it

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Received: 18 March 2020 / Accepted: 6 April 2020 / Published online: 27 April 2020

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Abstract With astonishing speed, COVID-19 has become a global pandemic. As it is uncertain when the pandemic will be controlled, it is crucial for procedurists of all stripes to be familiar and confident in performing procedures for COVID-19 patients to prevent intra-hospital infection. In this article, we will detail our approach on how to perform interventional procedures for COVID-19 patients at the bedside in the isolation room and with the patient transferred to the interventional radiology centre. These

workflows have been developed in conjunction with multiple other stakeholders within our hospital, drawing from valuable lessons we have learnt from the SARS outbreak of 2003.

Keywords COVID-19 · Interventional radiology · Procedures · Policy · Process · Infection control

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Introduction

The coronavirus disease 2019 (COVID-19) outbreak was declared a pandemic by the World Health Organization (WHO) on March 11, 2020 [1]. While COVID-19 is a mild disease in most, an estimated 20% of afflicted patients can develop a severe form of the illness [2]. The current estimated mortality rate of COVID-19 is 2%, in contrast with rates of 10% and 34% in Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS), respectively [3]. However, it is this milder smouldering infection which has allowed COVID-19 to spread worldwide, riding on the back of globalisation.

In this article, we will focus on the detailed processes when performing interventional radiology (IR) procedures for confirmed and suspected COVID-19 patients. These two groups of patients are handled identically in our institution, should an urgent procedure need to be performed.

Our experience with SARS has prepared us for a disease outbreak like COVID-19 [4, 5]. Local experience from another institution during SARS was reported by Lau et al.

Table 1 Roles of various other stakeholders

Stakeholder	Role
1. Infection prevention and epidemiology	Formulate infection prevention measures at all points of patient movement. This includes PPE, disinfection of procedural suites and equipment
2. Isolation ward staff	Coordinate transfer of patient and to handover/takeover care of patient
3. Anaesthesia	Manage airway/intubation Provide intraprocedural monitoring Coordination of anaesthetic unit personnel before, during and after procedure, including infection control measures
4. Environmental services	Provide prompt disinfecting services along the patient movement path and procedural areas
5. Security	Clear predesignated path to the procedure suite to minimise contact with other patients, hospital staff and visitors

[5]. Twenty-eight IR procedures were performed in 27 patients out of the cohort of 206 SARS patients: 12 pleural effusion drainages, 12 venous access catheter insertions, 1 retrieval of guidewire, 1 IVC filter insertion and 1 biliary drainage and stenting. While the total number of procedures performed by IR for COVID-19 patients may not be many to date, it is still necessary for all IR units to fully prepare themselves for this disease [6].

Methods

It is a major undertaking for any department to realign the diagnostic and interventional radiology services to combat COVID-19. Our colleagues (Cheng et al.) recently described such processes and included a quick summary checklist of major operational considerations for both diagnostic radiology and IR [7].

Hospital and Radiology Wide Measures

The early response for our hospital and radiology to COVID-19 has been reported in previous articles [8, 9]. In summary, strict infection prevention measures were implemented and patient throughput reduced with non-urgent procedures postponed to afford the time to plan and get ready for the surge of COVID-19 patients. All inter-hospital patient transfers will need to be screened for COVID-19. In the event that the transfer is emergent (e.g. stroke thrombectomy from another hospital), the patient will be managed as a suspected COVID-19 patient.

Various strategies of patient and staff segregation, according to the operational needs of each department are enforced to mitigate cross-infection. For example, in our department, inpatient and outpatient procedures are performed in separate locations. Prior to the pandemic, the team of 18 Interventional Radiologists (IRs) covered three different sites on a rotational roster. This has been stopped since the beginning of the outbreak and each site has been

assigned its dedicated IRs. Within the largest site at the Singapore General Hospital, the IR department is also divided into two functional IR teams (each team consisting of doctors, nurses and radiographers), and they are discouraged to intermingle socially during and after office hours. If in the instance one of the teams is quarantined, there would still be another to manage urgent cases. Physical distancing for staff within each team is practised during meal times when staff are not wearing their masks, and meal times are staggered.

In our institution, daily updates are sent out by the hospital management in the form of routine instructions with changes highlighted. It is crucial for the IR service to keep up with these changes as they can affect workflow.

Close Collaboration with Other Stakeholders is Crucial

The processes for infection prevention and transfer of COVID-19 patients should be developed in tandem with other procedural areas in the hospital to achieve synergy and standardisation, for example, the operating theatre and the endoscopy suites. Table 1 shows the various stakeholders and their involvement for the successful execution of these complex workflows, in addition to IR staff. Various scenarios were planned and then rehearsed, after which post-action reviews were conducted to gather feedback. Finalised protocols and pathways were clearly documented and formal endorsement obtained from management before implementation.

Personal Infection Prevention Measures

COVID-19 is spread via close contact, respiratory droplets, fomites and even possibly the faecal-oral route [10, 11]. In our current practice, all staff in clinical areas don surgical masks. When in direct contact with COVID-19 patients, full personal protection equipment (PPE) is necessary. Full PPE in our IR service includes scrub cap, N95 mask (FFP2

or FFP3), eye shield, full length gown and gloves. The proper sequence of donning and doffing of PPE can be found on the Centre for Disease Control and Prevention website [12]. There is currently no specific recommendation for use of powered air-purifying respirators (PAPR). While it is an alternative to N95 mask for protection against airborne spread, there are disadvantages such as communication difficulties due to the noise from the blowing air and potential cross-contamination if the filters are not disposed properly or if the hood is not cleaned properly [13]. In our institution, PAPR is used as an alternative for those who failed the mask fit test for N95 mask, and when performing aerosol-generating procedures (AGP) on COVID-19 patients [14]. We consider intubation and per-nasal or per-oral procedures like nasogastric tube insertion to be AGPs. In the scenario where the COVID-19 patient requires intubation for a non-AGP, only the anaesthetic staff will be donning PAPR while the rest of the staff in the procedural room is in full PPE only. It is our institutional practice for staff to shower following procedures involving COVID-19 patients as the final step in self decontamination. Shoes are also to be washed at the shower. All staff are thus encouraged to have a change of garments, including socks.

Location

All requests for IR procedures on COVID-19 patients will need to be vetted carefully. Non-essential procedures for suspected patients should be performed after they are declared negative for COVID-19 and this will have to be discussed with the referring clinicians. We have demarcated three locations to perform procedures for COVID-19 patients depending on which imaging modality is needed.

Our first choice would be to perform the procedure at the patient's bedside to minimise patient transfer and therefore infection transmission risk. These will largely be ultrasound-guided procedures (US-GP), such as pleural effusion and ascites drainages. Where necessary, portable digital radiography can be used to confirm catheter or wire positions.

If the procedure cannot be performed at the patient's bedside, the next choice would be to perform the procedure at an operating room (OR) designated for COVID-19 patients using a mobile fluoroscopy (C-arm) unit. Ideally, these designated ORs are located remotely from the main OR complex so as not to impede routine hospital workflow as large areas will need to be cordoned off during transfer of these patients [8].

Procedures which require angiography or CT will be performed at our IR Centre (IRC), which will require at least partial shutdown of the entire floor of the department. The recovery area will be turned into a PPE donning and removal area and a path will need to be cleared for the patient to enter the procedural suite directly. Hence, this option is reserved only for specialised procedures like stroke thrombectomy or complex procedures requiring our hybrid CT/angiography suite. Within our IRC, two procedure rooms were allocated to manage COVID-19 patients and simulations were conducted to work out detailed processes and workflows. Following the procedure, all areas along the patient's transfer path within IRC will need to be cleaned and disinfected. Detailed workflows for the first and last scenarios will be described. The second scenario closely mirrors that of the third.

Table 2 Personnel involved in bedside procedure

Initials	Staff	Role	Attire	Remarks
<i>Support team (no patient contact)</i>				
CO	Controller	Maintains command and control of the entire event and coordinates with various external parties Doubles up as runner nurse (RN)	N95/eye protection	Stays in corridor Holds walkie-talkie
<i>Procedural team</i>				
SN	Scrub nurse	Scrubs for procedure	Full PPE	
CN	Circulating nurse	Circulates for procedure	Full PPE	Moves between rooms. Not to touch surfaces in ante room Walkie-talkie in breast pocket
UR	Ultrasound radiographer	Operates US machine and cassette of digital radiography unit	Full PPE	
DR	Digital radiography radiographer	Operates digital radiography unit	Full PPE	Minimal patient contact
IR	Interventional Radiologist	Performs procedure	Full PPE	

Table 3 Detailed processes

Bedside procedure in isolation ward	Procedure in IRC	
<i>Pre-procedure</i>		
IR to confirm indication, urgency and where to perform procedure		
CO to gather team, assign roles and conduct briefing		
Gather necessary equipment for a portable procedure	<i>Patient prep</i>	<i>Procedure room prep</i>
To secure digital radiography unit if needed	Controller to liaise with ward, ED, security staff	Procedure room cleared of mobile cabinets and non-essential items. Remaining equipment to be wrapped
Proceed to isolation ward	Ward staff to prepare patient for transfer	Recovery area cordoned off and set up for post-procedure PPE removal
Wrap imaging equipment	Security to clear route	Signages placed to direct traffic
	Coordinate anesthetic support if needed	
	Security team meets ward staff at patient location	
	IR, PR, SN, MN, CN to don full PPE to receive patient inside IR suite. Perform buddy check for PPE	
	When patient and room are ready, CO to approve transfer of patient	
	Patient transfer directly to procedure room	
<i>Intra-procedure</i>		
CN to don full PPE, enter isolation room, brief patient, conduct preprocedural checks with CO via walkie talkie	Perform patient checks and transfer to angiography table	
UR to don full PPE enter room and position US machine	If required, anaesthetic team to perform intubation in PAPR	
CN and UR to position patient	Procedure commences. All personnel of procedure team to remain in room in full PPE	
SN to enter with full PPE to clean and drape	Patient's trolley to be cleaned and parked	
IR to enter with full PPE to perform procedure	Equipment or drugs to be passed into IR suite, from support to procedure team members without physical contact	
<i>Post-procedure</i>		
Procedure team to remove PPE and equipment as per guidance	Controller informs ward staff/security	
Proceed to shower	Patient transferred to ward, escorted by ward staff and security	
	Procedure team to remove plastic wrapping and wipe down equipment	
	Procedure team to remove PPE in designated order and locations and then proceed to shower	
	Controller activates Environmental Services to provide terminal cleaning of IR suite, recovery area and showers	

Performing Procedure in the Isolation Room

In our institution, IR may be required to perform some procedures in the isolation room (central venous catheter insertions, drainages, etc.). The manpower required for such a procedure is listed in Table 2. Table 3 details the steps taken for a portable procedure in the isolation room. Salient points will be highlighted below.

Pre-procedure

US-GP performed at the bedside will be in the dedicated isolation wards or ICU, with patients in single-bedded rooms. Our dedicated isolation ward rooms are designed such that each one is adjoined with an anteroom. The anterooms are equipped with non-touch hand motion door

sensors and interlocking mechanism where both external and internal doors cannot be opened concurrently (Fig. 1). Upon confirmation of the procedure, the controller (CO) and IR will convene the team.

A dedicated ultrasound machine (IU 22, Philips, Amsterdam, the Netherlands) is available in the isolation ward, in anticipation for the need of diagnostic US and US-GPs. The majority of our usual US-GPs involve drainage of symptomatic pleural effusions and ascites, however, in uncommon instances of more complex drainages like percutaneous nephrostomy insertions, arrangements will be made to have the portable digital radiography unit available. The use of digital radiography allows near real-time viewing of radiographs taken at the bedside in order to facilitate immediate confirmation of catheter positions, etc.

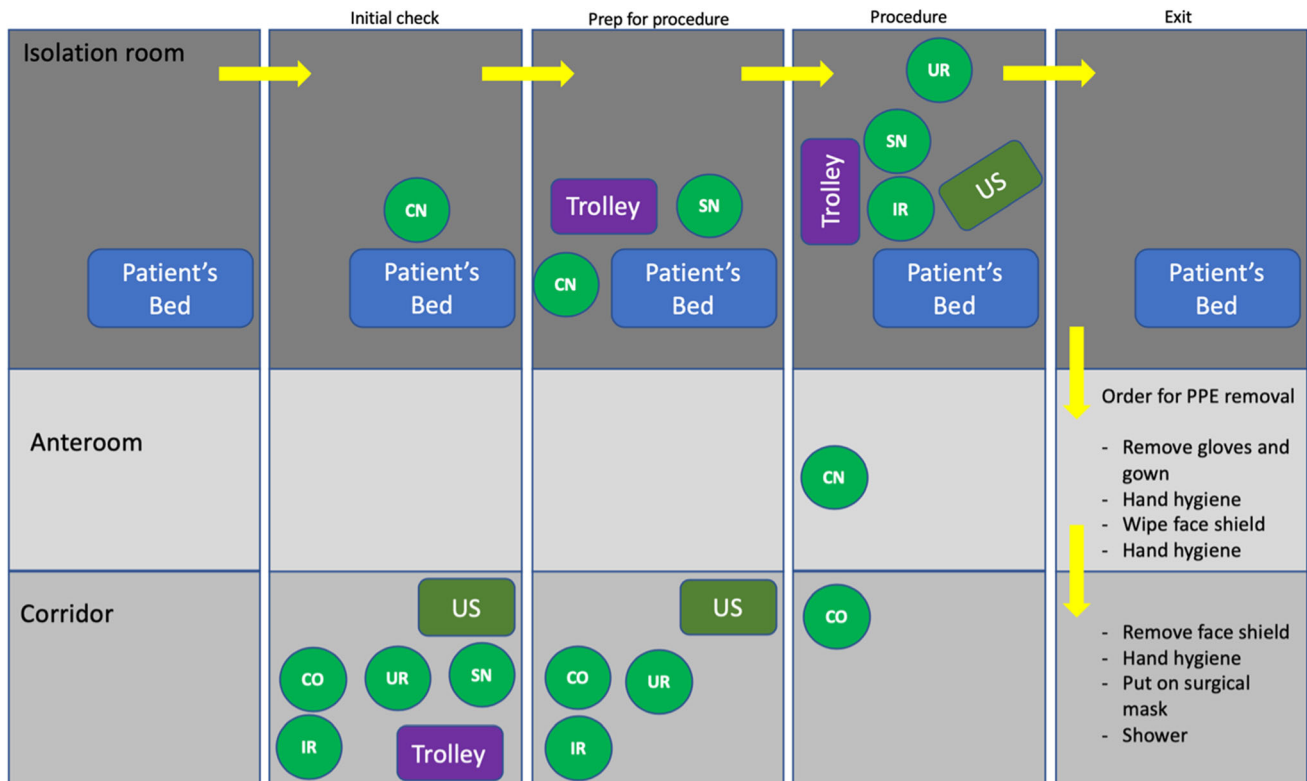


Fig. 1 Schematic diagram of isolation room with staff movement before and during procedure and order for PPE removal

Intra-procedure

To reduce movement in and out of the room, the IR will forego pre-scanning the patient, deviating from the usual practise. Hence, the circulating nurse (CN) and ultrasound radiographer (UR) will position the patient. A final procedural check can be conducted with the procedural team in the room communicating with the CO at the corridor via the walkie talkie, as the CO is checking against patient's notes and consent form. Patient's documents should not be brought into the isolation room. If fluid specimens are required, they will be collected only after the drainage system has been closed and only via a three-way tap. The fluid collected will be distilled gently into the specimen containers directly by the IR to reduce the risk of spillage. Specimens bottles will need to be wiped down and labelled by the CN in the procedural room before being dropped into the double bag held open by the RN. They will need to be labelled as possible COVID-19 sources, placed in a box and dispatched immediately to the laboratory. Should digital radiography be required, the digital radiographer (DR) will man the machine while the UR will man both the cassette and the US machine.

Post-procedure

Removal of PPE and disposal of waste should be done meticulously. The order of PPE removal is illustrated in Fig. 1. Clearing of trolley items and plastic wrapping will be performed at the anteroom.

The equipments are to be cleaned with disinfectant wipes (Wip'Anios Excel, Lille-Hellemmes, France). Equipment will then be parked in a designated area for ultraviolet C (UVC) light disinfection. The rest of the procedure team will then proceed to shower and change into a new set of scrubs. Personal particulars of each personnel involved in the procedure are recorded in case contact tracing is needed.

Staff Involved in Procedures at IRC for COVID-19 Patients

More staff will be needed to perform procedures on COVID-19 patients due to the enhanced infection control measures (Table 4). The key considerations are to maintain command and control of the situation and segregation between the procedural team managing the patient within the procedure suite and the support team who has no direct patient contact. The role of the controller (CO) is crucial; he/she is akin to the conductor of an orchestra, maintaining

Table 4 Personnel involved in procedure in IRC

Initials	Staff	Role	Attire	Remarks
<i>Support team (no patient contact)</i>				
CO	Controller	Maintains command and control of the entire event and coordinates with various external parties	N95/eye protection	
RN	Runner nurse	Circulates outside room	N95/eye protection	Hands equipment over to CN without direct physical contact Holds walkie-talkie
TN	Traffic nurse	Manages traffic at entry to department for all personnel involved in procedure as well as other parties like MRI staff and patients who use the same corridor	N95/eye protection	
CR	Control Radiographer	Manages control room	N95/eye protection	
<i>Procedural team</i>				
PR	Procedure Radiographer	Operates equipment inside procedural room.	Full PPE	
SN	Scrub nurse	Scrubs for procedure	Full PPE	
CN	Circulating nurse	Circulates for procedure inside procedure room. To minimise patient contact	Full PPE	Walkie-talkie in the pocket of the lead suit
MN	Monitoring nurse	Looks after patient in procedure room	Full PPE	
IR	Interventional radiologist	Performs procedure	Full PPE	
ANA	Anaesthetist/ICU team	Supports patient during procedure.		

situational overview as well as ensuring the whole event is carried out smoothly and safely. The CO is expected to coordinate multiple personnel across different departments in a crowded and tense environment to provide care for patients who can be critically ill. Allowing only a few nursing leaders to perform the role of CO will also allow them to be familiar with the workflow and boost confidence.

As there are multiple parties involved, staff are clearly identified by having their roles written on stickers which are stuck to their scrub caps for easy identification. It is paramount that staff working in these designated areas be familiar with their roles and the infection prevention measures required. They also need to keep in mind that *more haste is less speed*—a slip in infection prevention and control to save a few minutes may result in much longer remedial actions.

Effective communication between the procedure and the control room is maintained either via mounted microphones in the IR suite or hand-held two-way radio transceivers (walkie-talkies) manned by the runner nurse (RN) and the circulating nurse (CN). The CN put the walkie talkie at the upper pocket of the lead suit and should press the push-to-talk (PTT) button through the gown to

maintain. After the procedure, the walkie-talkie will be cleaned in the same manner as the PAPR.

Procedures Requiring Transfer to IRC

Table 3 details the steps taken for a procedure at IRC with patient transfer. Figure 2 shows the schematic diagram of IRC, manpower deployment and locations for donning and removal of PPE/PAPR.

Pre-procedure

The transfer of these patients will typically come from the inpatient wards, emergency department or an external hospital (e.g. urgent mechanical thrombectomy for stroke). Upon confirmation of the procedure, the IR will convene a team which includes nurses and radiographers with specified roles, led by the CO. If anaesthetic support is required, they should be notified in advance. All staff involved join a chat group on our hospital's secure text messaging mobile application (TigerConnect, Santa Monica, USA). We have found this effective in coordinating transfers and disseminating information to multiple parties.

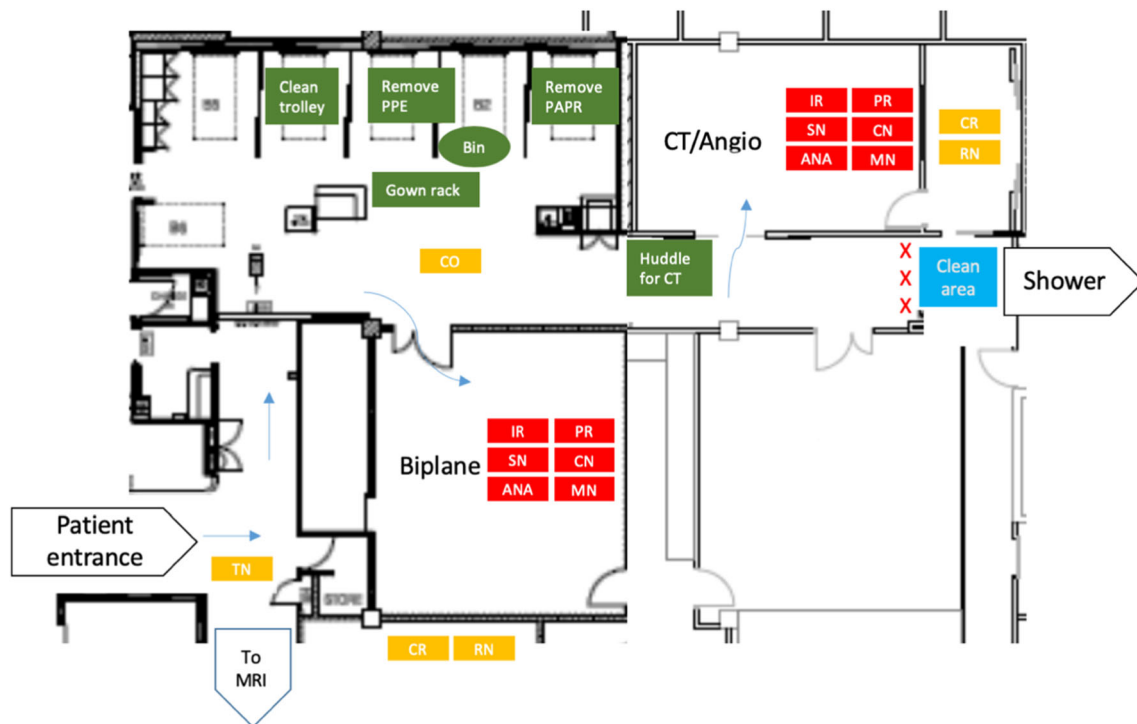


Fig. 2 Schematic drawing of staff locations and patient flow for procedure in IRC

Next, the patient and the IR suite will have to be prepped concurrently as detailed. Patients in the recovery room should be moved out quickly if possible. Procedures in other rooms along the path of transfer which cannot end before the COVID-19 patient is activated should remain in the room till the CO gives the clear signal (after cleaning and disinfection). All items that are non-essential and movable are removed from the suite. Cabinets are either moved out of the suite, have their doors shut and locked or draped with the disposable plastic sheets. The contents of cabinets that are left in the suite during the procedure should not be exposed. A mobile cabinet containing essential equipment (i.e. catheters, guidewires) is positioned just outside the suite for easy access. All other equipment that remains in the suite during the procedure is draped with disposable plastic sheets (Fig. 3A). The traffic nurse (TN) will put up signages along the corridor leading to the IR suite, serving both as a guide for essential personnel and restricting access to others (Fig. 4A–C). Only when all preparation is complete, will the CO authorise transfer of the patient.

Intra-procedure

Deviating from routine practise again, the patient will enter the IR suite directly. If required, intubation will be performed at this point by anaesthetic staff who will be in

PAPR (Fig. 3B) while the rest of the staff will be in full PPE without PAPR. For patients who require supplemental oxygen for a conscious sedation/local anaesthesia procedure, oxygen via nasal cannula can be given under a surgical mask. After the commencement of the procedure, all personnel in the room are not to leave the room unless absolutely necessary. Equipment or medications that are required during the course of the procedure are handed from the runner nurse (RN) outside the IR suite to the circulating nurse (CN) via the control room door. Care is taken to avoid contact between the procedure and support team members. All consumables passed into the IR suite but not used is assumed to be contaminated and thus disposed.

Post-procedure

Once the procedure is finished, the CO is notified and preparations made to transfer the patient to the ward. The team will continue to be vigilant about infection prevention as there is a high likelihood of contamination during removal of PPE. Gloves and gowns are removed in the IR suite, the face shield wiped and hand hygiene performed. The team then proceeds to the recovery area to remove their protective lead gown, N95 mask and eye shield. The anaesthetic staff will similarly remove and clean their

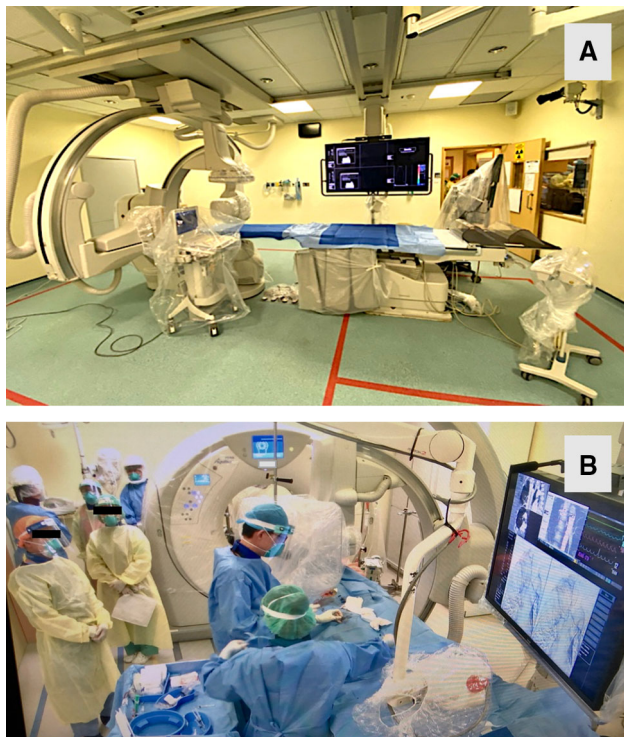


Fig. 3 Designated rooms for COVID-19 patients. **A** Biplane suite with mobile cabinets removed and equipment wrapped. **B** Hybrid CT/Angiography suite during bronchial artery embolisation for a suspected COVID-19 patient. Located at the far left upper corner of the image are ICU staff in PAPR as they need to manage the airway. The rest of the staff are in full PPE without PAPR

PAPR in the recovery area. (Figure 4D). Hand hygiene is performed and a new set of surgical masks donned. The entire procedure team will then proceed to shower and change into a new set of scrubs. When all staff have left the IR suite and shower area, the CO will activate the hospital environmental services to provide cleaning of the IR suite, temporary recovery area, corridors along the patient transfer path and the showers.

Miscellaneous

Biological Waste

If the patient needs to relieve himself or herself before the procedure, biological waste will be doubled bagged and disposed off into the biohazard bag in the room.

CT Scan During Procedure

If intraprocedural CT scan is required, all staff should exit the procedure suite via the main door and stand in a designated area, making sure not to touch the walls or to come into contact with other personnel. If available, doors should

be put to the automatic motion detection mode to allow staff to enter/exit the room without the need to touch the door surface. Once the CT is performed, staff can return to the procedure suite and the external area where they stood will be disinfected.

Disinfecting the Procedure Room

First, all imaging equipment inside the room are to be wiped down with disinfectant wipes (Wip'Anios Excel, Lille-Hellemmes, France). The floor and the walls of the procedure suite, recovery area and corridors will then undergo terminal cleaning with sodium hypochlorite solution 1000 ppm. Additionally, per our institutional protocol, ultraviolet C (UVC) light disinfection will be carried out by dedicated teams from environmental services [15]. The room will need to be aired for 20–30 min. Hydrogen peroxide vapour may be a more effective disinfection agent [16] but there is the risk of aerosol exposure, and thus a wait time of 4–6 h is needed for the hydrogen peroxide to be removed from the environment before safe use. Waste from the room will be disposed by a dedicated team.

Results

At the time of publication, all our cases were suspected COVID-19 patients. We have performed two bedside pleural drainage procedures for the same patient in the isolation ward. At the IRC, we have performed two stroke thrombectomies and one bronchial artery embolisation (the patient also needed an on table CT scan prior to the procedure).

Discussion

As the Chinese saying goes, train an army for a 1000 days to use for one morning. These detailed and laborious processes were collectively worked out by all stakeholders to keep our patients and staff safe. During the formulation of such processes, staff should concurrently undergo infection prevention refresher training, N95 mask fitting and PAPR training if required.

Everyone must bear in mind that the greatest risk of contamination may occur after the procedure is over. Meticulous PPE doffing technique, a buddy system to catch errors and designated spacious areas equipped with visual reminders and sufficient cleaning equipment are vital.

It is highly recommended that simulations and after-action reviews be performed. The roles of the CO and the TN were created after we found that additional personnel were required to manage the whole team. The decision to



Fig. 4 Various measures to ensure infection prevention. **A** Clear signage to prevent wrong entry, staff in PAPR. **B** Traffic nurse identified by label at scrub cap, situated at entrance. **C** Clear

demarcation of clean and dirty areas. **D** PPE donning and removal stations with posters with step by step instructions

expose more staff to the process was not taken lightly. We reasoned that as the CO and the TN did not have direct patient contact, the benefits of having them contribute to a more controlled and calm process outweighed the small risk of exposure. The walkie talkie was introduced as we found that the nurses are generally not situated near the mounted microphones and had problems communicating. All steps in the process were documented after they were finalised, with charts and schematic diagrams distributed to the rest of the team.

While we expect fewer pleural drainages for COVID 19 patients as pleural effusion seems to be a rare occurrence in this disease [17], given the protracted manner of the pandemic and the large number of infected patients, there may be COVID-19 patients afflicted with other conditions which require urgent IR procedures. The need for developing robust processes is thus urgent, even if the possibility

of performing a procedure on a COVID-19 patient seemed remote at the early part of the pandemic.

We recognise that these processes were developed in our local environment which may be different from that available in other centres. Each centre will have to come up with their own processes based on the principles we have shared. The CDC has a useful resource for interim infection prevention and control measures [18].

Conclusion

The COVID-19 pandemic situation is fluid and the operational processes will need to evolve to adapt to rapid changes. We hope that by sharing these detailed processes, each IR service can develop their own strategies to manage COVID-19 patients. Difficult transitions will need to be made, particularly with patient load reduction and staff segregation. It

can be challenging to close off an entire section of the department just to perform one procedure for a COVID-19 patient. However, this is a small price to pay to ensure the safety of our staff and our patients. The early phase of an outbreak is when decisive and effective actions can dramatically reduce spread. Lessons learnt from this pandemic can be applied to other emerging infectious diseases. IR suites of the future should also take into account pandemic situations during their conception and design.

Funding This study was not supported by any funding.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Consent for Publication For this type of study consent for publication is not required.

Ethical Approval This article does not contain any studies with human participants performed by any of the authors.

Informed Consent For this type of study informed consent is not required.

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