Commentary

Setting Up an Interventional Radiology Suite in an Infectious Diseases Centre: Lessons from the Novel Coronavirus (COVID-19) Outbreak

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Introduction

Interventional Radiology (IR) suites are designed to cater to needs of various specialties in a hospital. Their proximity to the Emergency Department (ED), Operating Theatres (OT) and Intensive Care Units (ICU) to centralise resources and maximise patient flow is commonplace. In the event of an infectious disease outbreak, this efficient workflow can be disrupted by measures instituted to minimise transmission of infection between patients, healthcare workers and the public. IR suites are thus often retrofitted to meet more stringent infectious control standards, are subject to prolonged downtimes from disinfection protocols and face a truncated list which cater mainly to essential procedures. These changes will be detrimental in already overwhelmed IR practices. Dedicating a standalone IR suite within a general hospital specifically for these cases may be ideal, but can be a waste of equipment and space.[1] If the hospital has an Infectious Disease Centre, creating an IR suite within it has many advantages, which we aim to highlight.

Historical Background

The history of treating infectious diseases in Singapore can be traced back to 1907, when a quarantine camp for infectious diseases was created. Over the subsequent years, this camp underwent expansion, transformation and change in name from Government Infectious Diseases Hospital in 1913, to Middleton Hospital in 1920 and then to the Communicable Disease Centre (CDC) in 1985. In this time, Singapore witnessed a change in disease patterns from smallpox, diphtheria, typhoid, cholera and malaria in the early and mid-1900s, to Severe Acute Respiratory Syndrome (SARS), H1N1 influenza and Zika virus infections in the 2000s. The CDC served as the national referral centre for the management of these communicable diseases during this entire period.[2]

The SARS pandemic in 2003 made us consider the need for decentralisation, to segregate infectious patients in a separate facility, so as not to disrupt daily work.[3,4] The National Centre for Infectious Diseases (NCID) was built in 2018 to replace the old CDC and began operations, just before the outbreak of novel Coronavirus (COVID-19) in December 2019.[5] Sited across the road from the main Tan Tock Seng Hospital, and connected via a link bridge, this fully-integrated 14-storey facility has a maximum inpatient bed strength of 500. It also houses operating theatres and the NCID Radiology Centre (NCID-RC) with en-suite IR facilities to cater to its patients.

Up until recently, the predominant cases treated in CDC and NCID included tuberculosis, acquired immunodeficiency syndrome and drug-resistant bacterial infections. Many of these patients required radiological procedures such as image-guided biopsies and drainages, line insertions for long-term antibiotics, and very rarely complex procedures like embolisation, angioplasty and caval filter insertion. Despite the NCID-RC having its own IR suite, a large proportion of patients were still brought to the IR suite in the main hospital for several reasons: (1) it was a more familiar environment for the Interventional Radiologist, (2) the fixed-arm angiographic machines had unmatched capabilities for all types of procedures, (3) the inventory was complete with all kinds of devices, (4) it was easier to depute personnel to the IR subsection from the existing pool within the Radiology Department, (5) workflows in the IR suite were well-established and (6) the mode of spread of the usual infections were well understood and there were established measures to contain them.

However, COVID-19 was a new entity.[3] Initial knowledge of its mode of transmission straddled between airborne versus respiratory droplets and fomites.[6] Furthermore, its infectivity ratio and mortality rate were yet undefined.[7] Under this shadow of uncertainty, and with NCID becoming the major referral centre for screening, isolation and management of

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suspected and confirmed COVID-19 infections, it was considered more favourable to contain the spread and perform IR procedures within NCID itself. [7]

Preparing the IR Suite

The main factors considered when planning an IR suite for patients with communicable diseases includes maximal containment of airborne disease, minimal transmission from fomites, reduced exposure of personnel to microbes and mitigating risk of transmission during patient movement.

(a) Location of Suite

The previous CDC was located in a facility 0.5–1 km away requiring patients to be transported to the main hospital for IR procedures via ambulance and dedicated corridors. Even with these measures, risk of contamination and deterioration of the patient during hospital transfer were potential problems. The new NCID building is connected to the main hospital building via a dual level link bridge, one of which is exclusive for patient transport. This ensures a safer, more convenient and speedier transfer of patients.

The NCID-RC is strategically located on a level that provides easy access to its own ED, OTs and ICUs via large capacity elevators. It is equipped with X-ray, ultrasound, and computed tomography capabilities that complement the needs of an IR suite. It has access to Picture Archiving and Communication System (PACS) and Radiological Information System (RIS) to enable seamless review of previous studies and issuance of post-procedure reports, and has an exclusive pool of nurses, radiographers and healthcare attendants.

(b) Room Requirements

Layout

The IR suite consists of a procedure room separated from the exterior by 2 anterooms, one for staff and the other for patient use (Figure 1). Entrance into and exit from the anteroom is via inter-locking doors that consists of two sets of doors electronically connected so that one set cannot open until the other set has closed (Figure 2). This maintains the negative pressure gradient and controls the entry or exit of contaminated air whenever the anteroom door is opened. Door opening is controlled by touch-free access to prevent contamination.[8] Next to the patient anteroom, the sluice room doubles as a doffing area, with disposal facility for soiled items into contaminated/biohazard bins.[1,8] Adjoining the procedure room is a side room separated by a lead-lined glass window, through which support staff can visualise and communicate with the procedure room staff.

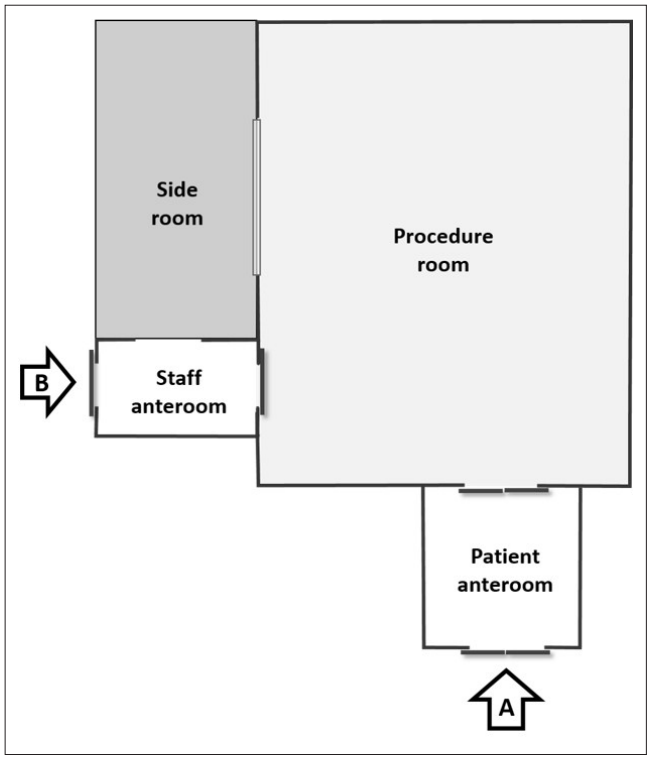

Fig. 1. Layout plan of the IR suite located within the new National Centre for Infectious Diseases Radiology Centre (NCID-RC). Staff enter the procedure room via the anteroom (Arrow B). After the procedure, both patient and staff exit the procedure room through the patient anteroom (Arrow A).

Fig. 2. Entrance to the patient anteroom. The outer set of inter-locking doors are currently ajar and this prevents the inner set of doors from opening.

Ventilation (Figure 3)

Flow of air occurs along a gradient, from higher to lower pressures. While operating rooms need to maintain positive pressure to prevent airborne microbes from entering the room, the IR suite in NCID is designed with negative pressurisation to contain the airborne contaminants within the room. This negative pressure is generated by a ventilation system that permits unidirectional flow of air into the room, and a pressure gradient is developed in continuous progression through zones with increasing sterility. The contaminated exhaust air from the room passes through a High-Efficiency Particulate Air (HEPA) filter and is treated with ultraviolet radiation before dispersion into the atmosphere with a high-plume dilution fan.[9] This ventilation system ensures airborne contaminants are contained within the room, removed, sterilised and expelled, rather than being disseminated from the procedure room towards the rest of the NCID-RC.[1,3]

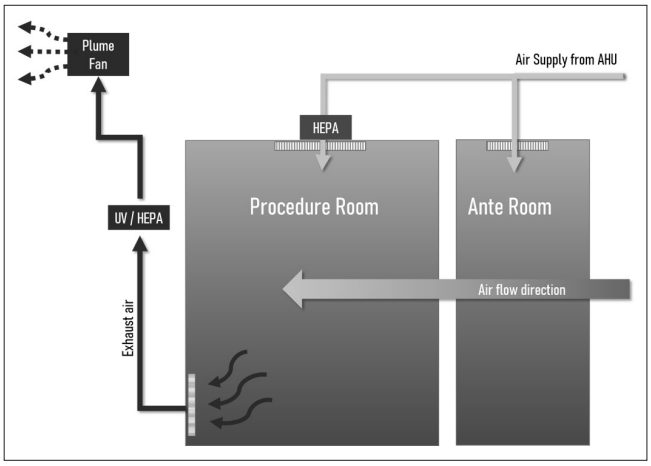

Fig. 3. In contrast to positive pressure in operating rooms where airflow is away from the operating table, airflow in our negative pressure procedure room is in the opposite direction. Its aim is to prevent dissemination of airborne contaminants into the rest of the NCID-RC. After appropriate treatment, this air is dispersed into the atmosphere.

Room Size (Figure 4)

As per the Society of Interventional Radiology guidelines, an IR room with a fixed-arm machine should be a minimum of 650 square feet (60 m^2) and a hybrid suite 800 square feet (75 m^2).[10] While there is no existing guideline regarding mobile C-arm machine, the suite should be of adequate size to allow parking of equipment and movement of staff and patient. In NCID, the area of the procedure room is approximately 35.9 m^2. When the areas of the 2 anterooms and sluice room are included, their total area becomes about 54.2 m^2. We have found this size to be reasonable for most procedures. A larger room size would be a boon if there was a need to accommodate extra staff like anaesthetists for patients requiring general anaesthesia, and surgeons during combined endovascular-open surgery. As a consequence, we perform such procedures in the NCID-OT, which is larger and has similar infection control specifications.

Storage

To reduce the surface area of potential contamination and facilitate efficient disinfection, all fixed cabinets in the room were removed and changed to portable mobile storage systems placed outside the procedure room. Indirectly, we gained extra space in the process.

Fig. 4. Panoramic view of the procedure room revealing our paraphernalia. From left to right: ultrasound machine, anaesthetic machine, anaesthetic drug trolley, C-arm with monitors and power injector. There is an additional sink and biohazard disposal bin within this room.

(c) Equipment Requirements

Imaging Equipment

The choice of the fluoroscopy machine will be based on clinical requirement, available space and economics. A fixed-arm angiography system will be ideal, but is expensive and requires a large space, risking the investment becoming a "white elephant" considering the small volume and limited variety of procedures required in infectious disease patients. While most procedures for these patients are drainages and venous lines, the machine should possess the ability to perform more complex interventions like embolisation, which minimises the need for transferring patients to the main hospital. Current mobile C-arm technology has made rapid improvements in hardware, image resolution, cooling and dose reduction, making it suitable for almost all IR procedures. These systems are being used in hybrid endovascular suites as such, and are loaded with imaging software such as vessel road map and stenosis quantification analysis. Not only does this software ensure higher success rates of procedures, it also reduces procedural time, a factor that is crucial when treating infectious patients. Furthermore, a C-arm has the ability to be transferred to the OT when required for procedures that require an OT set up such as hybrid endovascular procedures. Default settings on most mobile C-arms may not be appropriate for complex endovascular procedures, so we tweaked them to meet our requirements. Supplementing the C-arm is a free-floating, translucent carbon fibre table-top to reduce radiation exposure and improve image quality, and a portable power injector for endovascular procedures.

Another important equipment for IR procedures is the ultrasound machine.[4] Ultrasound guidance is required for most drainages, biopsies and for vascular access. The device should possess a reasonably high-end resolution, be portable and have a small foot print when room size is small as well as have a variety of probes.

Archiving images to the PACS system is done via Ethernet through ports within the room.[1] Nowadays, advanced machines can transfer these images to PACS via Bluetooth, further reducing cable clutter and risk of fomite transmission.[1]

Anaesthetic Apparatus

Our IR Suite is equipped with a general anaesthetic machine and gas outlets. However, space constraints to accommodate the anaesthesia team and equipment sway us towards performing complex cases in the OT.

Other Paraphernalia

Consumable items: These included a variety of angiographic catheters, wires and embolic materials on top of the usual drainage tubes and central venous lines. To prevent contamination, the stock cannot be stored in the procedure room but is kept in a side room or on a mobile cart, outside but within reach of the IR suite.

Radiation protection: Our lead gowns are stored on a mobile rack whilst the lead shields have wheels. These standalone items allow them to be easily moved between the NCID-RC and OT as needed. They are also more easily cleaned compared to fixed devices which may have multiple hinges, with narrow crevices near their attachments to the wall. A mobile rack for lead gowns is crucial, as this rack will have to follow the staff into the donning and doffing areas. This is because each lead gown requires terminal cleaning after usage before being sent back to the NCID-RC.

(d) Staffing

We work on the premise of minimising the number of staff within the IR suite, to reduce risk of exposure to infection and radiation. Nevertheless, there should be 2 teams available, an operating team and a support team.[4]

Optimally, 4 people are required in the operating team and their movement within the room should be kept to a minimum to reduce risk of cross-contamination. These includes one Interventional Radiologist who is experienced enough to perform procedures single-handedly. It is not an appropriate time for a trainee to accumulate experience, as failure to treat the patient's condition only results in a longer exposure time for remaining staff within the room. There needs to be one radiographer to move the equipment and help display images. Machine and table should have the capability for easy handling by a single radiographer and/or the Interventional Radiologist. Finally, we have one scrub nurse to assist the Interventional Radiologist and one circulating nurse to assist with monitoring and moderate sedation as well as receiving consumables from the anteroom and opening these packages.

The support team stationed outside of the procedure room comprises at least one radiographer, to help procure and handover equipment to the circulating nurse within the room and a nurse trained in infectious disease control, to help with donning/doffing and trouble-shooting.[11]

During an outbreak, it is important to ensure that staff stationed in the NCID-RC should not rotate back to the common pool in the main hospital.[1] This caveat should be

considered when making logistical provisions for staffing during the setting up phase.

Peri-Procedural Work Flow

There are universal or standard precautions whenever an individual or department handles infectious cases.[1,6,8,12] However, we would like to highlight changes in work flow we have undertaken since the SARS outbreak.

To do Bedside or in the IR Suite?

During the outbreak, the NCID-RC catered only to inpatients with suspected or confirmed COVID-19 infection. Patients requiring IR procedures will be selected for bedside interventions if they are in isolation wards, deemed unstable or unsafe for transfer and the procedure required only ultrasound guidance such as venous access or drainage procedures. For IR procedures requiring fluoroscopy and for those in non-isolation wards, the patient will need to be transported to the IR suite.

Transportation

Non-intubated patients are transported within NCID with a surgical mask on, while the transporting team would be in full personal protective equipment (PPE). Once in the NCID-RC, the patient goes directly into the procedure room, and depending on the procedural requirement, the bed either stays in the procedure room or in the anteroom. If there was a need to transport a patient between the main hospital and NCID, it would be via the dedicated link bridge.

Room Preparation

We place emphasis on planning each case properly. Good planning reduces the movement of staff and equipment within and between rooms. Imaging equipment is optimally positioned for unhindered movement within the room. Consumables and devices essential for the procedure are brought into the room before the patient arrives. Standby consumables are placed in the side room, and handed in only when required. Even as we strive to increase the variety of consumables to be on par with what is available in the main building, we are mindful to keep these numbers to a reasonable amount. This is because we regard consumables brought from the main hospital to the NCID-RC as a transfer from a less to more contaminated location. Hence, unused consumables should remain within the latter site and not be brought back against the contamination gradient. Therefore, it will be wise to stock judiciously to avoid wastage due to expired items.

Personal Protective Gear

There is a dedicated space outside the IR suite for donning the PPE or powered air purifying respirator (PAPR). Doffing involves 2 steps, removing the sterile gown and gloves in the procedure room followed by removal of PPE and lead aprons outside the procedure room. Given the complexity of using protective gear, having stepwise instructions displayed in the area and a "buddy" nurse to assist can minimise errors during the donning and doffing processes.

Communication

The support team in the side room must have good visualisation of the procedure and an intercom to communicate with the procedure room staff. Procedural data is conveyed by writing and displaying to the support staff through a glass panel for final documentation. As a result, the need to open and close interlocking doors are kept to a minimum, mainly for handover and receiving of extra items.[1]

Documentation

We have installed a touch screen computer system to access data and perform time out within the NCID-OT. The wall-mounted touch screen system (as opposed to table-top version) reduces contamination whilst allowing easy cleaning. If hardcopy documents are required, these should be printed and signed from a remote location outside of the IR suite.

Post-Procedure

After the procedure, the patient is stationed and monitored in the procedure room by the nurses, until transfer-out is completed. After the patient is transferred, the nurses and radiographer thoroughly clean all equipment in the room with alcohol wipes. Following this, terminal cleaning of the room, including floor, walls and doors is done using 5,000 ppm sodium dichloroisocyanurate (NaDCC).

Other Measures

We would like to suggest several items/practices for the scrub area, donning/doffing room and changing room. (1) Consider having an optional supply of disposable gowns instead of washable scrubs. These may be preferable in highly contagious cases where single use

wear is the better option; (2) an N95 mask may be used under the PAPR.[4] Apart from the given reasons, we are of the opinion that having this mask on whilst in an enclosed doffing area may provide additional protection once the PAPR (if used in a COVID case) has been removed, with the surrounding air transiently contaminated with particles; (3) there should be ample cubicles for all staff at risk of being contaminated to shower concurrently before leaving the NCID-RC.[6,8] The longer they hang around waiting in queue, the higher the risks of cross-contamination. Each cubicle should also have the appropriate cleansing solutions for disinfection; (4) consider having an emergency shower cubicle, such as those used in chemical labs. It may be useful for rapid decontamination when there is spillage of large amounts of contaminant on any susceptible area of any staff.

Conclusion

Our previous SARS experience has made our institution better prepared for the current pandemic by segregating our infectious cases into the new purpose-built NCID and adopting new work processes.[3,4] Despite having the luxury of the NCID-RC with en-suite IR capability, we do not discount facing newer challenges in the delivery of IR services.

The current concept of centralised IR services within the hospital to cater to patients across multiple clinical disciplines needs to be revisited, and if possible, redefined in the light of the COVID-19 pandemic and more recent outbreaks including SARS, Middle East Respiratory Syndrome and Ebola.[12] Restructuring of healthcare delivery which minimises contact of patients with non-communicable diseases from healthcare facilities has been suggested but acknowledged to be challenging.[5] A strong case may therefore be made for IR services to be integrated within an infectious facility to give ourselves more options and to be continually better prepared for the next outbreak.

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