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REVIEW COVID-19

How to Handle a COVID-19 Patient in the Angiographic Suite

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Abstract This is a single-center report on coordination of staff and handling of patients during the outbreak of the COVID-19 (coronavirus disease 2019) in a region with high incidence and prevalence of disease. The selection of procedures for interventional radiology (IR), preparation of staff and interventional suite before the arrival of patients, the facility ventilation systems and intra- and post-procedural workflow optimization are described. The control measures described may increase the cost of the equipment, prolong procedural times and increase technical difficulties. However, these precautions may help control the spread of COVID-19 within the healthcare facility.

Keywords Coronavirus disease 2019 · COVID-19 · Interventional radiology · Angiosuite

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Introduction

The corona pandemic COVID-19 (coronavirus disease 2019) has created a crisis in healthcare systems across the globe. Although interventional radiology (IR) is not among the leading forces in the fight against the virus, IR remains an important part of healthcare systems. Therefore, it is necessary that appropriate IR services can also be provided under these extreme circumstances. Such services include critical emergency interventions, such as embolization procedures to treat hemorrhage, and endovascular treatment of acute ischemic stroke. In addition, depending on the specific circumstances, oncology patients and cases of critical limb ischemia also need urgent treatment. However, the current outbreak may find some IR services unprepared to safely perform these important services. In this document, preemptive measures and potential challenges that are most relevant to the practice of IR are described based on the experience of an IR unit deeply affected by COVID-19.

General Principles

The novel human coronavirus, known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), emerged in Wuhan, China at the end of 2019. The rapid global expansion of this outbreak is the result of an efficient human-to-human transmission of the coronavirus disease (COVID-19) [1]. The high viral loads in upper respiratory tract samples indicate that virus transmission via respiratory secretions, in the form of droplets (> 5 μ) or aerosols (< 5 μ), may be most likely [2]. Surfaces contaminated by people coughing or sneezing on them represent another way of contamination [2]. Viable virus could

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be detected in aerosols up to 3 h post-aerosolization; its half-life on surfaces seems to depend on the contaminated surfaces. Laboratory tests reveal viable virus up to 4 h on copper, up to 24 h on cardboard and up to 2–3 days on plastic and stainless steel [3].

Due to the high rate of aerosol transmitted infections and permanence on surfaces, segregation is one of the basic principles for prevention of new viral infections. This also accounts for patients who are referred for an IR procedure. There is a need for decentralization of services and segregation of patients in response to the risk of nosocomial transmission of infection. Execution of IR procedures in situations with suspected airborne infections needs particular precautions to reduce the risk of transmission to the healthcare workers. As far as possible, procedures on patients with suspected or confirmed COVID-19 infection should be performed at a specially designed isolation facility. In our hospital, every patient and healthcare worker has to undergo RT-PCR testing (real-time reverse transcription polymerase chain reaction) for the qualitative detection of nucleic acid from COVID-19. Uncertain cases are managed as infected ones, and healthcare workers with suspected infection are kept away from the hospital (preventive quarantine). Luckily this has not been required yet, perhaps in part due to attention to these recommendations and guidelines.

The isolated patients should not take the conventional routes to the angiographic suite, but use (when possible) dedicated elevators and designated routes, and stay as short as possible in the recovery area. Waiting for the procedure and the performance of any preparatory tasks or paperwork that can be done directly in the procedure room should be done there, so as to minimize contamination along the route (while remaining vigilant about in-room sterility).

Few IR services are equipped with physically separate outpatient, inpatient and isolation facilities. Where the service is not equipped, the solution may be to explore temporal segregation of services to different groups of patients. If possible, procedures for non-infected patients should be performed in the first hours of the day, and those to the infected in the second part of the workday. It is also possible to take advantage of resources from other departments (cardiology or even operating theaters), supplemented with portable fluoroscopic units, to reduce the frequency of these patients in the IR services to a minimum.

Selection of Procedures

Every IR service must comply with the advice and directives given by each hospital, which depend on the location and the role that the hospital has in the geographic area, and also on the severity of the regional COVID-19 dissemination. Our protocols were implemented in accordance with advice from the directors of the hospital and the administrative service. It could be necessary to postpone non-urgent procedures until a patient's risk status is further evaluated. One approach is to continue with urgent and non-deferrable oncologic procedures, while postponing an appropriate number of other elective cases.

Our hospital is located in the area where infections are highly concentrated; therefore, the intensity of COVID-19 exposure is very high. In order to limit the risk of transmission between patients, and between patients and healthcare workers, the IR workflow has been reorganized. Procedures for life-threatening conditions (e.g., embolizations for bleeding, thrombectomy for stroke, acute mesenteric ischemia, endovascular aortic aneurysm repair for aortic ruptures), non-deferrable oncologic treatments (e.g., interventional procedures bridge to liver transplant, selected percutaneous ablations, chemoembolizations and biliary drainages, and few others), and organ-saving procedures (e.g., percutaneous nephrostomy, urgent diabetic foot angioplasty, prophylactic occlusion balloon placement for the prevention of postpartum hemorrhage due to morbidly adherent placenta) are performed whenever deemed to be necessary on a daily basis. Moreover, selected central vascular accesses and percutaneous thrombectomy of dyalitic fistulas were carried out. After multidisciplinary evaluation, bedside procedures (e.g., ultrasound-guided percutaneous abscess drainage and few biopsies) were performed.

Before the Arrival of the Patient

Rigorous training is necessary, especially in the initial phase. Written protocols should be available in every IR service and on hand for all operators. Careful hand hygiene, correct wearing of protective equipment and strict adherence to infection control procedures will ensure continued and complete compliance, balancing any critical equipment shortages as well.

Before a patient is called down for a procedure, it is mandatory that all pre-procedure preparations have been completed. This will reduce the unnecessary amount of time patients spend in the department. All the staff of the angiographic suite must use personal protective equipment (PPE), according to accepted infectious disease and epidemiology guidelines. These include masks, gowns, gloves, eye protection (goggles or face shield) and shoe covers. Sterile barriers (gown and gloves) must be worn by operators in addition to other protective equipment.

All non-essential and mobile equipment should be moved out of the angiographic suite to avoid possible contamination. Fixed and essential contact surfaces within the room need to be covered with clear drapes. Switches

and control panels should be covered by plastic that should be changed between patients (Fig. 1 A, B). Non-disposable materials (linen, etc.) should be avoided. Clean and contaminated work areas must be clearly separated.

Administrative staff, office workers and employees in the administrative areas of the IR service, who are not directly involved in the procedures but localized in IR services, should be kept away from the path of the patient and maintain a minimal distance of two meters from the patient. They do not require PPE [4]. In our IR Unit, we have 5 employees, including secretaries and administrative workers; in these weeks we reduced their presence to 2 per week from 8:00 a.m. to 3:00 p.m. instead of 8:00 a.m. to 7:00 p.m., to limit their exposure. The same scheme has been adopted for interventional radiologists: per week only 5 (2 for neuro and 3 for body) go to the hospital where they cover IR procedures and replace the peripherally inserted central catheter (Picc) team for COVID-19 and non-COVID-19 patients (Picc team is now employed in "COVID-area"). Staggering staff into team shifts minimizes impact of large exposures or full team exposures.

Geographic isolation of COVID-19 positive patients should occur in designated suites only, in order to minimize different room exposures and familiarize cleaning staff with the same rooms. Our IR Service is equipped with 2 angiographic suites; during the peak pandemic, only one remained open, mainly because technical and nursing staff were recruited elsewhere where more staff were needed. This approach facilitates cleaning protocols and limits the transit between the 2 rooms.

Ventilation of the Angiographic Suite

Modern angiographic suites may be equipped with a ventilation system similar to operating rooms; especially pressurized positive air has a vertical airflow and 12–15 air exchanges in the angiosuite per hour. Based on the available evidence, and as reported above, the COVID-19 virus is transmitted between people through close contact and droplets, exposure to particles in the air, or after touching contaminated objects and surfaces [2]. Consultation with local epidemiology expertise should be undertaken to assess the status of current suite ventilation, and whether positive, negative, filtered, or recirculating air is present. Such knowledge can assist in the development of specific and standardized workflow protocols that match the ventilation requirements to the degree of specific isolation. That being said, COVID isolation in the angiosuites may not require dedicated extra ventilation systems. However, high efficiency particulate air (HEPA) filtration systems in the angiographic suites may represent the best way to protect staff. Dedicated negative pressure rooms with air filtration may be ideal for COVID, especially in procedure rooms, but potentially also in waiting rooms, bathrooms and soiled equipment or decontamination rooms, when feasible.

Intra-procedural

Enhanced workflows within procedural suites should be structured so that each member is clear about their role. The World Health Organization (WHO) recommends the use of appropriate PPE for standard, contact and airborne precautions [4] (Fig. 2A–C). Aerosol-generating

Fig. 1 **A**, **B** Angiosuite immediately before the arrival of the patient. All fixed and essential contact surfaces within the room are covered with clear sterile drapes (**A**, **B**)

Fig. 2 **A–C** Operator wears shoe covers, cap, eyes protection and lead gown (**A**); face shield, repellent overall and gloves are worn above (**B**); operator wears sterile gown and gloves immediately before to start procedure (**C**)

procedures usually performed in an angiographic suite may include biopsy, fine needle aspiration, insertion of naso-gastric or naso-jejunal feeding tubes, percutaneous gastrostomy, esophageal, gastric or duodenal dilatation and/or stenting, tracheal dilatation and/or stenting, and bronchial artery embolization (for the risk of heavy bouts of coughing due to hemoptysis) [5]. For thoracentesis or paracentesis sample preparations, transfer should be avoided, or if absolutely necessary, be performed with needle tip below fluid surfaces to minimize aerosolization. When carrying out these procedures on Covid-19 patients, the WHO recommends N95 or FFP2 standard masks or equivalent, and gowns, gloves, eye protection, aprons and shoe covers [4, 6]. N95 masks are equivalent to PPE masks, designed to achieve a very close facial fit and protect the wearer from airborne particles; they are tested to block at least 95% of very small (0.3 μ) test particles. FFP2 masks have a minimum of 94% filtration of particles (0.4 μ) percentage (Fig. 3).

Fig. 3 FFP2 mask

According to the internal guidelines of our hospital, all staff members and every person operating in the same room as a positive or suspected COVID-19 patient have to wear N95 or FFP2 masks.

Moreover, all non-intubated patients who are either infected, or suspected of infection, who arrive in the IR service must wear a FFP2 mask, and should undergo patient hand washing prior to arrival. Remember that airway manipulation and intubation may represent special added risk circumstances and that this may of course occur urgently.

Powered air-purifying respirator (PAPR) is a positive pressure respirator system that protects inhalation of harmful substances. It is a battery-driven blower mounted in a helmet, equipped with a mask and eye protection. The blower is equipped with filters depending on the type of hazard present (e.g., chemical, biological, radiological, nuclear agents) [5]. In Singapore in 2003, during severe acute respiratory syndrome (SARS) outbreak, services used HEPA filters with 99.97% filtering efficiency for particles 0.3 μm or larger [5]. PAPR in angiographic suites was used in 2003 for SARS, as well as today for multi-drug resistant tuberculosis and contagious aerosol-generating procedures associated with COVID-19/SARS-CoV-2 infection. However, there are constant updates about COVID-19 and therefore recommendations may change in the immediate future, so attention to WHO and CDC and other global authority websites is recommended [6–9]. Several websites are indicated in Table 1.

These measures may add to the complexity and duration of a procedure. Fortunately, this is only in the initial period, as most individuals have been able to adapt and improve with time, as well as to develop practice and familiarity. Sterility should not be compromised as a result of donning and removing PPE. Practice minimizes self-contaminations during doffing, as well as sterility breakdowns. Electronic training is also beneficial for safe doffing, especially where glove doffing may easily self-contaminate staff.

In many cases, during IR procedures it is a common practice for staff to leave the suite and stay in the control room during image acquisitions to limit radiation exposure. On balance, we believe it is advisable for staff to stay inside the angiosuite protected by lead shields to avoid cross-contamination of less adequately protected staff outside the suite or in the control room. The doors of the positive pressure interventional suite must be closed during the entire procedure to prevent contamination. To minimize the in and out movement from the potentially contaminated room, the staff must remain close to the angiographic table with PPE and sterile equipment. A radiographer, with full PPE but non-sterile, could help control the angiographic table and any additional equipment. One or two more staff members, a radiographer and/or a nurse, may be stationed outside the angiographic room to help and assist the staff in the room (communication should be done by microphone, if available), without room to room travel.

Post-procedural

Although IR conditions do not recapitulate clinical, environmental, nor human-to-human transmission modes of coronavirus, a very recent report studied aerosolized virus in the experimental setting [3]. The virus remains viable for days on surfaces, and although fomite transmission is plausible, there is no definitive consensus at the moment. Viable virus was detected in a lab setting in the air 3 h post-aerosolization and up to 6 h later on copper, 24 h on cardboard, and 2–3 days on stainless steel or plastic such as polypropylene. Aerosol virus half-life was 2.7 h, while the half-life on steel was 13 h and 16 h on plastic. This information may have profound implications for room decontamination between IR procedures, surgery, or even imaging, but it remains unclear how this might specifically translate into decontamination practices or standard operating procedures [3]. In the present document, we can only refer to precautions adopted in IR services in the affected areas.

At the end of the procedure, the staff leaves the procedure room. Healthcare workers (IR, radiographer and nurse) are required to remove the PPE using the adjacent

Table 1 WHO, CDC and other global authority recommendations

	Recommendations
1	https://www.cdc.gov/coronavirus/2019-ncov/hcp/checklist-n95-strategy.html
2	https://www.cdc.gov/coronavirus/2019-nCoV/hcp/index.html
3	https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html
4	https://www.nih.gov/health-information/coronavirus
5	https://www.who.int/emergencies/diseases/novel-coronavirus-2019
6	https://www.asahq.org/in-the-spotlight/coronavirus-covid-19-information
7	https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-infection-prevention-and-control-healthcare-settings-march-2020.pdf
8	https://www.rsna.org/covid-19
9	https://www.who.int/emergencies/diseases/novel-coronavirus-2019
10	https://www.cdc.gov/coronavirus/2019-nCoV/
11	https://www.ecdc.europa.eu/en/publications-data/guidance-wearing-and-removing-personal-protective-equipment-healthcare-settings
12	https://www.nih.gov/health-information/coronavirus

small room, in order to avoid contamination of themselves or their colleagues (Fig. 4).

Used PPE must be collected in dedicated disposal bags. Access to the workstations in the reporting area and the writing of the post-procedure report by the IR are only allowed after removal of the PPE and proper hand washing. Strict personal discipline is needed.

Correct cleaning of the imaging equipment and the proper disposal of instruments and supplies must be ensured. Non-disposable instruments must be put in antiseptic solution before sterilization. Staff cleaning the room are required to have medical masks, gowns, heavy duty gloves, eye protection (if risk of splash from organic material or chemicals), and boots or closed work shoes [4]. Room cleaning should be delayed, if the patient fluctuation volumes allow, to allow time for air exchange. An ideal time delay may be set for room cleaning between patients, but depends on local, national, and/or global guidelines.

See Ventilation section for guidance, and consult with and follow local epidemiology guidelines and policies. Some centers will delay one hour before allowing cleaning staff to even enter the room, and cleaning staff are required to wear masks. Exposed surfaces in the angiosuite, including monitors, keyboards and console panels, must be cleaned with 70% ethanol or chlorhexidine-ethanol wipes. Floors must be cleaned with disinfectant (1:40 diluted bleach, sodium hypochlorite 1/1000 ppm). Taking down the sterile drapes and wiping down surfaces takes approximately 30 min. Immediately after, the room needs to be ventilated for a specific amount of time (consult with local standard operating procedures for time, but typically is at least 30–60 min). Waiting another 30 min with a closed door may be recommended before the next patient can access the room. Vacuuming floors is contraindicated, in order to reduce risk of aerosolization of potentially infectious material. Room turn-over takes about 90 min.

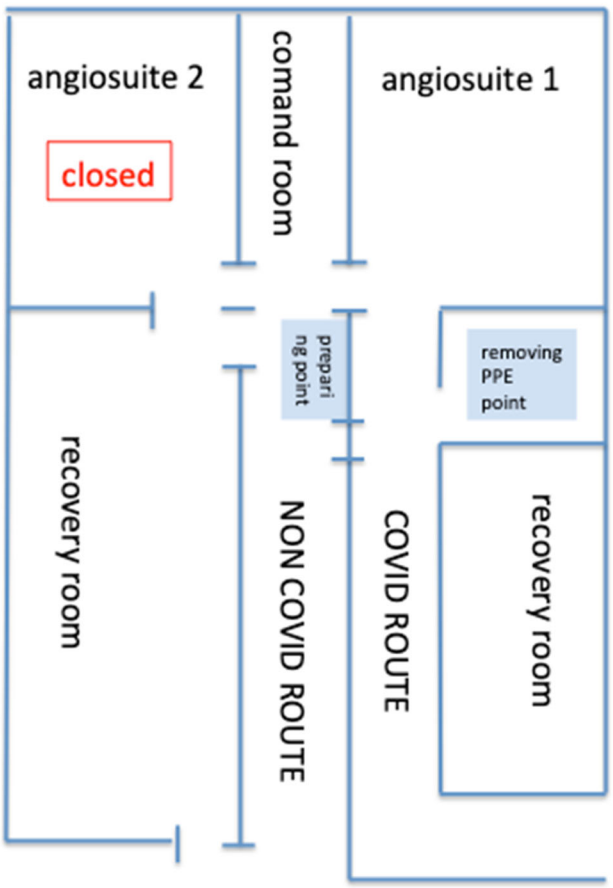

Fig. 4 Schematic representation of the 2 different routes (COVID-19 and no- COVID-19) in our IR service

Bedside Procedures

Ultrasound-guided interventions should be performed at the patient's bedside in their negative flow isolation room to minimize movement of infected patients, and the associated risk of nosocomial transmission of infection. Therefore, ultrasound (US) should become the modality of choice for image guidance in an increasing number of interventions. The US machine must be completely protected with clear transparent plastic before it enters the patient's room. The procedure can be normally carried out after covering the transducer with a sterile probe cover. Sterile probe cover should be carefully placed, with attention to reduction of contamination risk, or 2 probe covers may be used. Strict attention to probe cover removal is required post-procedure (with full PPE and eye protection) to avoid contamination. At the end of the procedure, the plastic covers must be removed and thrown away before leaving the room, with strict decontamination. All equipment must be cleaned with chlorhexidine-ethanol wipes, including the wheels of the ultrasound equipment. Dedicated ultrasound equipment should be marked and sequestered for contaminated use and decontamination cycles.

Conclusion

The control measures described are important to minimize intra-institutional spread of SARS-CoV-2 and COVID-19, and should not be underestimated, nor taken as set in stone. Guidelines will evolve and will have local variations. Consult frequently with your local hospital policies, infectious diseases, and epidemiology services. Call them when in doubt. Pre-, intra- and post-procedural approaches for IR workflow have been described in the setting of an IR unit highly exposed to COVID-19 (Table 2). In our department until now, no incidents between non-infected

Table 2 Summary of recommendations

	Recommendations
1	Different routes for Covid-19 patients and non-Covid-19 patients. In IR services not equipped with physically separate facilities, temporal segregation of services to different groups of patients needs to be explored
2	Every patient and healthcare worker, has been underwent to rRT-PCR test. Uncertain cases should be managed as infected in both case
3	Non-urgent procedures must be postponed
4	Ultrasound-guided interventions should be performed at the patient's bedside
5	Non-essential and mobile equipment should be moved out of the angiographic suite. Fixed and essential contact surfaces need to be covered with clear drapes
6	Careful hand hygiene, correct wearing of protective equipment, N95 or FFP2 masks and gowns, gloves, eye protection, aprons and shoe covers, are recommended
7	Reduce at minimum secretaries, office workers and employers in the administrative areas of the IR service to limit their exposition is strongly suggested
8	Likewise, interventional radiologists rotations (possibly per week) are necessary to limit their exposition
9	Locations where the operators should dress and undress are separate
10	All non-intubated patients who arrive in the IR service must wear a FFP2 mask
11	Used PPE must be collected in dedicated disposal bags
12	70% ethanol or chlorhexidine-ethanol must be used to clean up all exposed surfaces. Immediately after, the room needs to be ventilated for at least 30 min. Waiting 30 min with door closed is recommended before the next patient can access

and infected patients have been documented, and there has been no evidence of COVID-19 infection of healthcare workers in the IR service to our knowledge. Strict adoption of safe practices may increase the cost of equipment and procedural time and unavoidably create new technical difficulties during procedures. On the other hand, the daily catastrophic assault of the spread of COVID-19 on the global healthcare systems necessitates aggressive preemptive measures by all disciplines of medicine to do our part to combat this dangerous pandemic.

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Compliance with Ethical Standards

Conflict of interest Authors declare that they have no conflict of interest.

Ethical Approval All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent Not applicable.

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