

## Coronavirus (COVID-19) Pandemic: What the Nuclear Medicine Departments Should Know

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## **Introduction**

The new coronavirus (COVID-19-coronavirus 2019-nCoV-/SARS-CoV-2) pneumonia was first reported in Wuhan, China, in December 2019, and it was extracted from the lower respiratory tract samples of humans (1). The World Health Organization officially announced COVID-19 viral disease as pandemic on 11th March 2020 (2).

The COVID-19 virus is spreading rapidly despite precautions. The most common symptoms include severe pneumonia (fever, dry cough, dyspnoea), and fatigue (1). Sore throat, headache, loss of taste and smell, rhinorrhoea, and diarrhoea can occur uncommonly (1). Lymphopenia is commonly seen in patients with COVID-19 (3,4). The mean incubation is reported to be 5.2 days, and transmission can occur during the incubation period in asymptomatic patients (5). COVID-19 is reported to be transmitted via respiratory droplets and fomites during unprotected close contact with an infected individual (6,7).

The COVID-19 viral infection spread is reported from 212 countries and regions (2). Throughout history, humans have encountered several epidemics and pandemics, and several of them have changed the course of history. Pandemics increase morbidity and mortality and cause significant economic, political, and social disruptions in a negative way (8).

The aim globally is to encourage social (physical) distancing to slow the disease transmission and to avoid increased strain on the local health care systems. The significant health care challenges would be in the production, supply, and availability of equipment for caring patients and staff during this pandemic. A coordinated response and responsibility should be emphasized and implemented on time to maintain public health

awareness and information, reduction of transmission, and care for and treatment of the patients with COVID-19 (2). Despite this, significant gaps, misunderstandings, and challenges exist in fighting global pandemic preparedness. To compound this further, the guidance and recommendations are rapidly changing, as new evidence emerges and evolves. Local policy should be adopted in consensus with national and international recommendations. People must follow the local government or department of health recommendations and restrictions.

Hospitals and departments should have the standard operating procedure (SOP) in place for staff imaging patients suspected or confirmed with COVID-19 infection and systems in place to ensure these are regularly updated. This article is based on the currently available literature, and the purpose is to discuss and review precautions and safety measures for nuclear medicine department staff to manage patients with known or suspected COVID-19 disease. The situation is changing rapidly, and there is every chance that discussion from this article will change over the coming days and weeks. Secondly, the responsibility lies with each institution or hospital to ensure their written policy adheres to that outlined by National Public Health Guidance in their respective countries.

## **Coronavirus**

COVID-19 is an abbreviation for coronavirus disease-2019 and is a novel beta coronavirus (1). Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) is the name that has been given to the 2019 novel coronavirus with COVID-19 being the name of the disease (2). Coronavirus belongs to the family of coronaviridae family and is an

enveloped positive-strand RNA virus (1,9). Coronaviruses are named for the crown-like spikes on their surface (9, 10). The most likely origin of COVID-19 is zoonotic, given it has a genome identity of 96% to a bat SARS-like coronavirus (6,11). COVID-19 virus has been detected in respiratory, faecal, and blood specimens of infected patients (6,11). COVID-19 virus is reported to remain viable as an aerosol for up to 3 hours (12). There are reports that SARS-CoV-2 transmission can occur via ocular surfaces as infected droplets and bodily fluids might contaminate the human conjunctival epithelium (13). COVID-19 virus was reported to be found in upper respiratory samples, 1–2 days before the onset of symptoms (14) and is thought to be mainly spread via asymptomatic carriers (5,15,16).

### **Nuclear Medicine: Staff and patient**

World Health Organization (WHO) recommends respiratory protection with the use of a standard medical mask (17,18). In terms of personal protective equipment (PPE) WHO recommends contact and droplet precautions which include: wearing disposable gloves to protect hands; clean, non-sterile, long-sleeve gown to protect clothes from contamination; medical masks to protect nose and mouth; and eye protection (e.g., goggles, face shield), before entering the room of a suspected or confirmed COVID-19 patient (17,18) Respirators (e.g. N95) are recommended for aerosol generating procedures(17). With the increasing cases and shortage of testing kits for COVID-19, there should be greater emphasis on infection control and social distancing measures for both public and staff members in the healthcare environment. Effective and efficient use of both staff and equipment in nuclear medicine departments is crucial for patient care

and workplace safety. There are numerous measures reported from several national and international bodies, which could be implemented nationally and regionally (2,17,18,19). However, the policies and their implementation will vary from region to region. Departments should be aware of their national or local hospital policies and follow them accordingly. There are numerous articles related to radiology procedures, but there is limited advice and information related to nuclear medicine service. Compared to conventional imaging, the requirements and logistics for the nuclear medicine departments are relatively complex, such as scheduling appointments, patient contact, regulatory compliance, prioritizing procedures, duration of the scans, and infection controls are similar (20-25) (Table 1). Our top priorities should be (a) ensuring personal wellness of our staff and (b) provide sufficient training and staff cover to manage patients with suspected or confirmed COVID-19 infection.

The team should be made aware of the fact that there are asymptomatic carriers of the virus, and good contact history is of use. We should also ensure, the patients have access to alcohol gel, hand washing facilities, tissue boxes, and masks in the waiting areas. Nuclear medicine reception staff should self-protect and be vigilant at all times and encourage the patient to self-declare if they or any family members have any symptoms or have recently travelled from places affected with COVID-19 infection. The staff should ask specific and direct questions such as a history of fever, dry cough, dyspnoea, and fatigue. Patients should be encouraged to follow basic hygiene practices (26). The patient waiting area should be large enough so patients can maintain distance while

seated or schedule the patient appointments accordingly to avoid too many patients using the waiting area at a given time.

In general, the nuclear medicine staff, which includes technologists, nurses, and healthcare assistants, are at the risk of exposure to COVID-19. Nuclear medicine procedures require radiotracer injection, unlike radiological procedures, and staff contact is essential. In the majority of cases, nuclear medicine procedures are outpatient-based, and in limited circumstances are in-patient based. In-patients will be a combination of oncology and non-oncology patients. There is a probability that patients with COVID-19 infection may be asymptomatic at the time of attending the department for the scans. Furthermore, not all in-patients may be tested for COVID-19 before they are sent to the department for scans. These scenarios pose a risk for all staff from reception to the scanning room. In general, most nuclear medicine scanners are not portable types of machinery like the x-ray or ultrasound, and therefore, patients attending the department for scans is inevitable. Consequently, we should have a stringent mechanism in place to protect our staff and patients, and contingency plan for the temporary absence of staff from illness and quarantine which might affect regular work in the department.

In the current circumstances, most departments based in hospitals which are COVID-19 hubs are postponing routine elective scans, while continuing to provide urgent nuclear medicine scans (e.g. PET-CT scans for oncology patients) [Table 2-4]. Given widespread transmission and increased risk of asymptomatic patients, staff should use personal protective equipment according to the local policy. The PPE items must be donned before entering the patient area and the donning and doffing procedure should

be performed correctly. In general, the team should minimize the number of staff in each clinical encounter to reduce unnecessary movement in and out of injection or scanning rooms, and PPE should be worn while escorting the patients.

Airborne transmission of COVID-19 continues to be debated. There is an ongoing dilemma of whether or not to do ventilation and perfusion scans (VQ scans). It is reported that airborne viruses can spread in air conditioning and ventilation systems. Medical procedures associated with the generation of aerosols, such as ventilation scans and oxygen supplementation, might carry an increased risk of transmission. Therefore, some have suggested stopping VQ scan service due to an aerosol-based ventilation scan. Secondly, the use of perfusion only scans are unlikely to be of any benefit if COVID-19 infection is suspected (COVID-19 response might alter the MAA distribution) (20).

Others have proposed several alternatives, such as (a) performing only perfusion imaging (e.g. pregnant patients) or (b) Perfusion SPECT or SPECT-CT. Overall, it depends on the local conditions, and decisions should be made based on national or regional policies (22), and special precautions, especially for personnel conducting these tests must be taken. A chest x-ray should be mandatory before performing a VQ scan. The current reports suggest asymptomatic COVID-19 carriers may have positive chest X-rays after 14 days of quarantine, even with no RT-PCR (Reverse Transcription Polymerase Chain Reaction) testing for COVID-19 (27). The Chest x-ray findings in COVID-19 patients are reported to frequently show bilateral lower zone consolidation (peaked at 10-12 days from symptom onset) (28).

### **Nuclear Medicine: Radionuclide therapies**

Nuclear Medicine departments perform various radionuclide therapies for both benign and malignant disease. The hospital and department providing these services should have a practical and realistic solution. The multidisciplinary team must make a pivotal decision. The radionuclide therapy service depends on multiple factors such as (a) out-patient or in-patient treatments, (b) availability of beds for in-patient based treatments (c) regular supply/delivery of radiopharmaceuticals, (d) risk of a patient contracting COVID-19 during the hospital stay, (e) staff skill mix (in case therapy staff is infected with the virus), (f) robust selection criteria, and (g) treating elderly cancer patients with co-morbidities. Finally, when patients are treated, they should additionally consent for risk of COVID-19 infection during their stay in the hospital, and the need for radionuclide therapy should balance against the risk of contracting COVID-19 disease (Table 4).

### **Nuclear Medicine: Social distancing**

Social isolation or distancing is crucial to prevent transmission from asymptomatic carriers. In the scan reporting rooms, it is suggested that the workstations should be separated at least 6 feet apart (23,24,25). The department should consider providing alternative technological solutions for Nuclear Medicine consultants and residents for distant(remote) or off-site working (e.g., reporting scans, protocolling procedures). Secondly, multidisciplinary meetings or case discussions should be web-based/teleconferencing (23,24,25). Several departments have opted for flexible rota or schedules, e.g., by working in small-teams or with one week on-site and 1-week remote



working. Establishing a group email or social media to keep in touch and communicate effectively is essential.

### **Nuclear Medicine: Imaging equipment**

Local hospitals should have clear policies and procedures in place for nuclear medicine staff imaging suspected or confirmed COVID-19 patients. The department and/or healthcare system SOP should be updated regularly following the evolving evidence. Van Doremalen et al (12) have studied how long the virus survives in the air and on surfaces (plastic, stainless steel, copper, and cardboard). They have confirmed that SARS-CoV-2 remained active on plastic and stainless steel surfaces for 48-72 hours, cardboard for 24 hours, and four hours on copper (12). However, these times will vary under real-world conditions and might depend on the temperature, humidity, ventilation, and the amount of virus deposited (12).

The most important questions related to nuclear medicine include clean imaging techniques and decontamination of imaging equipment (e.g SPECT-CT, PET-CT scanners) in addition to any surface that may have come into contact with respiratory droplets. In general, after the patients are scanned, the scanner and room surface should be disinfected to prevent the potential spread, and appropriate training of environmental maintenance staff is recommended (20) [Figure 1]. Public Health England has published guidance “COVID-19: cleaning in non-health care settings”. The risk of infection depends on several factors such as (a) the type of surfaces contaminated (b) the amount of virus shed from the individual (c) the time the individual spent in the setting and (d) the time since the individual was last in the environment (29). All surfaces that the symptomatic

person might have come into contact with must be cleaned and disinfected (e.g., visible body fluids, imaging equipment, chair, bathrooms, door handles, telephones, grab-rails in corridors and stairwells)

(29). The PPE should be worn for cleaning an area where a person with possible or confirmed COVID-19 attends (29). Public Health England recommends the use of either a combined detergent disinfectant solution at a dilution of 1,000 parts per million available chlorine or if an alternative disinfectant is used within the organization, this should be checked to ensure that it is effective against enveloped viruses (29).

The British Society of Thoracic Imaging (BSTI) has produced action cards to assist with designing local radiology standard operating procedures for patients who have or are at risk of COVID-19 and could apply to nuclear medicine departments (e.g., Transfer of a patient to CT; performing a CT scan etc. (30). However, these are examples only, and responsibility lies with each institution or hospital to ensure their written policy adheres to their National Public Health Guidance in their respective countries.

### **Nuclear Medicine: Radiopharmaceuticals**

The functioning of Nuclear Medicine procedures depends on the availability of radioisotopes and kits. These are not always locally produced, and the Nuclear Medicine centres rely on an external supply from national and international supply and distribution channels. In the current scenario, with land and air traffic lockdowns, a shortage of radioisotopes and kits is expected, and it is difficult to predict when and for how long. For efficient use of kits, block booking of specific procedures should be envisaged. Alternately, PET-CT scans can be used in some indications (e.g., Bone imaging with  $^{18}\text{F}$ -

NaF, Infection imaging with 18F-FDG, etc.) in place of single isotope methods. Myocardial Perfusion Imaging could be performed as a one-day protocol ( stress/rest). The local nuclear medicine departmental managers or radiopharmacists should contact the suppliers and update the local team to plan bookings accordingly. In comparison to SPECT service, the PET centres with local cyclotrons might continue to function as usual in most cases. For departments without cyclotrons, the availability of FDG will depend on local conditions.

### **Nuclear Medicine: Staff well being**

The current scenario might cause psychological distress, social, and financial insecurity. Staff coming to work at the hospital have concerns that they might contract the virus and expose their friends or family members. We should make an effort to provide relevant and reliable information to allay their fears (e.g., social distancing, infection control, self-quarantine, etc.). There should be specific local guidelines for viral testing of staff returning to work after illness. The team should remain connected with each other or with their friends and families via group email or in-portals/social media etc.

### **Nuclear Medicine: Continuing Medical Education (CME) and Continuing Professional Development (CPD)**

Departments who are active in teaching and training could use on-line teaching material and webinars, which are available from most national and international nuclear medicine societies, which could be an alternative to face to face interaction and learning. National organizations should make some of their on-line education material available free for its

members. Research work will be challenging during the current circumstances (except research related to COVID-19 infection) as most institutions have suspended their projects, and alternative ways of collaborating should be envisaged to prevent disruption of vital projects (23,25).

### **Nuclear Medicine: Chest imaging findings in PET-CT & SPECT-CT**

Incidental parenchymal lung abnormalities have been reported in patients with COVID-19, and prompt recognition may be useful for timely isolation and treatment (1) [Fig2-5]. Chest X-ray and CT appearances of COVID-19 are reported to have significant overlap with previous coronavirus infections (31-33).

Chest CT is reported to be an essential component in the diagnostic algorithm for patients with suspected COVID-19 infection (32,33). The reported sensitivity of chest CT in detecting COVID-19 at the initial presentation is 56-98% during the early stages of disease development (34,35), and the specificity was low (25%) (36).

Chest CT is found to have limited sensitivity and negative predictive value early after symptom onset and is unlikely to be used as a reliable independent tool to rule out COVID-19 infection (32).

The initial findings in infected patients from Wuhan have shown bilateral lung opacities. The typical features include lobular and subsegmental areas of consolidation (31,32). Other groups have reported high rates of ground-glass opacities and consolidation, and sometimes with a rounded morphology and peripheral lung distribution (31,37). The more extensive disease is reported to be seen on the CT approximately ten days after the onset of symptoms (37).

The frequency of CT findings is related to the infection time course (31,32), and based on the current evidence, there are ground-glass abnormalities in the early disease phase, followed by crazy paving and increasing consolidation later in the disease course (32,37). Multifocal involvement is reported to be common, and the CT signs gradually improve approximately 14 days of post-symptom onset (31,32,36,37).

The hallmark of COVID-19 infection on CT is ground-glass and consolidation/ pulmonary opacities (often with a bilateral and peripheral lung distribution) (31,32). Bernheim A et al. have reported the absence of ancillary CT findings such as pleural effusions, lung cavitation, pulmonary nodules, and lymphadenopathy (31,32). Bai HX et al. have assessed the performance of the United States (U.S.) and Chinese radiologists in differentiating COVID-19 from viral pneumonia on chest CT and found high specificity but moderate sensitivity (38). The British Society of Thoracic Imaging has published a reporting guidance and proforma, which might help to report them with speed and accuracy (39) and have published a teaching library. Its content will be accessible without log-on via the BSTI website (39). COVID-19 suspected pneumonia is FDG-avid and might be detected as an incidental finding in asymptomatic patients undergoing PET-CT (40). Nuclear Medicine community should be vigilant to look for other unexpected scan findings which might reflect the effects of COVID-19 exposure/infection.

## **Conclusion**

COVID-19 infection has changed the way we work. We should stay informed and support each other and provide practical solutions for safety and social wellbeing during these uncertain times. We should adhere to our National and International recommendations.

The healthcare system and professionals must aim to deliver safe patient care, workplace safety, and personal wellness. *“Life imposes things on you that you can’t control, but you still have the choice of how you’re going to live through this.”* — **Celine Dion**

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**Conflict of Interest:** All authors declare no conflict of interest

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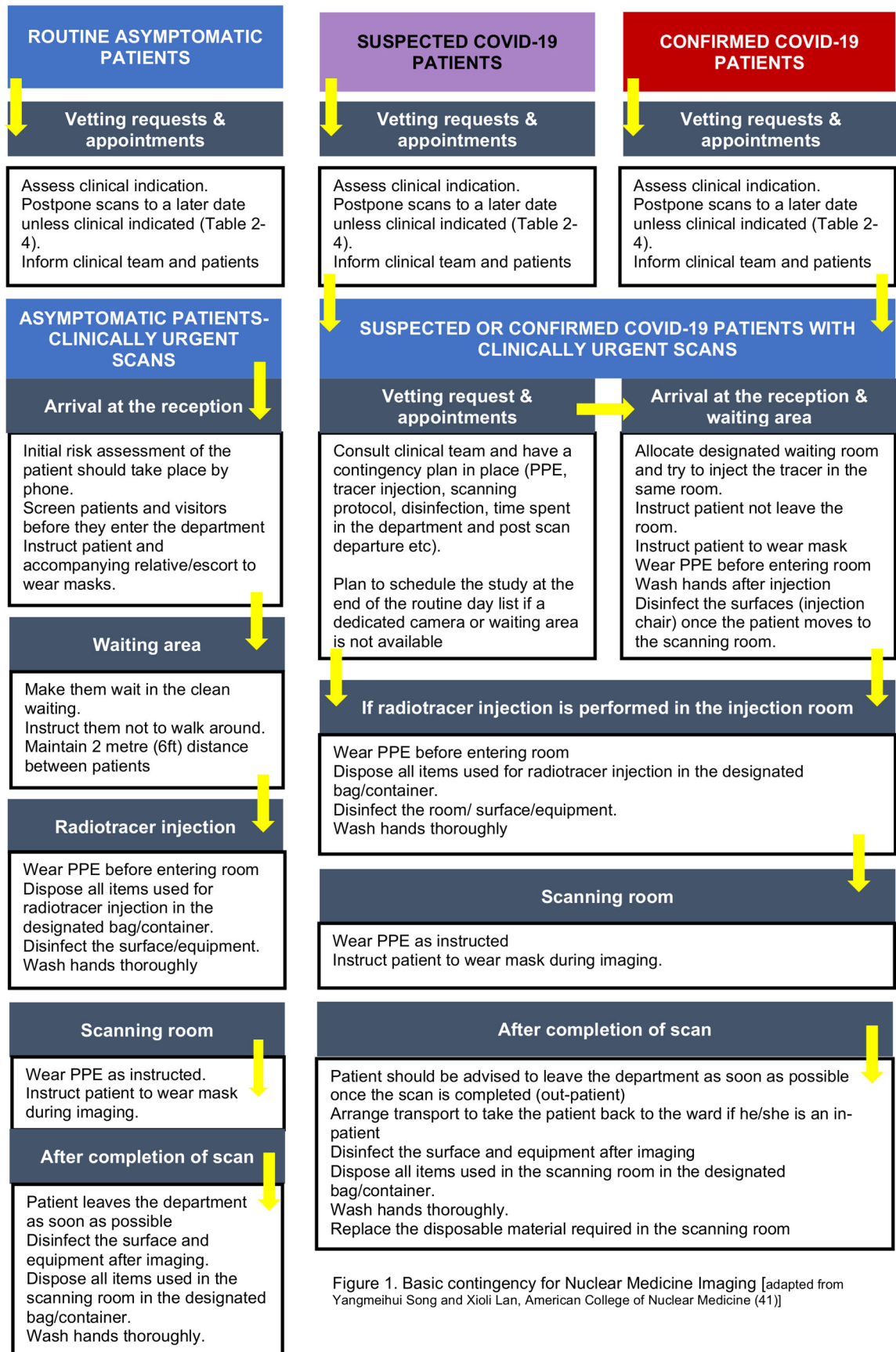


Figure 1. Basic contingency for Nuclear Medicine Imaging [adapted from Yangmeihui Song and Xioli Lan, American College of Nuclear Medicine (41)]

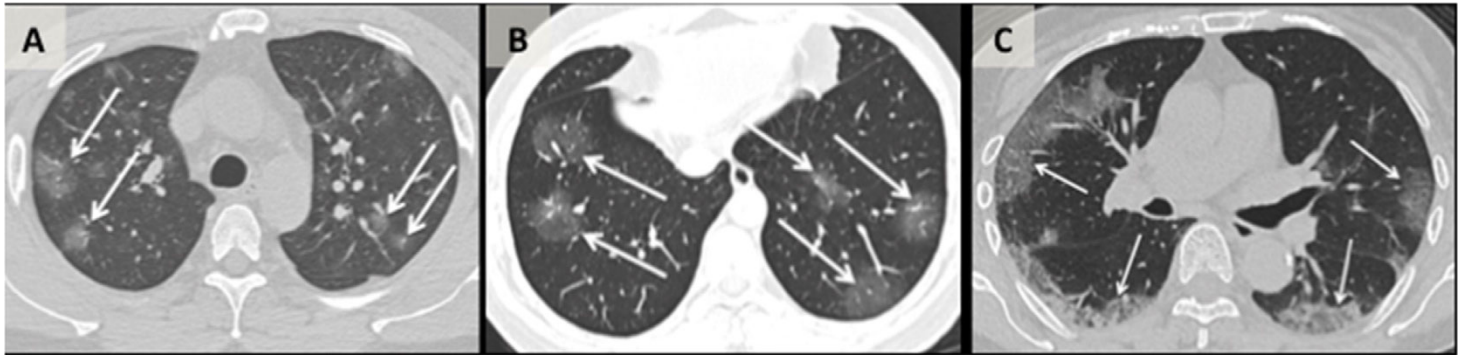


Figure 2: An axial CT image obtained without intravenous contrast in a 36-year-old male (Panel A) shows bilateral ground-glass opacities in the upper lobes with a rounded morphology (arrows). An axial CT image obtained in a 44-year-old male (Panel B) shows larger ground glass opacities in the bilateral lower lobes with a rounded morphology (arrows). An axial CT image obtained in a 65-year-old female (Panel C) shows bilateral ground-glass and consolidative opacities with a striking peripheral distribution[32]. Reproduced with Permission: Bernheim A, Mei Xueyan, Huang M et al Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection. Radiology. doi:10.1148/radiol.2020200463. Published online February 2020.© Radiological society of North America.

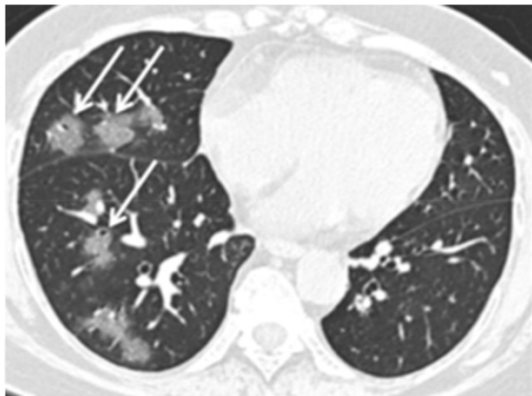


Figure 2: An axial CT image obtained without intravenous contrast in a 56-year-old female shows ground-glass opacities with a rounded morphology (arrows) in the right middle and lower lobes. The left lung was normal [32]. Reproduced with Permission: Bernheim A, Mei Xueyan, Huang M et al Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection. Radiology. doi:10.1148/radiol.2020200463. Published online February 2020.© Radiological society of North America.

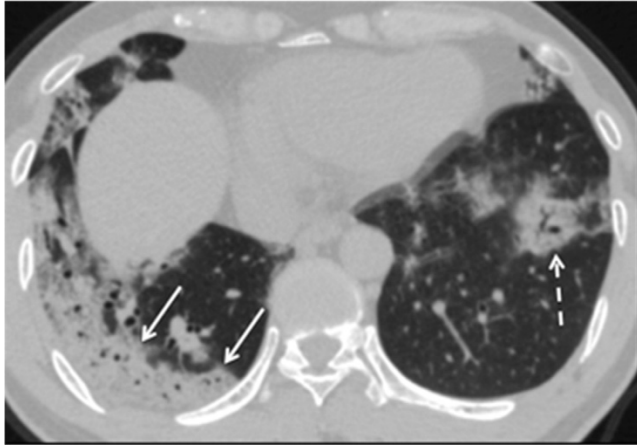


Figure 4: An axial CT image obtained without intravenous contrast in a 42-year-old male in the “late” time group (10 days from symptom onset to this CT) shows bilateral consolidative opacities, with a striking peripheral distribution in the right lower lobe (solid arrows), and with a rounded morphology in the left lower lobe (dashed arrow)[32]. Reproduced with Permission: Bernheim A, Mei Xueyan, Huang M et al Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection. Radiology. doi:10.1148/radiol.2020200463. Published online February 2020.© Radiological society of North America.

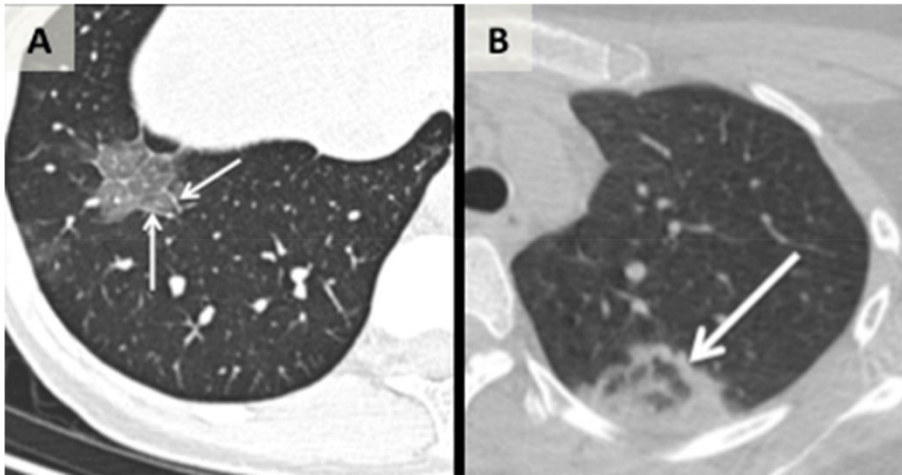


Figure 5: An axial CT image obtained without intravenous contrast in a 43 year old female (Panel A) shows a “crazy-paving” pattern as manifested by right lower lobe ground-glass opacification with interlobular septal thickening (arrows) with intralobular lines. An axial CT image obtained in a 22-year old-female (Panel B) shows an area of faint ground-glass opacification in the left upper lobe with a ring of denser consolidation (arrow, “reverse halo” sign)[32]. Reproduced with Permission: Bernheim A, Mei Xueyan, Huang M et al Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection. Radiology. doi:10.1148/radiol.2020200463. Published online February 2020.© Radiological society of North America.

Managing Nuclear Medicine Department	For Nuclear Medicine Staff	For Patients attending Nuclear Medicine centre
<p>Promote and practice social distancing (2 metres or 6 Feet)</p> <p>Risk assessment should be taken at local level with local context taken into consideration (should not replace of reduce the ability to provide optimal patient or staff safety)</p> <p>Coordination and transmission of information between Hospital information control and nuclear medicine departments</p> <p>Write to referring clinicians to clearly mention urgent or non-urgent scans while requesting for a scan</p> <p>Training for all staff members to ensure maximum compliance and vigilance in line with the local guidance</p> <p>Provide clear guidance for staff to deal when patient COVID-19 status is unknown and COVID-19 is circulating at high levels</p> <p>Establish local Policy to Reschedule non-urgent appointments</p> <p>Display posters to promote hand washing and good respiratory hygiene measures within the department</p> <p>Allocate or make provision for separate space for patients with suspected or known COVID-19 infection status.</p> <p>Develop clear escalation pathway to ensure cases are identified in a timely manner and triaged</p> <p>Implement a stringent local hospital policy for screening staff, patients and visitors before they enter the department</p> <p>Implement stringent local hospital policy to Minimize non-essential visitors into the department</p> <p>Provide PPE for staff and patients (due to concern of asymptomatic transmission of COVID-19)</p> <p>Make sure supplies are available and check the stock every day and during the day (centralise storage and distribution)</p> <p>Implement robust policy for cleaning and decontamination of imaging equipment.</p> <p>Explore options and encourage reporting scans from remote sites/home, whenever feasible according to the local policy</p> <p>Encourage use of virtual conference tools for Multidisciplinary meetings</p> <p>Encourage use of virtual conference tools for educational meetings</p> <p>Provide provision for flexible staff schedule rotation (on-site and off-site work, work in small groups)</p> <p>Provide relevant, regular and reliable updates daily</p> <p>Develop a contingency and business continuity plan</p>	<p>Training in infection control</p> <p>Promote and practice Social Distancing (2 metres or 6 feet)</p> <p>Minimize crowding in workplace ( e.g tea or lunch breaks)</p> <p>Maintain 6 feet (2 meters) distance in all patient/staff interactions when possible</p> <p>Should consider need for contact and droplet precautions (based on the nature of task being undertaken)</p> <p>Practice strict hand hygiene which should be extended to exposed forearms, after removing any element of PPE</p> <p>Should have access to the personal protective equipment (PPE)</p> <p>Training on donning and doffing PPE</p> <p>Appropriate PPE should be put on prior to providing care</p> <p>Should know what PPE they should wear for each setting and context</p> <p>Adopt single use policy of gloves and aprons</p> <p>Should take regular breaks and rest periods</p> <p>Staff at all levels should remain connected with each other or with their friends and families via group email or in-portals/social media</p> <p>Nuclear Medicine Physicians or radiologist should be familiar with the CT appearance of COVID-19 infection</p> <p>PET-CT and SPECT-CT scans should be checked for CT changes in the lungs before sending the patient home</p> <p>Be supportive and caring- Nominate a staff to look after staff well-being</p>	<p>Screen patients and visitors before they enter the department</p> <p>Initial risk assessment of the patient where possible should take place by phone</p> <p>Request patients to Inform nuclear medicine department (if patient or family members develop symptoms prior to the scheduled appointment)</p> <p>Display posters to promote hand washing and good respiratory hygiene measures on arrival in the reception area within the department</p> <p>Promote Social Distancing (2 metres or 6 feet)</p> <p>Recommend patient use of fluid-resistant surgical face mask (to minimise the dispersal of respiratory secretions, reduce both direct transmission risk and environmental contamination)</p> <p>Request patients to maintain strict hand hygiene</p> <p>Request patients to minimize accompanying visitors/patient escorts</p> <p>Give them telehealth option (teleclinics to provide reassurance and guidance)</p> <p>Inform and reschedule non-urgent appointments</p> <p>Inform and reschedule elective therapies</p> <p>Patient should spend minimum time in the department (do not allow patients to wait for long periods in the waiting area)</p>

Table 1 Consensus guidance for nuclear medicine departments, staff and patients (6,17, 20-25). *These are examples based on consensus only and responsibility lies with each institution or hospitals to ensure their written policy adheres to that outlined by National Public Health Guidance in their respective countries and hospitals.*

<b>Planar, SPECT &amp; SPECT-CT procedures</b> Referrals must be reviewed by Nuclear Medicine Consultant	<b>Scans to be booked and performed as requested (except patient is at risk of infection)</b>	<b>Liaise with the clinical team to cancel or reschedule (Inform the patient)</b>	<b>Postpone/reschedule (inform the patient and the clinical team)</b>
<b>Skeletal</b>	Bone scan in cancer patients	Severe pain Pre and post procedural orthopaedic indications (? Infection, offer FDG PET-CT as alternate solution)	Pre and post procedure orthopaedic indications  Metabolic bone disease Inflammatory arthropathy
<b>Endocrine</b>		99mTc04 thyroid scans not on antithyroid medications or? ectopic /neonatal hypothyroidism	99mTc04 thyroid scans on antithyroid medications 99mTc-MIBI parathyroid scan for pre-op localisation
<b>Cardiovascular</b>  Avoid exercise nuclear stress testing due to the risk of droplet exposure  Consider using pharmacological stress agents.  Consider one day protocols ( e.g stress/rest)	Myocardial Perfusion scan -Recent acute coronary syndrome ( moderate to high risk patients) for urgent coronary revascularization  New or increasing chest pain Pe-operative assessment (moderate to high risk patients)  MUGA scan- Oncology patients (prior to initiation or prior to subsequent chemotherapy)	Myocardial Perfusion scan-awaiting liver transplant surgery  Stable angina -Follow up evaluation  Cardiac Amyloid DPD scan	123I-MIBG heart scan  Myocardial Perfusion scan-awaiting renal transplant surgery  Cardiac Amyloid DPD scan- Follow up evaluation
<b>Brain</b>			DaTSCAN ( <sup>123</sup> I-FP-CIT or <sup>123</sup> I-β-CIT-FP)
<b>Respiratory</b> <i>The decision to proceed with the VQ should be discussed with the referrer before booking</i>	Lung Perfusion scan in Pregnant patients  Lung shunt study for 90Y-SIRT	VQ scan for Pulmonary Hypertension/chronic PE on treatment	VQ scan? resolution of PE ( patient's on Thromboprophylaxis)
<b>Gastrointestinal</b>	Gastrointestinal (GI) bleed Meckel's scan		Gastric emptying Oesophageal transit scintigraphy Gastro-Oesophageal reflux scintigraphy SeHCAT Small bowel/colonic transit
<b>Hepatobiliary</b>	HIDA scan-Biliary leak	HIDA scan-? acute cholecystitis	Liver/spleen scan HIDA scan -cystic duct syndrome/ sphincter of Oddi dysfunction etc Liver SPECT- Haemangioma 99mTc-Denatured RBC scan
<b>Genitourinary</b>	99mTc-DMSA (radiotherapy to abdomen) or prior renal surgery.  99mTc-MAG3 for urinary leak or transplant rejection  Testicular scan for torsion	MAG3 for? obstruction DMSA scan- Donor assessment	99mTc-MAG3 routine follow up 99mTc-DMSA follow up evaluation Captopril renogram
<b>Infection/inflammation</b>		? sepsis (COVID-19 negative)-suggest FDG PET-CT  ? Infection of prosthesis	
<b>Lymphatic system</b>	Sentinel lymph node injections and imaging		Lymphoscintigram for ? lymphoedema
<b>Oncology</b>	Octreotide/Tektrotyd prior PRRT	Octreotide/Tektrotyd for NET  123I- mIBGPheochromocytoma/paraganglioma	
<b>Miscellaneous</b>	GFR Oncology patients (prior to initiation or prior to subsequent chemotherapy)		Dacrosintigraphy Salivary gland scintigraphy DXA scan

Table 2. Scheduling Nuclear Medicine Procedures (SPECT tracers). *Kindly note:*



*Referrals must be reviewed by Nuclear Medicine Consultants or Multidisciplinary setting). These are examples based on consensus only and responsibility lies with each institution or hospitals to ensure their written policy adheres to that outlined by National Public Health Guidance in their respective countries and hospitals.*

<b>PET-CT</b> Referrals must be reviewed by Nuclear Medicine Consultant	<b>Scans to be booked and performed as requested (except patient is at risk of infection)</b>	<b>Liaise with the clinical team to cancel or reschedule (Inform the patient)</b>
<b>Oncology</b>	18F-FDG PET-CT: Staging; restaging; response assessment etc)  18F-FDG PET-CT: radiotherapy planning  18F-PSMA or 68Ga-PSMA: Biochemical recurrence  18F-Choline: Biochemical recurrence  68Ga-DOTATATE/DOTATOC:staging, restaging and selecting patients for PRRT  18F-NaF:Bone metastases  18F-DOPA:diagnosis and staging	18F-FDG PET-CT: Follow-up evaluation  68Ga-DOTATATE/DOTATOC :follow up evaluation  18F-PSMA or 68Ga-PSMA: follow up evaluation  18F-Choline: follow up evaluation  18F-NaF: follow up evaluation  18F-DOPA:follow up evaluation
<b>Non-oncology</b>	1.18F-FDG PET-CT: pyrexia of unknown origin (COVID-19 negative)  2.18F-FDG PET-CT: Sepsis  3. 18F-FDG PET-CT (viability): symptomatic patients awaiting CABG  4.18F-FDG PET-CT: Suspected device or prosthetic infection  5. 18F-FDG: cardiac sarcoidosis	18F-FDG PET-CT : known Sarcoidosis on treatment  18F-FDG PET-CT: Polymyalgia rheumatica  18F-FDG PET-CT : known cardiac sarcoidosis on treatment (follow up evaluation)

**Table 3: Scheduling Patients for PET-CT studies**

*Kindly note These are examples based on consensus only and responsibility lies with each institution or hospitals to ensure their written policy adheres to that outlined by National Public Health Guidance in their respective countries and hospitals.  
(20-22)*

Referrals must be reviewed by Nuclear Medicine Consultant Each patient needs to be assessed on an individual basis by the clinical team/MDT	Referrals must be reviewed by Nuclear Medicine Consultant Each patient needs to be assessed on an individual basis. [Liaise with the clinical team or MDT to cancel or reschedule (Inform the patient)]
177Lutetium--DOTATATE Peptide Receptor Radionuclide <i>Therapy (PRRT)</i> - Metastatic Neuroendocrine tumours (Consider marrow depletion post procedure)	131I (radioiodine) -thyroid cancer (kindly follow the thyroid cancer management guide for various risk categories)
Selective Internal Yttrium-90 Radioembolization Therapy (90Y- SIRT)-HCC or liver metastases	131I(radioiodine) -benign thyroid disease  Most patients can be postponed (Consideration should be given to patients who are unable to tolerate anti-thyroid medication).
131I-Meta-iodobenzylguanidine( mIBG) therapy- Metastatic Pheochromocytoma/paraganglioma	Radiosynovectomy-arthritis, haemophilia etc
177Lutetium--prostate specific membrane antigen (PSMA)- Metastatic Prostate cancer	
225Actinium-Prostate specific membrane antigen (PSMA)- Metastatic Prostate cancer	
223-Radium- Prostate cancer (skeletal metastases) (Consider co-morbidities )	

**Table 4: Scheduling patients for radionuclide therapy:**

*Kindly note: Referrals must be reviewed by Nuclear Medicine Consultants or Multidisciplinary setting). These are examples based on consensus only and responsibility lies with each institution or hospitals to ensure their written policy adheres to that outlined by National Public Health Guidance in their respective countries and hospitals.*

(20,22)