MJoSHT
Malaysian Journal of Science, Health & Technology
[mjosht.usim.edu.my]

Article

A Policy Examination of Covid-19 Impact on the Radiology Department Standard Operating Procedures (SOPs): The Malaysian Experience

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Article Info
Article history:
Received: 1 November 2023
Accepted: 1 January 2024
Published:5 April 2024
Academic Editor:
Sharifah Najwa Syed Mohamad
Malaysian Journal of Science, Health & Technology
MJoSHT2024, Volume 10, Issue No. 1
eISSN: 2601-0003
https://doi.org/10.33102/mjosht.v10i1.386

***Abstract*— The purpose of this paper is to review the new management policy in medical imaging of the Covid-19 post-pandemic transition. This paper discussed the Standard Operating Procedure (SOP) introduced by the Ministry of Health (MoH) Malaysia to prevent and control intrahospital transmissions of Covid-19. A conceptual framework is proposed to highlight the key areas in the national SOP for preventing Covid-19 intrahospital transmissions in the radiology department. The key areas were classified into four categories: planned requests (patient appointments), (ii) open-access management (walk-in patient workflow and the triage system), (iii) direct contact (during radiology procedures), and (iv) exit policy and disinfection (post imaging conduct). The paper ends with a summary of diagnostic imaging classifications based on chest radiographs (CXR) and Computed Tomography (CT) images of suspected and confirmed Covid-19 patients. The Covid-19 SOP for the radiology department by the MoH was found to retain most of the patient quarantine and isolation guidelines by the Centre for Disease Control and Prevention (CDC) and incorporated several international policies on patient triage and disinfection of radiological equipment. The majority of the SOP is also sustained, like the SOP during the pandemic, except for the SOP that has been proven to be insignificant by recent research. The Covid-19 SOP for the radiology department plays an important role in reducing the intrahospital spread of Covid-19, with some areas needing improvement. Health workers in the radiology department should continue implementing the Covid-19 SOP and increase their knowledge in identifying Covid-19 signs on radiographic images to help safeguard themselves and the patients from intrahospital transmissions.**

***Keywords*— medical imaging, radiology workforce, standard operating procedure, Covid-19 policy**

I. INTRODUCTION

In late 2019, a coronavirus disease (Covid-19) was detected in Wuhan, China, causing a cluster of pneumonia. The World Health Organization (WHO) then proclaimed Covid-19 as a Public Health Emergency of International Concern on January 30, 2020, and a worldwide pandemic on March 11, 2020. The first cases of Covid-19 in Malaysia were detected in travelers from China who came from Singapore earlier on January 25, 2020. Initially, the number of reported Covid-19 cases in Malaysia remained less than 30 and was limited to imported cases. However, a significant increase in localized clusters happened in March 2020 due to a mass religious gathering held in Sri Petaling, Kuala Lumpur. The mass gathering involved participants who returned from countries reporting high Covid-

19 cases and later spread the infection in the community [1]. There were times when Malaysia managed to lower the recorded cases to single- and double-digit numbers from July to September 2020, arguably by implementing a nationwide Movement Control Order (MCO). By October 2020, Malaysia entered the third wave of the pandemic, with the number of confirmed cases having increased by about 381% in two months. Since then, cases have grown to five digits by September 2021 [2]. However, a year after that, the total number of cases showed a significant decrease in the number of Covid-19 cases [3], resulting from the government's effectiveness of the Standard Operation Procedures (SOP).

Chest radiography (CXR) and Computed Tomography (CT) examinations, coupled with blood biomarkers and the patient's clinical history, play a vital role in early identification of Covid-19 due to their capacity to identify lung abnormalities. Thus, the radiology department is one of the key hospital departments handling suspected and confirmed Covid-19 patients. It was reported that about 30% of healthcare workers were infected by Covid-19 from direct contact with patients. The Radiology Workforce (RWF) routinely performs physical contact with suspected Covid-19 patients, for example, to [2] place the patients in the correct position for radiology examinations. Hence, the RWF had to strictly follow the SOP to reduce the possibility of being infected by the deadly virus. However, the RWF has a high probability of being infected by the Covid-19 virus, which has a high mortality rate and causes psychological and mental trauma to both public and medical personnel [4][5].

Even though the radiology workforce in Malaysia has experienced several epidemics such as the Nipah and SARS virus before [2] and has been trained in infection control, the challenges brought by Covid-19 are unprecedented and unique. The objectives of Covid-19 preventive actions are to stop or reduce its transmission and delay its spread. Additionally, the Covid-19 SOP was implemented to provide optimal care for all patients, particularly the critically ill, to reduce the impact on health systems, social services, and economic activity [6]. Thus, Malaysia's success in reducing Covid-19 cases has been successful in making this nation from the pandemic phase to enter the "Transition to Endemic" phase of Covid-19 on 1 April 2022 [7]. This transitional stage will allow the community to learn to adjust and live with public health measures that are least disruptive to daily life before Malaysia completely enters the endemic phase. As the virus spreads, we are moving away from relying on governmental interventions, such as stringent SOPs and laws, toward individual accountability and communal cooperation. Therefore, this paper aims to review the current literature on managing radiology procedures for post-pandemic Covid-19 in Malaysia, as well as the diagnosis and prognosis of Covid-19. Its objectives include i) to discuss the planned request for radiology examinations, including how the appointment for radiology examination should be scheduled during the process towards the endemic and the open-access management for walk-in patients, ii) summarise the new MoH SOP, guidelines and policies for the radiology department during Covid-19, iii) outline the post-imaging conduct and iv) present the imaging findings on Covid-19 signs and patient prognosis.

II. CONCEPTUAL FRAMEWORK

Experiences of the RWF in other countries on managing the risk of intrahospital Covid-19 infections have been documented in the literature. However, to the best of our knowledge, literature that utilizes a conceptual framework to outline newly developed guidelines, SOPs, and policies on post-pandemic Covid-19 for the radiology department remains scant. We propose a conceptual framework adapted from a draft for the Emergency Department [8] to highlight four key areas for preventing and controlling Covid-19 intrahospital transmissions in the radiology department. The four key areas, as shown in Fig. 1, are (i) planned request (patient appointments), (ii) open-access management (walk-in patient workflow and the triage system), (iii) direct contact (the radiology procedures), and (iv) exit policy and disinfection (post imaging conduct).

The RWF plays an essential role in keeping things running smoothly in a radiology department. They must be trained in infection prevention and control methods against Covid-19 following SOP to avoid intrahospital transmission of Covid-19 among health workers. Poor adherence to the SOP could result in high incidences of Covid-19 infections in the RWF. If left unmanaged, it could result in reduced radiological services due to many RWFs taking sick leave. Hence, reorganization of the radiological services based on updated SOP is imperative as the radiology department plays a vital role in treating Covid-19 patients, particularly in monitoring lung conditions.

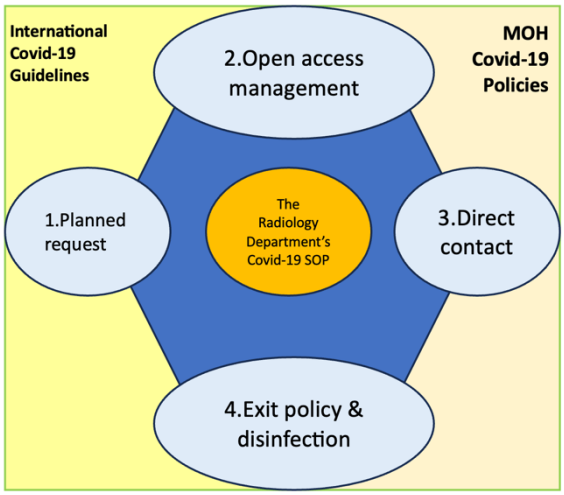

Fig. 1: Conceptual framework on the key areas in the Covid-19 SOP for the Radiology Department

A. Planned Requests - Patient Appointments

The Ministry of Health Malaysia (MoH) has established an SOP on performing radiological examinations to restrict the spread of Covid-19 [8], per the Center for Disease Control and Prevention (CDC) recommendations. We identified that the first key area in the MoH SOP was the reorganization of planned requests, specifically how patient appointments in the radiology department were set up. All medical imaging examinations related to Covid-19, such as chest X-rays (CXR) and CT scans, must be requested on paper or using the online appointment system well in advance, as the procedure during the Covid-19 pandemic. The ward staff in charge of the suspected or confirmed Covid-19 patient will notify the request made by the RWF, who will schedule the examination accordingly. The MoH Covid-19 SOP were found to retain CDC guidelines on planned requests. It was reported that the

radiology departments in Malaysia implemented this SOP at the beginning of the pandemic by deferring non-urgent radiology cases to limit the risk of intrahospital infections among RWF and patients. As a rule, non-urgent CT scans would be scheduled by the RWF for later in the day, usually after the elective list has been completed [8]. Scheduling urgent requests for CXR and CT chest has helped the RWF plan for the safe use of human resources and examination rooms in managing suspected and confirmed Covid-19 patients. Furthermore, by prioritizing urgent cases and rescheduling non-urgent cases to later, large gatherings in the radiology department could be avoided even though the 2-meter physical distancing is no longer compulsory between individuals in the department during the post-pandemic [6].

According to the MoH SOP, urgent cases involving patients of unknown Covid-19 status will be treated as Covid-19 positive, while semi-urgent cases have to undergo a reverse transcription-polymerase chain reaction (RT-PCR) Covid-19 swab test before a radiology examination could be conducted. The SOP also emphasized that CT scans should only be conducted in circumstances such as to assist in clinical decisions for critically ill patients or to follow up on illness progression. Next, to avoid unnecessary close contact or interaction with patients, the CT scans for confirmed or suspected Covid-19 cases were scheduled after normal working hours [6]. This SOP on planned requests, which were also implemented by institutions such as the University of Washington, was based on the top priorities of the radiology department to prevent Covid-19 exposure among the RWF and its patients. Based on the SOP, non-urgent patients who developed respiratory symptoms suspicious of Covid-19 on the day of the radiology examination will have their imaging examination cancelled for the day and were asked to follow up with their doctors. Those who are confirmed for Covid-19 have their non-urgent radiology examinations postponed until they recover from the illness and are no longer contagious.

CT scan is confined to circumstances that will impact patient management. Most often, CT scans are considered when an alternate diagnosis is ruled out, or acute symptoms become worse. Even though CT scans have a sensitivity and specificity of 60-70% for Covid-19, the current workflow does not commonly require its use due to the greater accuracy and rapidity of the RT-PCR swab test in detecting Covid-19. Even when the symptoms of Covid-19 worsen, performing a CT scan on the patient will not improve the outcome of the treatment plan as oxygen supply through ventilators and other supportive care takes much precedence [9]. Instead, the Canadian Association of Radiologists (CAR) and the Canadian Society of Thoracic Radiology (CSTR) proposed that CXR be used on individuals who have severe symptoms and deterioration in their respiratory condition. The results could positively affect the treatment management plan [10]. In fact, medical imaging is not suggested for suspected Covid-19 patients with mild symptoms, according to the Fleischner Society, a multinational consortium of lung imaging experts, radiologists, and pulmonologists [11]. Nonetheless, the SOP by MoH stated that attending doctors still have the final say on whether or not to request CXR and CT chest scans based on the patient's clinical status and disease stage.

B. Open Access Management - Workflow for Walk-In Patients

The second key area in the MoH SOP is the implementation of open access management, which refers to the workflow of walk-in patients. The MoH has adopted a triage system for walk-in patients at the entrance of its facilities. According to its Covid-19 SOP, all walk-in patients will have their body temperature checked and assessed for Covid-19 symptoms such as fever, cough and respiratory problems. Those whose body temperature exceeds 37.5°C would not be allowed access to the hospitals or clinics. However, moving forward to the endemic era, the recent MoH SOP requires temperature checks, and MySejahtera check-in was abolished when entering public places or premises [12]. This action is supported by research that found out how using temperature checks as a COVID-19 screening tool is ineffective as it only gives little benefit in diagnosing infected persons [13]. In the past SOP, hospitals and clinics were required to limit the number of entrances to limit the number of patients and prevent visitors from entering their premises. However, in the new SOP, there are no more limitations on the patients arriving. There are only new policies for caregivers and visitors at government hospitals to take effect [14]. Non-Covid patients are only permitted to have one carer with them in the emergency and outpatient departments. Before visiting healthcare institutions, carers are urged to self-test for Covid-19. In contrast, non-Covid patients are also permitted to have visitors in normal wards or critical care units (ICU). Each patient can only have two visitors present at once, though. Prior to their visits, visitors are also urged to self-test for Covid-19. The new procedures are being implemented after considering how crucial psychosocial support is for patients' recovery, particularly from their families. Reminders for patients to follow the Covid-19 SOP were always placed strategically in the hospitals and clinics. In the workflow management of walk-in patients, physical distancing was identified as an important rule. Patients and the RWF must keep a 1-meter distance between each other to reduce the risk of infection. All hospital staff and patients were also required to wear a three-ply face mask for their protection. The new MoH SOP also stipulated that hospital staff would hand in a 3-ply face mask to patients with Covid-19 symptoms and offer a Covid-19 screening test to them at another part of the premises, such as at the Fever clinic using a different route. The patients would also be asked to sanitize their hands before entering the premises [15]. A regular filter and a temporary tensile structure as entry-point triage were erected for walk-in patients and hospital personnel entering the premises [16].

The Covid-19 triage system is not unique to Malaysia; it has been implemented in other countries. Some hospitals in Switzerland have set up triage units outside the main hospital buildings, which consist of three areas: pre-triage, triage, and triage plus. Pre-triage checkpoints would screen for walk-in patients with Covid-19 symptoms, and they would only be permitted entry into the main hospital building by presenting an appointment letter. The patients and hospital staff in Switzerland must always keep a physical gap of at least 2 meters. Patients directed to the main Triage area would be screened before being sent for a nasal swab or referred to Triage Plus if more diagnostic testing were required. The patients would either be sent home or admitted to the hospital for further treatment [17].

From our analysis of Covid-19 international policies, we found that the radiology department of an Italian cancer center conducted a pre-access telephone triage one day before a patient was scheduled for an examination [16]. The RWF would conduct this pre-access telephone triage with the patient to rule out possible flu-like symptoms and close contact with confirmed or suspected Covid-19 cases in the previous 14 days. The results of the telephone triage results were then entered into the hospital database. Those who experienced Covid-19-like symptoms were advised over the phone to contact their doctor, and their radiology appointments were rescheduled. Meanwhile, hospitals in Sichuan [18] and Nanjing in China [19] implemented a three-category triage system to classify patients based on their risk levels. The first category was outpatients at the fever clinic with a body temperature above 37.5°C in the past two weeks. Patients presenting at the emergency department with or without general respiratory symptoms fall under the second category, whereas patients scheduled for radiology or clinic appointments with no respiratory symptoms fall under the third category. The patients were further classified into three groups based on their risk levels: low-risk (ordinary outpatients and inpatients), medium-risk (emergency non-respiratory patients), and high-risk (fever outpatients) [18]. Later, the patients would undergo a chest CT, a blood test and a nasal swab test for Covid-19. Based on policy analysis of China's Covid-19 SOP, we believe the triage system in China is relatively more stringent than in Malaysia and other countries cited in this study.

C. Direct contact - The Imaging Procedure

Droplets, respiratory secretions, and direct touch are ways for the Covid-19 virus to spread quickly in the respiratory tract. Small virus-carrying particles have been reported to spread up to 10 meters from the emission source in indoor environments. In addition, this virus may remain infectious for up to 72 hours in aerosols and 3 hours on plastic and stainless steel. Therefore, radiology examinations should be performed with extreme caution to reduce the risk of patients and RWF being exposed to Covid-19. Direct contact during the imaging procedure is the third key area that requires strict adherence to the MoH SOP. The RWF were expected to perform radiology procedures in low-traffic locations to minimize exposing other patients and personnel. An ideal scenario would be to use a different imaging equipment and make an examination room available specifically for Covid-19 patients. For patients with moderate and severe respiratory symptoms, a study in Japan suggested that CXR and CT scans be helpful in evaluating the Covid-19 disease by observing for abnormalities in the chest area that indicate Covid-19 pneumonia [20].

Before conducting a CT scan, the RWF must ensure that the examination room is well-ventilated by switching on the air conditioning and opening the doors and windows wherever possible. The radiologist and other RWF must wear complete personal protective equipment (PPE) when assisting the patient during the examination. Non-essential equipment must be removed from the room to provide more space for the RWF and reduce the risk of cross-infection. Furthermore, the contact surface of the imaging equipment, such as monitors and the pressure injector for the contrast media, must be fully covered with a plastic sheet. Up to four RWFs were involved in a CT scan examination, consisting of two radiographers, one medical officer or a staff nurse, and a radiologist. Each radiographer will be assigned either to a clean or contaminated area. The radiographer assigned to the clean area will call up the ward to send their patients to the radiology department along with accompanying staff. The patient from the ward must use a designated route to reach the radiology department. The CT scan will be performed as per standard protocol [8].

Our study reviewed the workflow adaptation in Hospital Ampang, Malaysia, during the Covid-19 pandemic. A "Purple Code" would be activated and announced through hospital public broadcast when patients with a severe acute respiratory infection (SARI) need to be mobilized from the ward to the radiology department or vice versa [21]. In the recent SOP of the handling CT scan procedure, one radiographer wearing complete PPE and three layers of surgical gloves would be on standby to receive the patient for the CT scan. The radiographer would be tasked to position the patient with the help of accompanying staff on the CT gantry before moving into the designated waiting room with full PPE waiting until the scan is completed by the other radiographer that remains in the CT control room. This radiographer will sanitize his or her hands before touching the CT controls. After scanning has finished, the patient would be escorted back to the ward by the accompanying staff through a designated route [21]. The schematic of the CT suite in the setting for suspected, probable, and confirmed Covid patient examination is shown in Fig. 2. While Fig. 3 shows the process and staff distribution in the CT scanner and console room during the CT examination of suspected, probable, and confirmed covid-19 patients.

We found several discrepancies in the CT scan SOP performed in hospitals in China on patients with or without Covid-19 during the pandemic. For example, the RWF in China would prioritize performing CT scans on patients with suspected Covid-19 pneumonia, followed by those with confirmed Covid-19 pneumonia. Furthermore, the RWF in China practiced working in a 2 +2 working mode for CT scans, where the radiographers would complete a first period of 14 workdays in the isolation area and subsequently take a second period of 14 days in a dedicated isolation ward for observation before resuming normal work [21][22]. Additionally, the radiology departments in China would switch off their air conditioning before suspected or confirmed Covid-19 patients were brought into the X-ray examination or CT scan room. To the best of our knowledge, none of these practices were part of Malaysia's Covid-19 SOP for the radiology department [8].

There were recommendations regarding the technical aspect of CT scans for Covid-19 patients in the SOP for hospitals in China [23]. For example, it was recommended that non-contrast-enhanced CT scans with a low-radiation dose technique would be superior to Covid-19 patient imaging compared to conventional CT acquisition. The patient would lie on the CT table in a supine position and be asked to take a single breath-hold at full inspiration as the whole thorax was scanned. Low-radiation-dose chest CT was suggested to be feasible for imaging Covid-19 patients, producing acceptable diagnostic quality images at a 90% reduction in radiation dose to the patient. Hence, it was recommended that the standard CT chest to evaluate lung parenchyma of Covid-19 patients should apply the as low as reasonably attainable (ALARA) principle on radiation dose and technically performed as a low-dose CT scan instead of a full-dose CT [24]. Another recommendation

in a hospital SOP in Japan suggested that the RWF should receive a brief course on how to recognize the typical appearance of Covid-19 pneumonia so that they can immediately report or contact on-duty radiologists to prioritize the interpretation of these images with significant findings and initiate the SOP [24]. Both recommendations were absent from the MoH SOP for the radiology departments, and we believe it should be included in the next update to improve the policy document.

Apart from CT scans, CXR has also been used to evaluate the lung condition of suspected and confirmed Covid-19 patients. In the MoH SOP, the RWF were advised to continue wearing a lead gown underneath the PPE when performing radiology procedures to protect themselves against radiation exposure. Before putting on the PPE, the RWF would wear a lead gown that had already been cleaned and disinfected on both sides. The X-ray cassettes, X-ray detector, and anatomical marker were cleaned and disinfected before being covered with two layers of plastic sheet. For the mobile X-ray unit, the wheels of the machine must be adequately wiped clean with disinfectant before and after each X-ray examination [8][21][22].

A modified mobile CXR procedure was developed by The University of Washington in 2014 for Ebola patients and is now included in the university's SOP for Covid-19 patients. In the technique, there are two ways to perform the CXR, either by taking the X-rays through the Covid-19 isolation room glass window panel or placing the Covid-19 patient in a wheelchair or gurney in the isolation room facing an open door and the X-ray machine directly outside. This technique has proven to be quite effective when used with clear and wire-reinforced glass windows and glass windows with open metal Venetian-type blinds [25]. The radiographs will be obtained from 3 – 4.5 meters across a semi-isolation antechamber into an isolation room lengthier than the typical distance between a patient and an x-ray detector. The X-ray cassettes would be double-bagged and placed behind the patient by a ward staff member wearing full PPE. The radiographer would speak into a loud hailer or speaker to give breathing and optimal positioning instructions to the patient. The modified technique for patients with confirmed infectivity has been tested by Yale University and proved to be effective, with the entrance dose for an average-sized patient using the modified methodology comparable to that of the standard method. The radiographs developed through the modified techniques were found to be of acceptable diagnostic quality, safer for the patients and easier to perform by the radiographers [26]. However, the radiology department in Malaysia has not used the modified technique practiced by the University of Washington, possibly from a lack of awareness. The modified techniques were also not mentioned in the MoH SOP. Therefore, it is highly recommended that radiology departments in Malaysia use the new technique to prove its effectiveness in providing excellent quality chest radiographs and reducing patients' amount of entrance dose (Fig. 4).

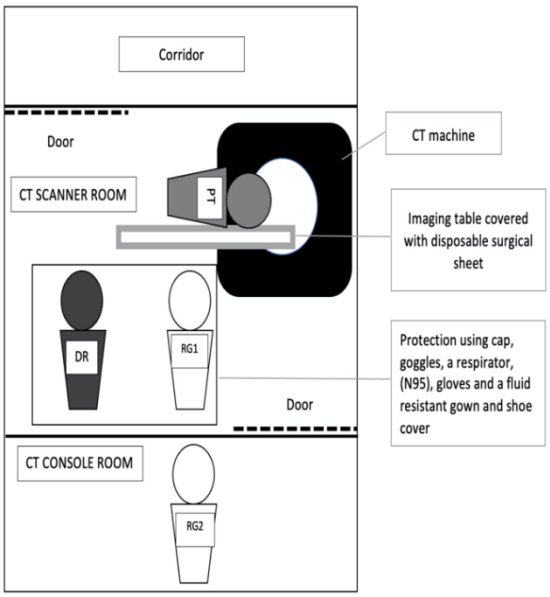

Fig. 2: The schematic of the CT suite in the setting for suspected, probable, and confirmed Covid patient examination [21]

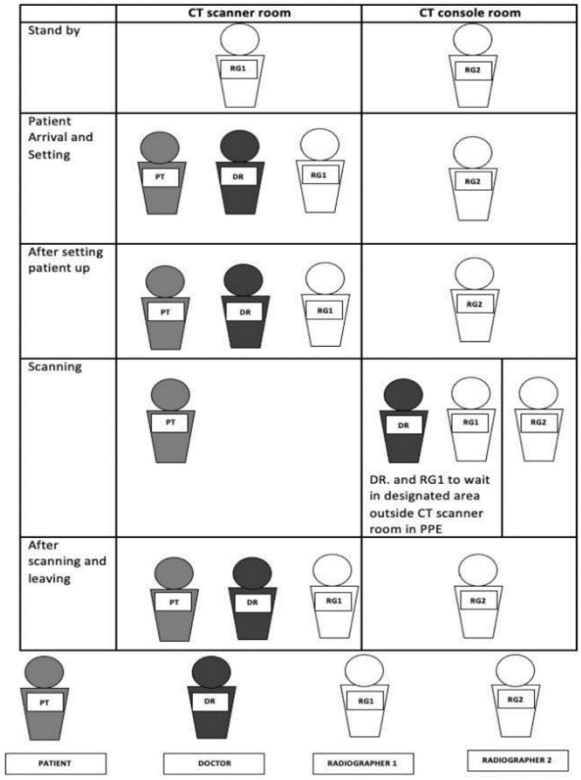

Fig. 3: The process and staff distribution in the CT scanner and console room during the CT examination of suspected, probable, and confirmed Covid-19 patients [21]

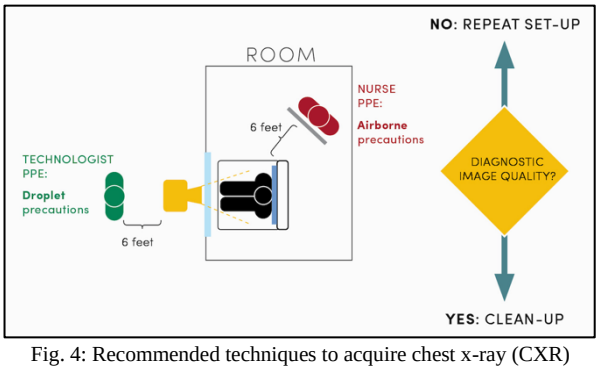

Fig. 4: Recommended techniques to acquire chest x-ray (CXR)

D. Exit Policy & Disinfection - Post-Imaging Procedure Conduct

Some infected individuals may show no indications or symptoms of Covid-19 infection, allowing them to pass the triage system at the main entrance of the hospital building. As a result, the RWF must maintain a constant state of vigilance. Because Covid-19 patients with mild upper respiratory tract involvement can cause environmental contamination, an SOP on patient exit after they have completed their radiology examination is essential, particularly in terms of disinfection [27]. From the MoH SOP, we identified the fourth key area of exit policy and disinfection that requires strict implementation by the RWF. After the imaging procedures were completed, the radiographers were instructed to look closely at the images for any signs of Covid-19. In the case of suspicious images, the radiologist would be immediately informed so that the reading and reporting of the images could be done as quickly as possible. After the radiologist has signed off on the report, the radiographer in the clean area will notify the security guard that the suspected Covid-19 patient will return to the ward assisted by accompanying staff. The patients were asked to always wear their masks. Patients and the accompanying staff will use a separate, designated lift and access route. Next, the radiographer will remove the equipment covers and disinfect the machines in the contamination area. The RWF required to wear PPE were to take it off in a designated area [8].

The RWF are vital to the disinfection process. The following disinfection methods were used by the radiology department in line with the ideas of triage, safety, and best practices to avoid intrahospital transmission based on the best practices recommended by professional organizations [28]-[31]. At least two members of the RWF would have to work together to disinfect the machine and equipment used by the Covid-19 patient. For example, one radiographer would be responsible for cleaning and disinfecting the CT gantry and control panel using a 75% ethanol, then disinfecting the CT table with a 500-ppm bleach solution. This cleaning and disinfection procedure is performed for each Covid-19 case and done after the patient has left the scanning room. The radiographer involved would remove the PPE first in the following sequence. First, the hands would be dry cleaned using 75% ethanol. Next, the face shield would be removed and disinfected with a 500-ppm bleach solution. The face shield would be hung on the wall and disinfected with UV light for 30 minutes. From top to bottom, the whole PPE garb will be folded outwards from the inner part to the outer layer, beginning with the disposable hair cap, gown, and gloves. In between each item of clothing, the hands would be dry cleaned. After the fourth dry clean of the hands, a tissue paper soaked in 500 bpm bleach solution would be placed outside the door of the scanning room. Remove the disposable shoe covers into the clinical bin and dry clean the hands again before removing the inner layer of gloves. Stand on the soaked tissue paper to dry clean the hand once more before leaving the scanning room. Outside the CT scan room, clean gloves need to be put on first to remove the N95 mask. Finally, take off the gloves and wash hands with soap.

Following the radiographer's disinfection of the CT gantry, a cleaning staff would enter the scanning room to disinfect the floor and surrounding areas. The cleaning staff should also be instructed to put on the PPE. The PPE should be thrown into the biowaste bin after use. If the hospital gown is not single-use, it should be placed in a double-layer plastic bag with a biohazard label and disposed of separately. Any contaminated gowns should be cleaned and disinfected according to the SOP. In accordance with the MoH's infection control protocols, hazardous waste would be incinerated. Another radiographer would use 75% ethanol to sanitize the CT console and facilities outside the scanning room.

After the procedure, 1-hour downtime will be implemented at the examination room for passive air exchange [8]. The passageway between the inpatient ward and the CT room would be disinfected as per the SOP. To avoid unintended aerosolization of Covid-19, vacuuming and mechanical buffing of hospital floors were temporarily discontinued [24][25][32][33]. When disinfecting equipment, corrosive disinfectants would not be permissible. Disinfectant sprays would also be used sparingly since they can corrode metals and penetrate surfaces, causing short-circuits or other damage. To avoid the disinfectant to corrode the surface of the x-ray machine, the equipment must be turned off first, left to cool, and then covered with a plastic sheet before deep cleaning could commence [34]. If there is plastic equipment, it should only be disinfected with a soap solution. When visible pollutants such as vomitus are found, the disposable absorbent material should be used first to remove the pollutants fully before disinfecting [35][36].

From the analysis of the SOP followed by a teaching hospital in Trivandrum, Kerala, India, we found that after a mobile X-ray examination was done, the radiographers were assisted by the ward staff to remove the cassette from under the patient [33]. This practice was not included in Malaysia's SOP as the radiographer alone removed the cassette from under the patient [8]. The second layer of contaminated plastic bags was then removed from the cassette and discarded in the yellow clinical waste bin. The cassette was placed inside the hatch on the mobile X-ray machine. The radiographers proceeded to disinfect the x-ray machine before doffing their PPE. At the designated areas, the mobile X-ray machine would be wiped with a disposable sani-cloth, and the X-ray machine was pushed so that its wheels would roll over an alcohol-soaked cloth or sanitary sticky mat. Then, the radiographers should doff their PPE and disinfect the anatomical markers before removing them from the cassette. The first layer of plastic cassette cover was removed and wiped with a disinfectant before the image was processed [8].

Deep cleaning of a mobile X-ray machine should be performed twice a day with a diluted bleach solution. After each Covid-19 cases, isopropyl alcohol 70%, rather than bleach is used to clean delicate parts of the machine, such as the collimators, control consoles, and the exposure buttons [37]. From the imaging procedures, steps in donning PPE to the disinfecting of radiological equipment, the disinfectant measures advised by the MoH have been mostly similar with the practice of other countries.

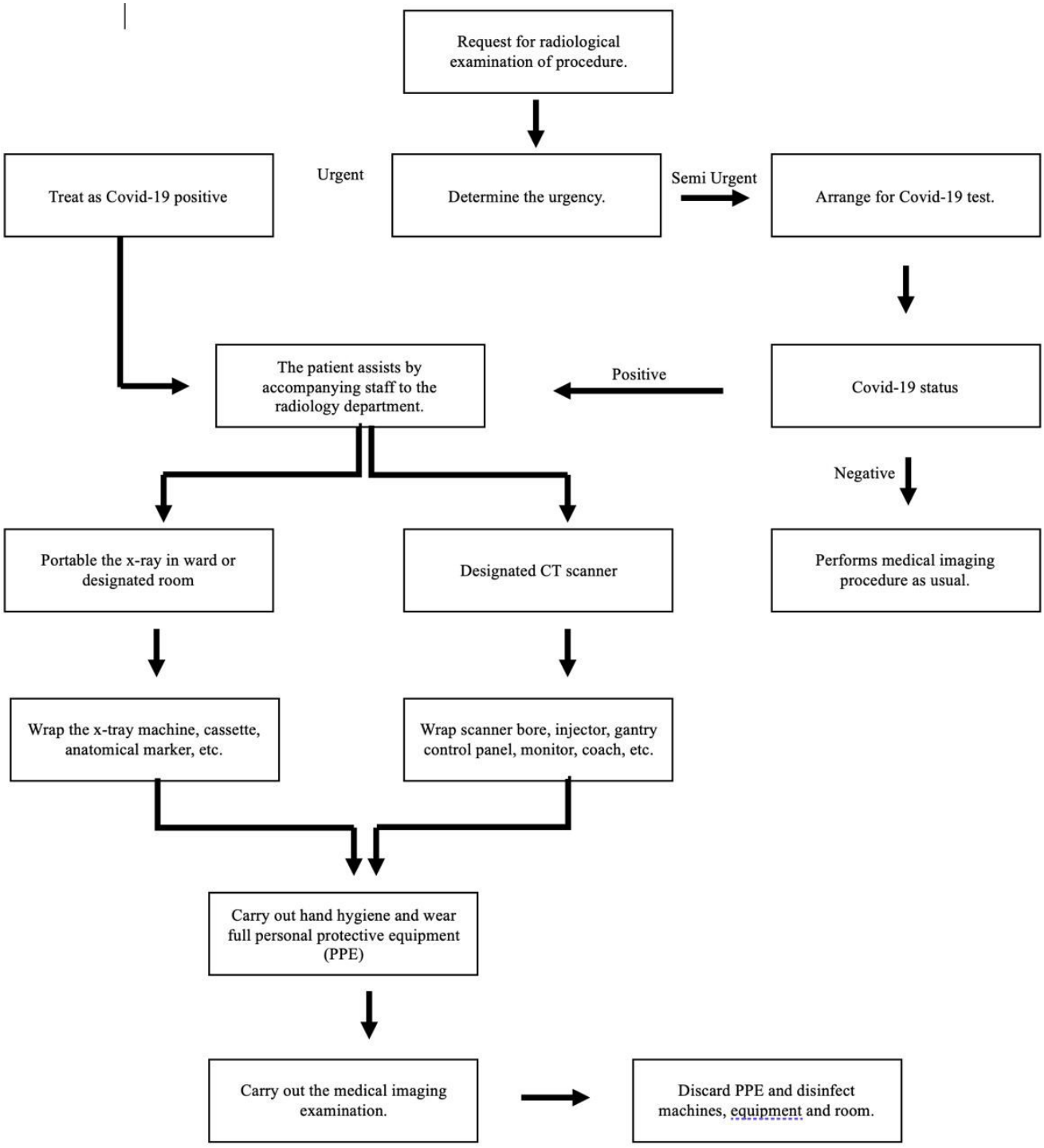

Fig. 5: Workflow for radiological examination during Covid-19

III. DIAGNOSIS AND PROGNOSIS OF COVID-19

Covid-19 symptoms include fever, a dry cough, and fatigue. Some infected persons may develop mild headaches, muscle pains, runny nose, sore throat, or diarrhea. Patients infected with Covid-19 may develop severe pneumonia, organ failure, acute respiratory tract infection, and septic shock, all of which can lead to death. On the other hand, some who are infected exhibit no signs or symptoms or feel unwell [38]. Medical imaging is needed to support clinical decision-making in the diagnosis, management, and treatment of Covid-19 patients due to the wide range of symptoms experienced by individuals. Covid-19 can be distinguished from other viral respiratory infections with similar symptoms using medical imaging. The diagnosis of Covid-19 using chest CT and chest radiography will be discussed in this section.

Chest CT serves a limited but significant role in the clinical management of Covid-19 patients. Because CT should only be used in severely sick patients, in the case of equivocal chest radiographs, or when reverse-transcription polymerase chain reaction (RT-PCR) testing is unavailable [39]. On CT, the most common imaging indicators of the disease were bilateral, basal, ground-glass opacities (GGOs), crazy-paving, peripheral

consolidations, reverse halo ("atoll" sign), and peri-lobular patterns (Fig. 6) [40]-[42]. Bilateral pneumonia was more prevalent than unilateral pneumonia, and most patients had more than two lobes involved, with the bases of the lungs being afflicted more often than the apices. Infrequent CT findings with Covid-19 pneumonia include lobar or segmental consolidation without GGOs, discrete small pulmonary nodules, pulmonary cavitation, septal thickening, pleural effusion, and pneumothorax [40][43]. The appearance of Covid-19 on CT imaging might change over time. According to Pan et al. [44], the appearance of Covid-19 on a CT picture is classified into four temporal stages: acute and subacute Covid-19. GGOs might be unilateral in the early stages and lack the characteristic peripheral lung distribution. When pulmonary opacities grow more severe and confluent with more common bilateral lung involvement, generally occurring between days 5 and 8, patients will experience greater progression (Fig. 7). The peak phase happens around 9-13 days and shows more extensive consolidation, like how acute lung injury progresses. Pediatric patients experienced less severe symptoms than geriatric patients, albeit having similar CT results. GGOs in children appear more localized and have lower attenuation than in adults [45][46]. As a result, these findings were labelled as uncommon. In addition, bronchial wall thickening and peri-bronchial infiltrates are more prevalent in children than adults. The bronchial wall thickening and peribronchial infiltrates might be due to differences in Covid-19 infection distribution over the respiratory epithelium between the two groups or the existence of co-infection [47].

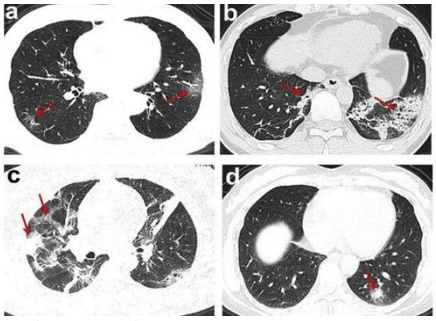

Fig. 6: CT manifestations of Covid-19 disease. a. Ground-glass opacities, b. Consolidations, c. Consolidations with ground-glass opacities, d. Solid nodule

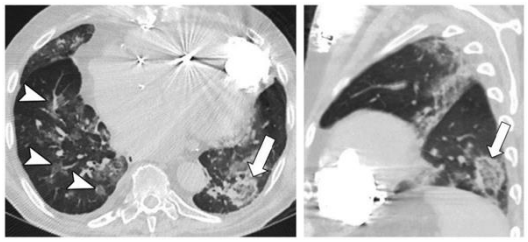

Fig. 7: Images of a 72-year-old man with Covid-19 and a history of heart failure presenting with ten days of cough. (a) Axial and (b) sagittal unenhanced thin-section chest CT images show peribronchial ground-glass opacities (arrowheads), as well as ground-glass opacity in the left lower lobe with a ring of denser consolidation (reverse halo sign) (arrow).

CXR is another common imaging modality for suspected and confirmed Covid-19 cases. However, on chest radiographs, the appearance of Covid-19 may range from normal in the early stages of the infection to unilateral or bilateral lung opacities progression and, in rare cases, particularly peripheral distribution (Fig. 8) [40]. Complications such as pneumothorax or lung cavitation are infrequent [48]. The abnormalities on chest radiographs grow more widespread 10 to 12 days following the beginning of symptoms [49]. A study was conducted in Tawau Hospital in the Sabah state of Malaysia to identify Covid-19 radiographic patterns. On chest radiographs, ground-glass opacities where peripherally put with a proclivity towards the lower zone were the most common anomalies, with 29 out of 82 patients showing the same result. After ground-glass opacities, seven people consolidated, making it the second most prevalent anomaly. Consolidation occurred 5 to 8 days after the beginning of symptoms in most cases. Based on the study, most radiographic abnormalities appeared multifocal and mostly located in the left lung [50].

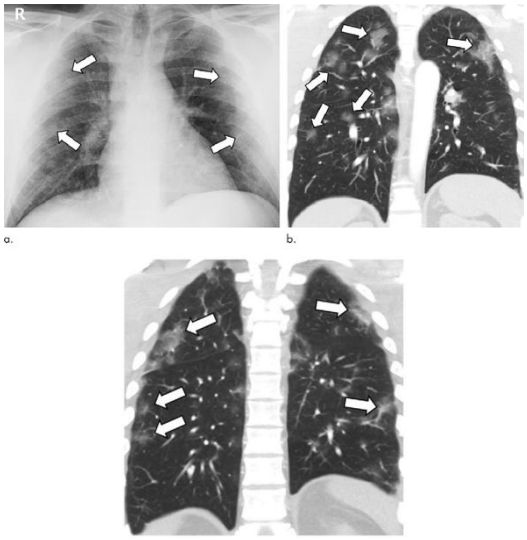

Fig. 8: Images of a 37-year-old woman with Covid-19 who had been sick for a week with fever, cough, nausea, and diarrhea. (a) Posteroanterior chest radiograph shows mild, ill-defined pulmonary opacities bilaterally in the periphery of the lungs (arrows). (b, c) Coronal contrast-enhanced CT images of the chest show corresponding peripheral ground-glass opacities bilaterally (arrows), some with a rounded morphologic presentation.

Covid-19 prognosis varies depending on the injury, disease, age, sex, race, and treatment received [51]. It was reported that the mortality of Covid-19 patients is lower than patients with severe acute respiratory syndrome (SARS-Cov-1) or Middle East respiratory syndrome (MERS). The occurrence of severe acute respiratory distress syndrome (ARDS) appears to be the driving factor in Covid-19 mortality, ranging from 12% to 78%, with an average of 25% to 50%. Diseases such as cardiac arrhythmia, cardiac arrest, and pulmonary embolism can also cause mortality in Covid-19 patients [52]. According to Ioannidis et al., patients under 65 years old had a low chance of mortality even in pandemic epicenters, especially if they have no underlying conditions [53]. In contrast, in one study of over 2000 critically ill patients, those beyond 80 had an 11-fold greater chance of mortality [54]. According to a US cohort study, nearly all Covid-19 patients had at least one underlying health issue when they died. Obesity, anxiety and fear-related disorders, and diabetes, as well as the overall number of underlying diseases, were the highest risk factors for mortality [55]. Several studies also agreed that comorbidities such as obesity, chronic cardiac and pulmonary conditions and diabetes increase the risk of death [56]-[58].

Familiarisation with the radiographic appearance of the disease may help in the early detection of Covid-19. Both CXR and chest CT visualize the lung condition, which can help doctors detect the deadly Covid-19. Based on the discussion above, the CT scans revealed a greater extent of lung involvement than what was depicted from the baseline radiographs. It comes to light that the appearance of Covid-19 in both X-ray and CT scans changes over time. The Covid-19 pulmonary findings on chest radiographs and CT images often resolve over time. On the other hand, the disease could evolve into a more structured and organized phase over weeks, in which case GGOs and consolidation would transform into more reticular opacities and may be associated with fibrosis, volume loss, architectural distortion, and traction bronchiectasis [40]. The prognosis of Covid-19 is associated with factors influencing the rate of mortality, such as elderly patients have a higher risk of death than young people, and patients with comorbidities are more likely to experience severe Covid-19 infection and death than infected patients without any underlying disease.

IV. CONCLUSIONS

Medical imaging plays a critical role in the Covid-19 pandemic because it offers the benefit of complementary diagnostics for Covid-19 identification. Contact between patients and staff when performing medical imaging examinations is necessary. Therefore, the government has enacted tight regulations to combat the spread of Covid-19 even during the post-pandemic era. As frontline workers, radiographers should be conversant with the new SOP in order to protect themselves against this fatal infection. This paper also discusses the recommended medical imaging examination procedure to minimize contact between the radiology staff and the patients. From the perspective of non-radiology staff, they will gain new knowledge regarding the current SOP and know what to expect when setting an appointment for a medical imaging examination. Most importantly, readers will be more aware of ways to keep themselves safe and well during this unprecedented situation by strictly following the SOP. This paper reviewed the abnormalities found in CXR and chest CT of Covid-19 so that the reader, especially the radiology staff, has a comprehensive understanding of these lung disorders and can make a timely and accurate diagnosis.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGEMENT

The authors would like to thank the Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM), for supporting the current study. This work was supported by the Universiti Sains Islam Malaysia Research Grant (PPPI/FST/0119/051000/17519).

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