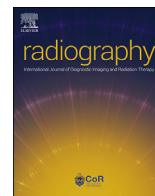




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Initial data from an experiment to implement a safe procedure to perform PA erect chest radiographs for COVID-19 patients with a mobile radiographic system in a “clean” zone of the hospital ward

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ABSTRACT

Introduction: With the current Covid-19 pandemic, general wards have been converted into cohort wards for Covid-19 patients who are stable and ambulant. A 2-radiographer mobile radiography team is required to perform bedside Chest X-rays (CXR) for these patients. Hospital guidelines require both radiographers to be in full Personal Protective Equipment (PPE) throughout the image acquisition process and the mobile radiographic unit needs to be disinfected twice after each case. This affects the efficiency of the procedure and an increase usage of limited PPE resources. This study aims to explore the feasibility of performing mobile chest radiography with the mobile radiographic unit in a “clean” zone of the hospital ward.

Methods: An anthropomorphic body phantom was used during the test. With the mobile radiographic unit placed in a “clean” zone, the phantom and the mobile radiographic unit was segregated by the room door with a clear glass panel. The test was carried out with the room door open and closed. Integrated radiation level and patient dose were measured. A consultant radiologist was invited to review and score all the images acquired using a Barco Medical Grade workstation. The Absolute Visual Grading Analysis (VGA) scoring system was used to score these images.

Results: A VGA score of 4 was given to all the 40 test images, suggesting that there is no significant differences in the image quality of the images acquired using the 2 different methods. Radiation exposure received by the patient at the highest kV setting through the glass is comparable to the regular CXR on patient without glass panel at 90 kV, suggesting that there is no significant increase in patient dose.

Conclusion: The result suggests that acquiring CXR with the X-ray beam attenuating through a glass panel is a safe and feasible way of performing CXR for COVID-19 patients in the newly converted COVID wards. This will allow the mobile radiographic unit as well as one radiographer to be completely segregated from the patient.

Implications for practice: This new method of acquiring CXR in an isolation facility set up requires a 2-Radiographer mobile radiography team, and is applicable only for patients who are generally well and not presented with any mobility issues. It is also important to note that a clear glass panel must be present in the barriers set up for segregation between the “clean” zone and patient zone in order to use this new method of acquiring CXR.

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Introduction

Chest radiographs can be obtained outside the Radiology department using a mobile radiographic unit. When justified, this examination can be performed at the ward or in special areas in the hospital where the patient is isolated. With the rising number of the Corona Virus Disease 2019 (COVID-19) cases in Singapore,¹ Sengkang General Hospital (SKH) has converted three general

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wards into COVID wards in order to accommodate the increasing number of COVID-19 patients. The Radiology Department (DoR) has been experiencing a high load of bedside Chest X-ray (CXR) requests in these COVID wards.

The COVID-19 outbreak is both a sanitary emergency and an economic challenge for the whole healthcare system and also for Radiology Departments where there is a need to contribute to the successful management of COVID-19 patients.² As the COVID-19 pandemic threatens to overwhelm healthcare systems worldwide, chest radiography may be considered as a tool for identifying and monitoring warded COVID-19 positive patients. In a cohort of patients with COVID-19 infection and imaging follow-up, baseline chest x-ray has a sensitivity of 69%, compared to 91% for initial RT-PCR.³

As the pandemic progresses, the medical community will increasingly rely on mobile Chest radiography due to its widespread availability and reduced infection control issues; that currently limit Computed Tomography (CT) utilization.⁴ Mobile chest radiography should be performed for diagnostic indications in patients who, because of their clinical condition, cannot be transported for standard chest radiography. In cooperative adults and older paediatric patients, postero-anterior (PA) fully upright mobile chest radiographs should be performed at a source-image distance (SID) as close as possible to 72 inches (180 cm).⁵

At SKH, COVID-19 positive patients who are generally well and without significant respiratory symptoms will be grouped together and managed in the cohort wards. Most of these patients are ambulant and able to manage their daily activities unsupervised. As such, all mobile CXR for these patients in the cohort wards will be performed as PA erect instead of antero-posterior (AP) sitting projection.

Two radiographers are required to perform a PA Erect CXR for these patients.⁶ One of them will be the 'dirty' radiographer – handling patient, while the other will be the 'clean' radiographer – handling the mobile radiographic unit. Apart from the mobile radiographic unit, there is also a mobile detector stand to secure the direct radiography (DR) wireless flat panel detector (FPD) in place during image acquisition. The workflow requires both radiographers to be in full Personal Protective Equipment (N95mask, face shield, isolation gown and gloves) even though one is the 'clean' radiographer who will not have any direct contact with patient. The DR FPD will be covered in a disposable plastic cover to prevent direct patient contact to the FPD. After the procedure, the 'dirty' radiographer will remove the DR FPD from the mobile detector stand and remove the disposable plastic cover without touching the detector. The 'clean' radiographer will hold the uncontaminated FPD and put it back into the detector slot of the mobile radiographic

unit. The mobile radiographic unit, detector and mobile detector stand will be disinfected twice after the procedure; once inside the room and the second time outside the room.

While the average time needed for a radiographer to get the CXR done is about 6 min, disinfection of the mobile radiography unit requires an intensive 10 min to complete, disinfection of the mobile detector stand require approximately 4 min and the donning and doffing of PPE takes up around 6 min. This translates to an astonishing 26 min to complete one PA Erect CXR, with direct effect on the service turnaround time in these cohort wards. Disinfecting the mobile radiographic unit inside the patient's room also translates to a longer duration that both radiographers will spend in close proximity to the COVID-19 positive patients.

Hence, to increase efficiency and to further minimize exposure and contamination of the mobile radiographic equipment and staff, a possibility of imaging the patient through a physical barrier such as glass was explored. With a physical barrier in place, the 'clean' radiographer and mobile radiographic unit will be completely segregated from the patients. This paper aims to test and implement a safe procedure to perform PA erect CXR to COVID-19 patients with a mobile radiographic unit in 'clean' zone; by a two-radiographer team in the hospital ward with a physical barrier in place.

Methods

A Samsung GM-85 mobile radiographic system (manufactured in 2017) was set up outside one of the rooms in a newly converted vacant COVID-19 ward. The set-up was tested with room door open (no glass panel) and with door closed (with glass panel). The X-ray tube was positioned facing inwards the ward room and against the glass panel as shown in Fig. 1a and b respectively. The glass panel is a laminated double glaze glass with a dimension of 60 cm × 100 cm and a thickness of 0.25 mm. In SKH, all our general ward room doors are constructed by the same manufacturer and the glass panels are identical.

An Anthropomorphic body phantom (Kyoto Kagaku) and the mobile detector stand with a wireless DR FPD were placed inside the room at SID of 180 cm (Fig. 2).

Four exposure settings (Table 1) with a fixed collimation and SID of 180 cm were tested. Five exposures were made for each settings and a total of 40 images were acquired. All the images were evaluated by a consultant radiologist on site and off site. In addition to that, the patient dose was also measured using the Aloka PDM-222 Electronic Pocket Dosimeter (EPD) for each exposure with and without the glass panel.

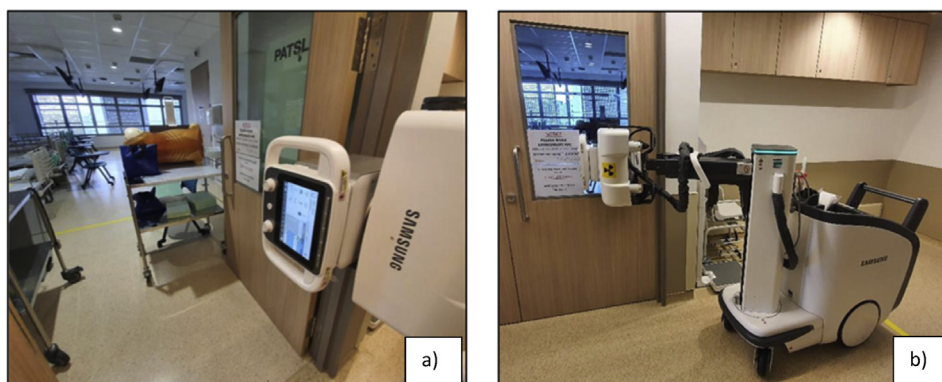


Figure 1. Set-up of Mobile radiographic equipment to wireless DR detector with door open a) and through the glass panel b).



Figure 2. Set-up for the anthropomorphic body phantom and the wireless DR detector.

Table 1
Exposure settings used for the phantom test.

kVp	mA	mAs	No. of exposure made without glass panel	No. of exposure made with glass panel
90 kVp	250	4	5	5
100 kVp	250	4	5	5
110 kVp	250	4	5	5
120 kVp	250	4	5	5

The trial was performed at two different rooms in the Ward with different bed capacities; a three-bedded and an eight-bedded room. The integrated radiation level were measured with an ambient dose ion chamber survey meter, Ludlum 9DP*. The values measured were the dose equivalent readout that would be measured at a (human) tissue depth of 10 mm.

The scattered radiation exposure was measured at selected points, corresponding to where the other patients within the isolation room would be resting during the image acquisition process of one patient. Scatter radiation dose received by the radiographer standing 2 m away from the x-ray tube was also measured. Five exposures were made at the highest setting of 120 kV, through the glass panel and the average scattered radiation exposures received by others around the area for each CXR performed were measured (Table 2).

40 images were anonymised, randomised and stored in a single DVD for review by a Consultant Radiologist. The study was blinded and each image was assessed and graded using the Absolute Visual Grading Analysis (VGA) tool⁷ (Table 3).

Results

All 40 test radiographs performed using the phantom were given a VGA score of 4 by the radiologist. The patient dose measured with the test images acquired with and without the X-ray beam passing through the glass panel is presented in Table 4 below.

At 90 kV, the dose received by the patient during CXR through the glass panel is lower than without. This could be due to further beam hardening when x-ray passed through the glass. At 100 kV, it

Table 2
Scattered radiation measured at different location within the eight-bedded room and three-bedded room during the exposure of the CXR.

Eight-Bedded Room	
Location	Distance from CXR Patient (m)
Bed 1	2.3
Bed 2	2.7
Bed 3	2.8
Bed 8	4.3
Three-Bedded Room	
Location	Distance from CXR Patient (m)
Bed 1	2.7
Bed 2	4.0
Bed 3	5.0

Table 3
Absolute visual grading analysis tool.

Absolute Visual Grading Analysis (VGA) score
5 – excellent image quality: no limitation for clinical use
4 – good image quality: minimal limitations for clinical use
3 – sufficient image quality: moderate limitations for clinical use but no substantial loss off information
2 – restricted image quality: relevant limitations for clinical use, clear loss of information
1 – poor image quality: image not useable, loss of information, image must be repeated

Table 4
Images acquired with and without the X-ray beam passing through the glass panel.

Exposure Setting	CXR Patient Dose (μSv)	
	Without Glass Panel	With Glass Panel
90 kVp, 250 mA, 4 mAs	14.6	9.0
100 kVp, 250 mA, 4 mAs	12.2	11.8
110 kVp, 250 mA, 4 mAs	11.0	13.4
120 kVp, 250 mA, 4 mAs	9.2	14.8

is observed that the radiation dose received by the patient during CXR with and without the glass panel is approximately the same (Fig. 3). However as kV increases, the patient dose continued to increase, which may be due to higher scatter as the x-ray beam passes through the glass panel. Nevertheless, the radiation exposure received by the patient at the highest kV setting through the glass is comparable to the regular CXR on patient without glass panel at 90 kV and it is well within the ICRP60 and ICRP103 standard.⁸

Scatter radiation dose accumulated for each CXR made at the highest setting of 120 kV through the glass panel for the surrounding patients were calculated and presented in Table 5 below.

It is worth noting that the position and structural orientation differs between the two rooms (Fig. 4). In the eight-bedded room, the area at bed 1 was partially blocked by the walls of the nurse sub-station resulting in the patient resting at bed 1 to receive a

lower scatter radiation than the patient at bed 2. Nonetheless, the radiation exposure to the other patients in the room resulted from the scatter of the CXR scan within the room, was very low. The scatter radiation dose received by the radiographer standing 2 m away from the x-ray tube was also measured and approximated to be $0.03\mu\text{Sv}$ for each CXR procedure. Although the radiation exposure to radiographers are low, they will still need to don on lead protective gear to further reduce the radiation received by them as they will be performing multiple X-rays throughout their duties.

Discussion

This phantom trial has proven that the new method of acquiring CXR for COVID-19 patients in these cohort wards is a potential way to save both time and cost while also minimizing exposure and contamination to the mobile radiographic unit and radiographer. As there is no significant difference in image quality acquired using the conventional method and the new method, approval was granted by the hospital Chief Executive Officer and Chairman of Medical Board for Radiology to adopt this new method of performing CXR for COVID-19 positive patients in these cohort wards. In consideration that the radiation dose received by patients during CXR with and without the glass panel is the same at 102 kVp, Radiographers are highly encouraged to use 102 kVp when performing CXR in these cohort wards using this new method.

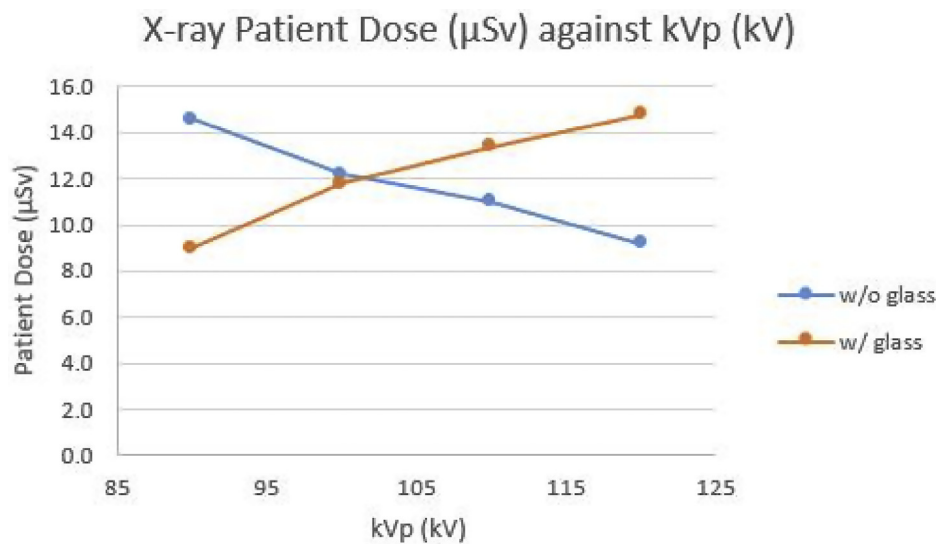


Figure 3. Graph showing patient dose in relation to kVp.

Table 5
Scatter radiation dose accumulated for each CXR made at the highest setting of 120 kV through the glass panel for the surrounding patients.

Eight-Bedded Room		
Location	Distance from CXR Patient (m)	Scatter Radiation Dose Accumulated for each CXR (μSv)
Bed 1	2.3	0.02
Bed 2	2.7	0.05
Bed 3	2.8	0.03
Bed 8	4.3	0.00
Three-Bedded Room		
Location	Distance from CXR Patient (m)	Scatter Radiation Dose Accumulated for each CXR (μSv)
Bed 1	2.7	0.06
Bed 2	4.0	0.04
Bed 3	5.0	0.05

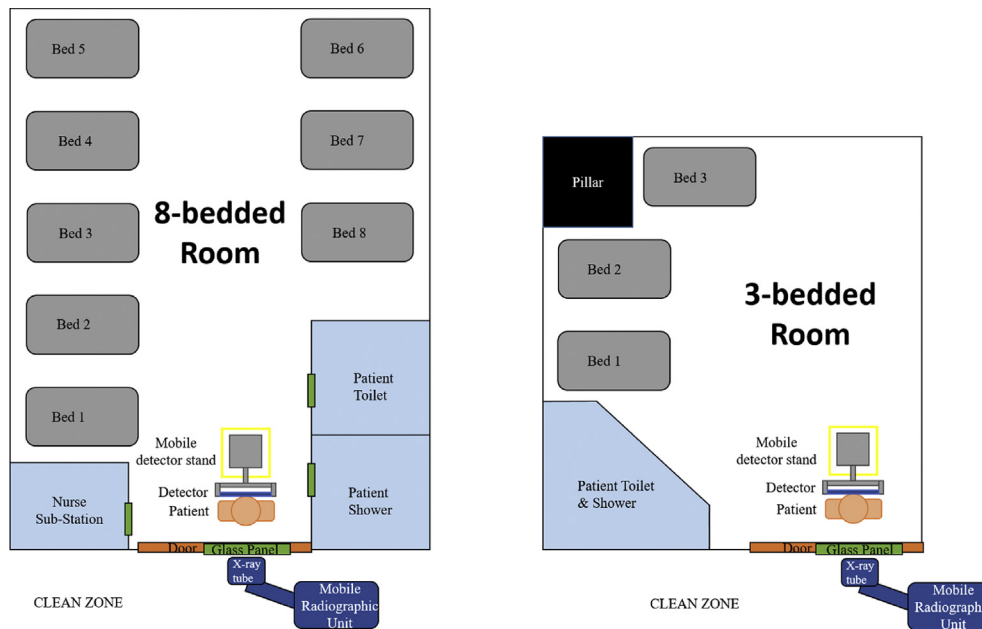


Figure 4. Position and structural orientation of ward layout.

In an attempt to reduce risk of cross-infection to staff and other patients during patient transportation, most of our local hospitals have convert all plain radiography examinations for COVID-19 patients to done at the patient's bedside.^{9–11} While covering the mobile radiographic unit with multiple layers of disposable poly-thene sheets can reduce the risk of cross contamination to the mobile unit,¹² this new method allows a further reduction in risk of cross-infection with the mobile unit in a 'clean' zone. This new method requires only the 'dirty' radiographer to be inside the patient's room while the 'clean' radiographer remains outside. The 'clean' radiographer no longer needs to be in full PPE and this translates to a 50% cost saving of PPE per case. With a worldwide shortage of PPE for healthcare workers,^{13,14} this 50% saving in PPE will allow more Healthcare workers to gain access to PPE. As the mobile radiographic unit only stays within the 'clean' zone, the mobile radiography team no longer needs to disinfect the mobile radiographic unit. The 'clean' radiographer can now take over the second disinfection of the mobile detector stand while the 'dirty' radiographer doffs his/her PPE. This translates to a total of 46% reduction in time taken to perform a PA Erect CXR for patient in these cohort wards. In addition, cross infection of patient due to improper disinfection of the mobile radiographic unit is no longer a concern.

The data of the patient dose in Table 4 has also shown that the radiation received by the patient at 100 kV setting was approximately the same when they were imaged with and without the glass panel. A setting of 102 kV was then tested to image the phantom through the glass panel and was found to be of diagnostic quality. Thus, balancing between the radiation dose and image quality, a setting of 102 kV was selected to be of the most optimized.

At the point of writing this paper, SKH Radiology has adopted this new method of acquiring CXR for COVID-19 positive patients in the cohort wards. Both radiographers will don lead rubber aprons and the 'dirty' radiographer will ensure there are no Healthcare workers inside the nurse station during image acquisition process. The 'clean' radiographer will also ensure all Healthcare workers are at a distance of at least 2 meters from the X-ray tube before making an exposure. A preliminary review of the CXR acquired using this new method showed no significant difference in terms of image

quality when compared to the conventional method. Studies have shown that the typical radiological findings of COVID-19 positive patient CXR are bilateral ground glass opacities in the lung periphery.^{2,4} As such, audit of CXRs acquired using this new method is necessary as it provides a systematic process of evaluating the image quality to ensure the CXRs produced are of good diagnostic quality.¹⁵ Further analysis of these CXRs in terms of image quality has been put in place and the team is in the process of data collection at the point of writing this paper.

Conclusion

Based on this study, it can be concluded that acquiring PA Erect CXR for patients in cohort wards with the x-ray beam penetrating through a glass panel is safe and effective, without any compromise to the image quality. With the number of COVID-19 cases escalating globally, we hope that our study can provide some insights to Radiographers and Radiological Technologists in providing Mobile Chest Radiography services in a safe and efficient way in isolation facilities. This study can also provide some insights to hospital administrators in designing ward set-up that can be pandemic-friendly for new hospitals in future.

Implications for practice

This new method of acquiring CXR in an isolation facility set up is applicable only for patients who are generally well and not presented with any mobility issues. It is also important to note that the patient's room door needs to have a clear glass panel that is large enough to allow superior and inferior adjustment of the centering point without any obstruction of the primary beam. A 2-radiographer team is also necessary for this workflow. It is also important to note that different glass materials may affect the image quality differently. Hence, a trial test should be done prior to implementing such a set up to ensure that imaging through the glass will not interfere with the CXR image and that the image will still be of diagnostic value.

Conflict of interest statement

None.

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