

Social Distancing with Portable Chest Radiographs During the COVID-19 Pandemic: Assessment of Radiograph Technique and Image Quality Obtained at 6 Feet and Through Glass

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Social Distancing with Portable Chest Radiographs During the COVID-19 Pandemic: Assessment of Radiograph Technique and Image Quality Obtained at Six Feet and Through Glass

Abbreviations:

CXR = chest radiograph, ED = emergency department, EI = exposure index, SBAR = situation background assessment recommendation, PPE = personal protective equipment

Key Points:

1. Portable chest radiographs can be performed with a six foot distance through a glass door with images that remain diagnostic compared to conventional portable radiographs.
2. The described modified portable technique results in similar radiation dose to the patient and similar or decreased radiation to performing X-ray technologist.
3. Increased distancing and placement of technologist and X-ray unit outside of the patient's room allowed for conservation of personal protective equipment with technologist's feeling safer.

Summary statement:

A modified portable chest radiography technique with increased distancing between the x-ray unit and detector provided diagnostic quality images with a similar radiation dose to the patient and staff while conserving personal protective equipment.

Abstract

Purpose

To develop a technique that allows portable chest radiography to be performed through the glass door of a patient's room in the emergency department.

Materials and Methods

A retrospective review of 100 radiographs (50 [mean age 59.4 ± 17.3 , range 22-87; 30 women] performed with the modified technique in April 2020, randomized with 50 [mean age 59 ± 21.6 , range 19-100; 31 men] using the standard technique was completed by three thoracic radiologists to assess image quality. Radiation exposure estimates to patient and staff were calculated. A survey was created and sent to 32 x-ray technologists to assess their perceptions of the modified technique. Unpaired T-tests were used for numerical data. A *P* value $< .05$ was considered statistically significant.

Results

The entrance dose for a 50th percentile patient was the same between techniques, measuring $169 \mu\text{Gy}$. The measured technologist exposure from the modified technique assuming a 50th percentile patient and standing 6 feet to the side of the glass was $0.055 \mu\text{Gy}$, which was lower than standard technique technologist exposure of $0.088 \mu\text{Gy}$. Of the 100 portable chest radiographs evaluated by three reviewers, two reviewers rated all images as having diagnostic quality, while the other reviewer believed two of the standard images and one of the modified technique images were non-diagnostic. A total of 81% (26 of 32) of eligible technologists completed the survey. Results showed acceptance of the modified technique with the majority feeling safer and confirming conservation of PPE. Most technologists did not feel the modified technique was more difficult to perform.

Conclusion

The studies acquired with the new technique remained diagnostic, patient radiation doses remained similar, and technologist dose exposure were decreased with modified positioning. Perceptions of the new modified technique by frontline staff were overwhelmingly positive.

Introduction

The spread of the coronavirus disease 2019 (COVID-19) has placed an unprecedented strain on healthcare resources. Radiology departments around the world have been pressed to work in new and different ways to ensure that the level of services provided to patients is maintained while also ensuring staff safety.

Chest radiography (CXR) has long been the front line test to assess for the presence of pneumonia and verify line and tube placement (1, 2). Due to the current COVID-19 pandemic, portable chest radiographs are being maximized to reduce patient transfer, including in the emergency department (3, 4). Extra precautions are justified as early stages of the infection are asymptomatic (5). Most national guidelines do not recommend the use of CXR as a screening tool for COVID-19 however it can play in a critical role in assessing for pneumonia complications and excluding other pathology that can present with similar symptoms(6).

The standard procedure to acquire a portable CXR involves close contact between the technologist and the patient. Infection control guidelines require the technologist to use full personal protective equipment (PPE) consisting of a gown, gloves, face shield or goggles, and an N95 respirator (or equivalent airborne precaution protection) when imaging a COVID-19 positive or suspect patient.

Disinfectant wipes are also needed to clean the x-ray machine. At our institution and across the globe, healthcare workers have been faced with shortages of PPE. Therefore, our health system leadership

asked all teams to develop methods to minimize PPE and disinfectant use while maintaining high quality care.

In order to meet this goal, our radiology team worked together to modify the usual procedure for portable chest radiography. We hypothesized that a modified portable chest radiograph technique could be created with X-ray acquisition through the glass door of the patient's room that would allow for increased distancing between staff and patient, maintenance of diagnostic image quality, less PPE use, and similar patient and staff radiation exposure.

Materials and Methods

Study design

This Health Insurance Portability and Accountability Act compliant retrospective study was performed following approval from our university institutional review board with waiver of informed consent. A team involving a senior technologist (KT), a medical physicist (MH), and three radiologists (JP, JB, IC) was formed to develop a new protocol for portable chest X-ray acquisition in the emergency department (ED) based on reports of increased distancing published by others (3, 4). Measurements of scatter radiation and patient dose estimates were performed by the physicist to ensure that safety standards were met. The modified technique group included 50 patients (mean age 59.4 ± 17.3 , range 22-87; 30 women), which consisted of the first portable CXR images taken in our ED. The control group included 50 patients (mean age 59 ± 21.6 , range 19-100; 31 men), which were taken one week prior to implementation of the new technique. Patient's body mass index (BMI) and COVID status were obtained by electronic medical record review by an investigator (AR).

Standard Technique

The routine protocol for portable CXR in the ED for all patients during the pandemic was that the technologist used full PPE. The portable X-ray unit is brought into the patient's room and parked at the end or parallel to the stretcher. The technologist positions the patient and places the detector (within a disposable plastic bag) behind the patient's chest. The distance from the detector to the tube is approximately 50 inches. The technologist then stands 6 feet away when acquiring the image. The technologist removes the detector from the bag, doffs the PPE following standard procedure, and sterilizes the detector and the portable machine with approved disinfectant wipes. Patients wear face masks when possible.

Modified Technique

A new technique was designed to acquire portable CXRs at 72 inches (6 feet) through a glass door which allows the technologist and the X-ray unit to remain outside of the room during image acquisition (Figure 1). The increased distance requires a technique that emits a higher quantity and energy of radiation to ensure good penetration through the glass, adequate exposure at the detector, and low exposure duration to minimize motion blur. The six foot source-detector distance remains within the American College of Radiology practice parameters for portable chest radiography (7). The detector is covered by two plastic bags and given to the nursing staff already in full PPE to place behind the patient's chest under direction of the X-ray technologist. Communication between the patient's nurse and technologist is needed so the X-ray acquisition is coupled with routine in room care. Once the image is acquired, the nurse partially removes the outside bag and the technologist grabs the inner bag containing the detector from outside the room while wearing a standard face mask. The new technique was instituted on each of the portable X-ray units used to obtain portable CXRs in the ED. Generic sizes were used by technologists in choosing technique, with parameters shown in Table 1, although the technologists were free to adjust these parameters to the patient.

A conventional anti-scatter grid was not used with the modified technique. Instead, the increased scatter radiation from high energy X-rays was adjusted for by using a scatter improvement software called SmartGrid (Carestream Health, Inc., Rochester, New York). SmartGrid is a commercially available post processing technique that provides image quality comparable to images acquired with an anti-scatter grid (8). Conventional anti-scatter grids are very sensitive to positioning errors resulting in grid cutoff. Since the detector was not going to be placed directly by the technologist, a software approach was chosen to minimize errors and yield an image with comparable contrast to noise ratio expected with a conventional anti-scatter grid.

Radiation Exposure Measurements

Exposure index (EI) values allow for estimates of radiation exposure at the detector (not patient dose) and can be used as a surrogate marker of image quality and signal to noise (9). Importantly, the EI values can help the technologist know whether proper technique was used for the individual patient size to ensure that ALARA (as low as reasonably achievable) principles are followed (10, 11). The target EI chosen was 300, compared with 200 which is used for standard portable CXR, since using a higher kVP with the same target entrance exposure will result in a higher detector exposure because of less attenuation in tissue. Patient entrance skin doses were estimated using a look-up table from physical measurements and applying the inverse square law to a reference point 30 cm from the detector. Analysis was conducted with an anthropomorphic phantom to assess scatter radiation dose to staff using parameters and distancing of a typical portable X-ray and from the modified algorithm portable chest X-ray (12).

Protocol Implementation

The first five radiographs obtained with the technique were assessed for diagnostic quality immediately after acquisition by the interpreting ED radiologist to ensure the images were adequate. These

radiologists had prior comparison exams available to review. Once the technique was refined, an SBAR (Situation-Background-Assessment-Recommendation) document was created (Figure 2) to frame the communication to all staff, with inclusion of basic workflow for both the X-ray technologist and the patient's nurse. An estimation of PPE savings with the modified protocol was completed.

Image Review

A blinded retrospective review of radiographs taken both before and after the new technique was implemented was performed by three board certified, fellowship trained chest radiologists (IC, AB, CG) with 10, 4, and 2 years of experience to assess diagnostic image quality. The 50 portable CXR images taken with the modified technique were randomized with a control group of 50 portable CXR images taken with the standard technique. Examples of these images are included in Figure 3.

The 100 CXR images were randomized for radiologist review after anonymization and removal of all image notations. The radiologists were blinded to patient and image technique information, including history and indication for the exam. Each radiologist rated the images as diagnostic or non-diagnostic and noted if any parenchymal abnormality was present. The official reports of the 50 CXRs performed with the modified technique were also reviewed by a different chest radiologist (AR) for any mention of limitation described by the radiologist who interpreted the exam clinically.

Technologist Survey

A web-based survey was sent to all 32 technologists who had performed portable CXRs in the emergency department at our primary hospital site from the time the modified technique was instituted. They were informed that their answers were anonymous. The survey consisted of six questions with a choice of responses assessing agreement using a 5-point Likert scale from strongly agree to strongly disagree as shown in figure 4. The technologists were also able to add additional comments by free text.

Statistical Analysis

Statistical analysis was completed in Microsoft Excel (Microsoft, Redmond, WA). Unpaired T-tests were used for numerical data. A P value $< .05$ was considered statistically significant.

Results

Radiation Dose Estimates

Compared to standard technique, the modified protocol resulted in a higher exposure index to the detector ($P < .001$) across all patients (Table 2). Measurements compiled after 1 week of using the modified technique demonstrated that the EI for a patient in 50th percentile by BMI (“average sized patient”) was 316, which was close to the target of 300 (Table 2). The technologists did not use the lower kVp for smaller patients, as even patients in the 10th percentile of BMI (21 kg/m²) were imaged using a kVp of 110. The mean BMI for the modified protocol patients was 30.2 ± 5.9 kg/m², and the mean BMI for the control group was 28 ± 6.5 kg/m² which was not significantly different ($P = .08$). The patient BMI values for the 10th, 50th, and 90th percentile were 21, 29.4, and 41.4 kg/m² for the modified technique group and 19.9, 28.3, and 39.7 kg/m² for the control group. Entrance skin exposures were slightly increased but not significantly different for patients with a BMI less than the 50th percentile ($P = .06$), but higher for patients with a BMI above the 50th percentile ($P = .004$, Table 2).

The estimated technologist entrance dose exposure when standing off to the side six feet from where the x-rays are intercepted by the glass (positioning shown in Figure 1B) was less than the typical portable technique (7 μ Gy vs. 10 μ Gy). However, estimated dose when technologist was positioned six feet directly behind the X-ray unit was greater than a standard portable (16 μ Gy vs. 10 μ Gy).

Image Quality

Of the 100 portable CXRs reviewed, two of the three radiologists considered them all to be diagnostic quality. The third radiologist felt that three of the 100 CXRs were nondiagnostic, two of which were performed with the standard technique and one of which was performed with the modified technique. None of the official reports of the films performed with the modified technique interpreted by the emergency room radiologists mentioned limited exam technique. At least one reviewer labeled parenchymal abnormalities in 23 of the 50 CXRs (46%) performed with the modified technique and 26 of the 50 CXRs (52%) in the control group. Twenty-one patients (21 of 50, 42%) in the modified technique group were COVID positive by lab testing. None of the patients in the control group were COVID positive by lab testing.

Survey Responses and PPE Use

Survey results from the X-ray technologists on the modified technique are detailed in Figure 4. Response rate for survey completion was 81% (26 of 32 eligible technologists), although one technologist only answered four of the six questions. When assessing the modified technique, most agreed (73%, 19 of 26) they felt safer, recognized the decreased use of PPE (92%, 23 of 25), and felt the modified technique was equivalent or less difficult to complete compared to standard portable chest film technique (81%, 21 of 26). Only three of 26 (12%) respondents reported substantial resistance from the emergency room nurses in assisting with detector placement.

An estimation of PPE savings was difficult to quantify as N95 masks and face shields were asked to be used until visibly damaged or soiled at the beginning of the pandemic. This resulted in variable periods of re-use. The technologists reported using the modified technique frequently with 48% (12 of 25) stating they used it in 61-80% of the cases, 36% (9 of 25) reporting they used it in 81-100% of the cases, and 16% (4 of 25) in 0-60%. During the first 2 weeks the modified protocol was in use, 1043 portable chest radiographs were performed in the ED. Assuming an average of 500 portable chest radiographs

per week with 80% use of modified technique and one gown with three disinfectant wipes per encounter results in an absolute savings of 400 gowns and 1200 wipes per week. This also results in 400 less close (ie within 6 feet) patient encounters (and don and doff episodes with a N95 mask and face shield).

Discussion

Our study confirms that a modified portable chest radiograph technique with the technologist and X-ray unit remaining outside the patient's room results in no difference in diagnostic image quality compared to standard portable technique. Forty-nine of the 50 (98%) CXRs using the new modified technique were considered diagnostic quality by all three chest radiologists. In addition, interpreting radiologists who had prior images available for comparison did not report any limitations in their clinical reports. Actual emergency department cases during the pandemic were used, with almost half of the overall group having lung parenchymal abnormalities. This confirms the clinical value of the technique in a real world setting during the COVID-19 pandemic.

Comparing parenchymal abnormalities to COVID lab test data was not possible with our sample because none of the control group had positive tests. The lack of positive testing is likely related to testing availability at that time since parenchymal abnormalities were present in many patients. Presence of abnormalities on chest radiograph is not being used to primarily diagnose COVID-19 and the chest radiograph is not part of the routine screening of these patients, as findings (if present) are non-specific and the CXR can also be normal in patients with a positive lab test (13, 14). Our department and hospital have echoed the American College of Radiology recommendations that CXR and CT should not be used to diagnose COVID-19, but the tests are available, and clinicians often order them, for a variety of indications (6).

Using entrance dose as a measure of patient radiation exposure, the dose was similar between techniques for patients in the 50th percentile of BMI (“average size patients”), but slightly increased for patients with lower or higher BMI. Given the higher energy X-ray beam used in the modified technique, organ doses would be expected to be higher, however they were not calculated for this study. The EI was increased in all patients using the new technique reflecting a higher X-ray beam energy, but this was purposeful to allow for better penetration through the glass and increased distance the beam needed to travel. Future efforts can be focused on decreasing the EI for the new technique closer to the standard, however the amount of noise and motion blur in the images will be a limiting factor and will require continuing feedback from radiologists (15). The scatter removal software was used to reduce errors in grid placement since the detectors were not being placed directly by the technologists. Further testing with a larger sample size of cases would be needed to determine if software use reduces retakes and is necessary to preserve quality. Due to the importance of reducing the use of PPE, a slight tradeoff in image quality would be acceptable if the images remained of diagnostic quality. Our data also confirmed standard safety with regards to estimated scatter radiation dose to staff. Estimated dose was decreased with the modified technique and technologist positioning to the side of the X-ray unit outside the patient room.

Frontline staff perception is also important when implementing changes in a challenging environment (16). The survey responses from our technologists were positive, with most reporting that the initiative was worthwhile, improved safety, conserved PPE, was not more difficult to complete, and was well received by ED nursing staff. Our PPE saved estimation for our institution was also substantial for gowns and disinfectant wipes, N95 masks and facial shields. Grouping the portable radiograph with other care provided to the patient by the ED nursing staff is important to allow PPE savings. If no nurses were available, the standard technique would be used. The modified technique was used for most examinations, attesting to its ease of use and embracement by frontline X-ray and ED nursing staff as a

method to increase safety while conserving PPE. This technique has become the standard in our emergency department and represents an example of administrative controls to prevent exposure as suggested by the Centers for Disease Control (17). Further adaptations to portable radiography techniques are being explored at other sites in our system, as we continue to adapt our practice to the pandemic.

There were limitations in our study. Our sample size was small as this was a single institutional pilot study. Defining the testing characteristics for the radiographs compared to lab testing for COVID-19 was not possible due to sample size and limitations on availability of testing before our protocol was implemented. This study was not designed to validate the findings on the modified radiographs compared to subsequent standard radiographs, as some patients did not have follow up imaging, and those who did were only imaged if their clinical status changed which would be expected to show a change in CXR findings. The image review was not equivalent to the typical process in the clinical setting since prior imaging was not available and clinical histories were removed. The technique was designed and tested for the conditions present in our institution's ED which had room design capable of implementing the modified technique. Our technique requires specific room design features, high quality portable X-ray systems, and a team based approach between ED nursing and radiology technologists, which may not be available at all institutions. We did not specifically study ED nursing opinion in this report and did not study this technique in the intensive care unit or on the clinical floors. Other departments looking to adopt this technique will need to verify that local factors, including the equipment and room construction, do not increase radiation dose or degrade image quality. Anti-scatter software was used in this study which may affect image quality. Lastly, the modified technique requires patient upright positioning (at least 45 degrees) which could limit the use for critically ill patients,

however the nursing staff is often able to tilt the beds forward to allow semi-upright position, allowing the majority of patients to be imaged with this technique.

In summary, we describe a procedure of a modified portable chest radiograph technique using 72-inch unit to detector distance with images acquired through a glass door with the technologist and X-ray unit outside of the patient's room. Image quality remains diagnostic with no increase in technologist radiation exposure and similar patient radiation dose, while allowing conservation of PPE during the COVID-19 pandemic. This modified technique has been embraced as a positive initiative by frontline staff.

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Table 1. Portable X-ray Device Settings for Modified Technique

Subjective Patient Size	Suggested Tube Potential (kVp)	Suggested Tube-Current Time Product (mAs)
Small	105	4
Medium	110	6.3
Large	115	10

Table 2. Summary of the Exposure Index, Estimated Patient Entrance Skin Dose, and Patient BMI between the Standard Portable Chest Radiograph and Modified COVID-19 Chest Radiograph Technique with 6 Foot Distancing

Routine Portable CXR					Modified COVID Technique				
Patient Percentile (corresponding BMI)	EI ($\mu\text{Gy} \cdot 100$)	kVp	mAs	Entrance Dose (μGy)	Patient Percentile (corresponding BMI)	EI ($\mu\text{Gy} \cdot 100$)	kVp	mAs	Entrance Dose (μGy)
10% (19.9)	105	86	2.2	132	10% (21)	165	110	5.9	157
50% (28.3)	209	86	2.9	169	50% (29.4)	316	110	6.3	169
90% (39.7)	405	86	3.6	217	90% (41.4)	665	115	10.0	288

Note.— EI = exposure index



A



B

Figure 1. Ideal positioning while acquiring a portable X-ray. *A*, Before protocol implementation measurements were completed to see where the 6 foot mark was from the glass of the patient's room with the door open. For our facility, this essentially meant moving the patient's stretcher so the foot of the bed was up against the glass door and positioning the X-ray unit just outside the patient's room. *B*, Technologist positioning to the side of the X-ray tube results in less scatter radiation dose. X-ray is taken with door closed and no staff in patient room.

Situation:

During COVID crisis a rise in the use of portable radiographs has been recommended to minimize risk of spread and equipment down time.

Background:

Portable chest imaging is a frequently ordered exam in the work-up of complicated pneumonia and may have a role in patients being admitted with suspected or known COVID infection to assess extent of lung disease. The standard work-flow for a portable chest radiograph for any suspected or known COVID patient would require full PPE use by the technologist and full equipment wipe down if brought into the patient room.

Assessment:

A modification to the portable chest radiograph process for suspected or known positive COVID patients in the Emergency Room may allow for less risk to staff and decreased use of PPE.

Recommendation:

Portable chest radiographs in the ED may be acquired at 72 inches source to detector distance with portable unit outside of patient room

- Patient must be able to sit upright
- RN should don full PPE (note in ED setting surgical mask may be used instead of N95)
- Technologist will wear surgical mask and gloves
- RN will be handed bagged detector and given instructions on proper placement
- RN will move stretcher closer to glass door and exit patient room
- Proper techniques to be set on Revolution portable unit
 - Select “Covid chest” tile
 - with glass: 110 @ 6.4
 - without glass: 110 @ 4
- Exposure will be made with RN outside of room
- After exposure, RN will retrieve the bagged detector and slide it partially out of bag
- Tech will grab detector from inside of bag and disinfect detector with cavi wipes
- RN will then dispose of bag in trash in room

Figure 2 – The SBAR (Situation-Background-Assessment-Recommendation) document that was sent to staff and radiologists to clarify the change in technique for performing portable chest radiographs in the emergency department.



A



B



C

Figure 3 – Examples of portable chest radiographs with clear lungs performed with the *A*, modified technique and with *B*, the standard technique, and *C*, one with parenchymal abnormalities easily visible using the modified technique. *C* demonstrates bilateral, peripheral airspace opacities in a patient who was COVID-19 positive.

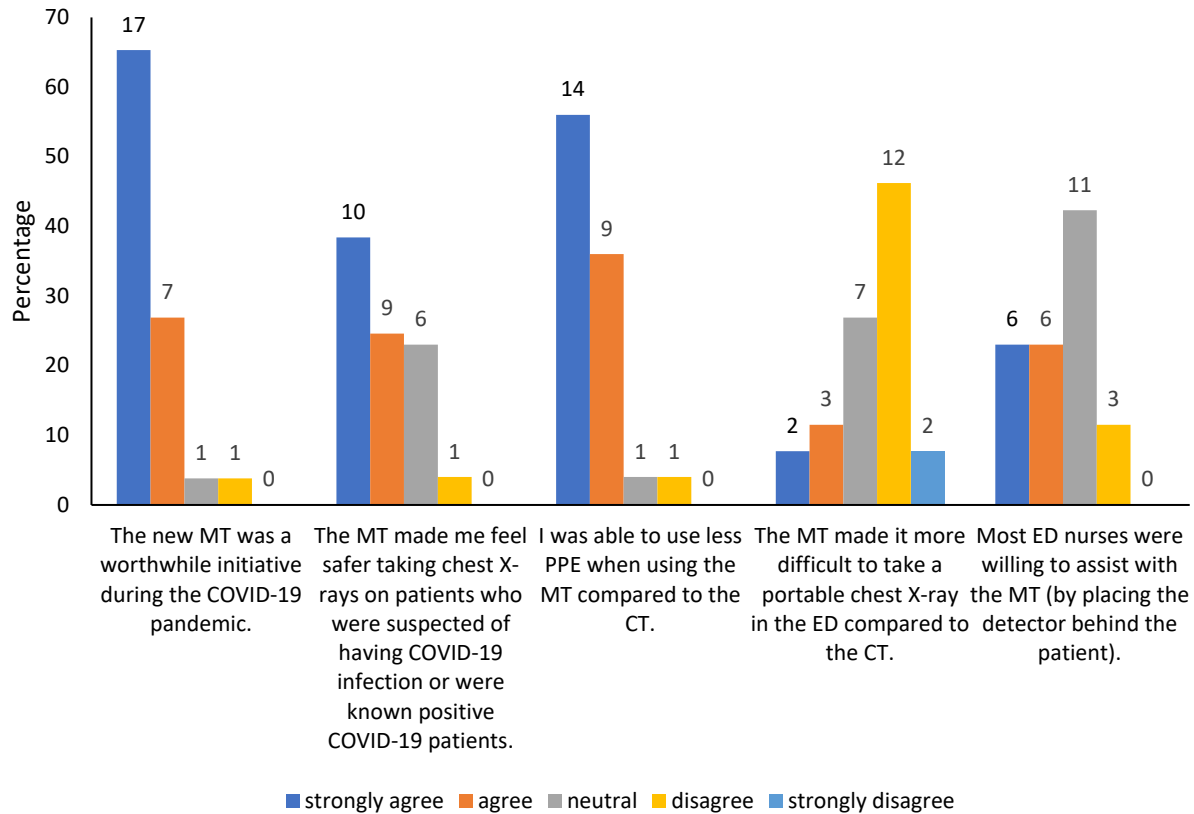


Figure 4. Technologist Likert survey results by percentage of responses. All questions had 26 responses, except for “I was able to use less PPE when using MT than CT”, which had 25 responses. CT = conventional X-ray technique, ED = emergency department, MT = modified X-ray technique, PPE = personal protective equipment