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REVIEW ARTICLE

Modified Chest X-Ray Radiography through Glass Window for Imaging COVID-19 Pneumonia: Techniques and Radiation Dose

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Abstract

The requirement for infection control during the COVID-19 pandemic led to modifying the exposure parameters in conventional radiography for performing chest X-ray radiography (CXR) through-the-glass (TTG) for imaging COVID-19 pneumonia. Herein, we reviewed and reported the current experiences with the TTG protocol, and summarized the current implementation strategies and modified technique factors. For implementing TTG techniques, measurements are required in a simulated environment using a patient equivalent phantom, and a certain number of investigations must be performed before the patient examination. However, the TTG technique requires modification due to the decrease in photon intensity caused by the attenuation in the glass barrier. This study discussed factors affecting CXR and some related radiation dose terminology required for implementing the TTG technique. Moreover, it summarized the exposure factors of CXR using the TTG technique compared with the standard CXR. Radiation exposure to the patient and the staff using the TTG technique remains within the recommended limits for safe practice. Image quality issues arose following the implementation of the TTG technique, mainly related to suboptimal positioning; image artifacts resulted due to glass attenuation, the increased source-to-image distance (SID), and patient movement. Overall, the reviewed results in this study could help formulate international guidelines and recommendations for the TTG technique for COVID-19 patient imaging, thereby minimizing the cost and time required for setting up the protocol.(**International Journal of Biomedicine. 2023;13(2):194-201.**)

Keywords: X-ray radiography • glass window • COVID-19 • radiation dose

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Abbreviations

AK, air kerma; **CXR**, chest X-ray radiography; **EI**, exposure index; **ED**, emergency department; **FSD**, focus to skin distance; **FFD**, focal film distance; **ICU**, intensive care unit; **pCXR**, portable CXR; **PA**, posteroanterior; **PPE**, personal protective equipment; **RT-PCR**, reverse transcription polymerase chain reaction; **SID**, source-to-image distance; **TTG**, through-the-glass.

Introduction

COVID-19 is an infectious respiratory disease caused by the SARS-CoV-2 virus that spread rapidly and became a global pandemic. It causes serious respiratory infections, resulting in a significant number of mortalities.(1-3) Timely detection is essential for quick intervention through necessary control measures to prevent the further spread of the disease to reduce mortality rates and general life disruption. Reverse transcription polymerase chain reaction (RT-PCR) is the standard technique for diagnosing COVID-19, with a sensitivity of 91%.(4) X-ray computed tomography (CT) and chest X-ray radiography (CXR) are other options used to detect and follow up on COVID-19 pneumonia. Compared to CXR, CT has several disadvantages:(5-10) (1) CT scans are not as easy to perform because of the limited availability and scanner disinfection requirements; (2) CT scans cause significant radiation exposure to examined individuals, compared to CXR; (3) during the peak period of the pandemic, the constant use of chest CT scans became difficult to sustain over time. In this regard, CXR is valuable in detecting lung involvement, assessing disease progression, confirming line and tube placement, and evaluating the onset of complications, such as volume overload.

During the pandemic, conventional radiography protocols had to be modified to align with infection control protocols. This led to the use of CXR through a glass window (TTG) to detect COVID-19 pneumonia.(11) TTG is carried out in an isolated room in the intensive care unit (ICU) or emergency department (ED) to minimize cross-infection. The use of glass barriers decreases the need to use personal protective equipment (PPE) and minimizes the risk of staff exposure. Moreover, the patients can remain in isolation and do not need transportation to other areas of the hospital, which would increase the infection risk. In general, it is useful in situations where infection control is important.(5) In hospitals, CXR is used as a primary diagnostic tool for screening suspected COVID-19 cases; it provides results faster than RT-PCR, which minimizes the risk of cross-infection by reducing patient movement.

The TTG method involves imaging with pCXR outside the patient's room and taking pictures through a glass barrier.(7,12,13) A technician outside the isolation room performs the pCXR. In our study, the image receptor was placed in two plastic bags and handed to the staff inside the isolation room, who cleaned the outer bag and placed it for exposure. After the instructions were provided, the technician outside the isolation room was exposed. The staff in the room removed the detector, cleaned it, and sent it for processing. Patients can be involved in this process by holding the detector during exposure. TTG reduces the need for PPE, cleaning supplies, and staff time for cleaning, thus preventing contamination.

Although radiation doses in CXR are low compared to other imaging procedures, the radiation's carcinogenic effect has no threshold, with probability increasing with radiation dose. Thus, the Commission on Radiological Protection (ICRP) has established a radiological protection system that governs the peaceful use of ionizing radiation, comprising justification of practice, optimization, and dose limit.(14) For optimal protection, the radiation dose should be kept as low as reasonably achievable, which is known as the ALARA principle. A radiation shield, minimal time, and distance were combined to reduce radiation exposure when implementing the TTG technique for imaging COVID-19 pneumonia. This study aimed to review and report the technical factors and radiation doses used in TTG for imaging COVID-19 pneumonia. As an additional feature of this article, radiation safety practices will be discussed in comparison with conventional radiography using TTG.

Materials and Methods

In this study, we reviewed all published data concerning the use of CXR through a glass window for imaging COVID-19 pneumonia, up to 2022. We identified the data by searching the Web of Knowledge, Scopus, PubMed, and references from relevant articles, using search terms with suitable keywords. The authors reported their first experience at their hospitals regarding the steps taken to implement the TTG technique, including environment simulation, exposure factors used, and measurement of patient and staff doses. The authors then critically evaluated the articles to extract the relevant information. A search of a scientific literature database yielded 136 articles. After removing duplicates and evaluating titles and abstracts, 20 full-text articles were accessed for eligibility criteria analysis. We analyzed and presented data from 10 articles per predetermined eligibility criteria.

Inclusion and exclusion criteria

All studies on radiation exposure and technical parameters for implementing CXR using a glass window were included. The following were excluded: literature reviews and internal reports, articles that present only clinical data, and articles written in languages other than English.

Data extraction

Data extracted from the surveyed literature included information on glass attenuation factors, patient radiation dose, associated exposure factors used for chest PA examination, scattered radiation data, and the overall influence of the TTG technique on image quality. Two authors checked all the extracted data against the publications to ensure the completeness and accuracy of the collected data.

Results and Discussion

Table 1 summarizes the surveyed studies, their objectives, subjects, and major findings. The survey results have been analyzed in the subsections.

Requirements for the TTG technique

Setting for the TTG technique

When implementing the TTG technique, measurements are required in a simulated environment, such as in the ICU. The subjects needed for the experiment may include the ICU or ED room where TTG will be performed, an anthropomorphic chest phantom, an ionization chamber for patient dose measurements in diagnostic radiology, a survey meter for scattered radiation measurement, and a personal dosimeter. Although the techniques vary from hospital to hospital as they depend significantly on the clinical setting, they most commonly involve the three steps.(7,12,13,15,16) These investigative measurements must be performed before the clinical examination of the patient.

The patient radiation dose can be determined by using a suitable patient equivalent phantom placed in a typical testing room, as well as by the CXR exposure factors: peak kilovoltage (kVp), tube current-exposure time product (mAs), and source-to-image distance (SID) needed to accommodate the TTG X-ray technique.

1. With the glass in place, measurements were made to estimate the glass transmission, which is important in

determining the amount of increase required in the technical parameters (kVp and mAs).

2. The scattered radiation in different positions inside and outside the isolated room was measured to determine the best staff locations to ensure that the TTG technique results in a minimal dose to staff.

3. The scattered radiation was measured at 1m from the glass window to mimic the location of the emergency department staff.

4. The dosimeter measured scattered radiation at 1 m from the phantom to mimic the location of the radiographer within the patient's room.

5. The maximum number of X-ray examinations per week was determined based on a dose constraint of 1mSv for the uncontrolled area.

6. The image quality parameters were assessed to ensure that the diagnostic image quality was preserved when using the TTG technique.

Glass Transmission

The anthropomorphic chest phantom was placed in an isolated room to simulate a real TTG technique. Measurements were taken with a glass in place to estimate the glass transmission. Glass transmission can be estimated from the measurement of the AK before and after glass placement.(15) Glass transmission can also be estimated using the fitting parameters for plate glass published by the National Council on Radiation Protection and Measurements (NCRP) Report No 147.(21) According to this report, the transmission factor of the X-ray beams passing through a glass sheet is determined as follows:

$$B = [(1 + \beta/\alpha)e^{\alpha\gamma x} - \beta/\alpha]^{1/\gamma}$$

where α, β, and γ are fitting parameters and x is the barrier thickness.

The measurement of transmission is important in determining the amount of increase required in the technique factors (kVp and mAs) due to the glass barrier.

Table 1.

Surveyed studies: objectives, subjects, and major findings

Authors	Task	Study Type Parameters Measured	Major Findings
Moirano et al.(12)	To use TTG to minimize infections and keep working efficiency	Phantom Study: TTG portable chest radiography protocol Radiation dose	TTG technique is easy to implement and safe to use for imaging COVID-19 patients and can be used in conditions where infection control is required.
Chan et al.(13)	To evaluate TTG implementation strategy and assess the image quality, radiation safety, and the amount of PPE saving	Phantom Study: Transmission Scattered radiation, Radiation dose, Phantom image quality	Rapid implementation of TTG is possible with the buy-in and training of staff; the resulting image quality is sufficient for COVID-19 detection.
Brady et al.(15)	To evaluate the technical parameters used in the TTG, radiation safety needs, and image quality	Clinical Study: Glass attenuation Radiation dose Scattered radiation Image quality	Successfully implemented TTG for imaging COVID-19 patients; the time for imaging COVID-19 patients is greatly reduced by avoiding the need for disinfection of the X-ray unit.
Mckenney et al.(16)	To provide comprehensive recommendations on TTG technique, including glass transmission, beam penetrability, and radiation	Phantom & clinical Study: Glass transmission Patient safety Staff safety	TTG techniques produced no apparent degradation of image quality, and the patient dose remained unchanged. Scattered radiation levels were low. The authors recommend the use of protective tools to reduce occupation exposure where feasible.
Rai et al.(17)	To ensure radiation safety and acceptable image quality using TTG for imaging adult COVID-19 patients	Phantom Study: Image quality assessment Backscattered dose measurements	TTG technique using smart glass is achievable at acceptable image quality and patient dose.
Schelleman and Boyd (18)	To study the effect of TTG on scattered radiation levels and image quality	Phantom Study: Radiation dose Image quality	Increased exposure factors used in TTG resulted in a good image quality but relatively higher patient doses. The increase in scattered radiation is negligible and can be further reduced by applying common radiation protection measures, including wearing lead aprons and keeping an appropriate distance.
England et al.(19)	To evaluate the effect of TTG on image quality and radiation dose	Phantom Study: Radiation dose Image quality assessment	It is possible to TTG in certain conditions that cause an increase in radiation output and reduction in image quality; TTG implementation requires additional training.
Gange et al.(20)	To develop TTG for saving PPE and reduce the need for disinfectants without compromising much on image quality	Phantom Study: Radiation exposure measurements Image quality PPE use	Unchanged image quality and patient radiation exposure while minimizing PPE needs

Exposure factors and dose quantities in radiography practice

During imaging of COVID-19 patients, technique factors (kVp, mAs, and FFD) used in conventional CXR require modification because of the required increase in FFD for practical reasons and the decrease in photon intensity caused by attenuation in the glass barrier. Table 2 shows other factors affecting CXR and some related radiation dose terminology required to implement the TTG technique.

Table 2.

Factors affecting X-ray radiography and related radiation dose terminology.[22-29]

Source to Image Distance (SID)	Increasing film-focus distance (FFD), X-ray photon intensity will decrease according to the inverse square law hence the radiation dose. There is a requirement to increase the radiation dose to keep the same level of image quality.
Peak tube voltage (kVp)	In the TTG technique, glass attenuates about 40-60 % of the X-ray photons. There is the need to increase kVp, which leads to beam Harding. The TTG technique inclines to reduce image contrast, which necessitates an increase in the exposure factors to preserve the image quality.
Tube current-exposure time (mAs)	mAs represents the quantity of the x-ray photons or the intensity interacting with the human body to form the image. In imaging, through the Glass, the mAs value decreases in two ways: first, by using longer
The exposure index (EI)	EI is a measure of the signal level produced by the image receptor/detector for a given incident air kerma corresponding to the required image quality.
Deviation Index (DI)	The purpose of DI is to give feedback to the technologist on whether the exposure factors used are appropriate for the target imaging quality.
Entrance Surface Air Kerma (ESAK)	ESAK is the air kerma at the entrance of the skin at the center of the beam and includes the backscattered radiation. Radiation dose to a patient undergoing radiographic X-ray is expressed in ESAK.
Effective dose	Effective dose is the tissue-weighted sum of the equivalent doses of all specified tissues and organs of the human body and represents the risk to the of the cancer whole body from partial body irradiations.

Typical technique factors and patient exposure in TTG

As the first step, glass transmission is measured to determine the amount of increase needed in the technique factors (kVp and mAs) due to X-ray beam attenuation in the glass. Brady et al.(15) estimated the glass attenuation to be in the range of 41% at 90 kVp to 49% at 120 kVp for TTG performed using a glass door. McKenney et al.(16) reported a mean transmission value of 39±3%, corresponding to an estimated increase in the exposure factors by a factor of 2.5, yielding the same EI. They reported a glass barrier attenuation of 61% with an effective dose reduction ranging from 50% to 80%. However, when the TTG technique was applied at the same SID, the patient's effective dose increased by approximately 5%–10%. The authors concluded that when all other exposure factors are held constant, due to glass attenuation, the TTG technique requires an increase in the X-ray intensity by a factor of 2.5, which is normally achieved by increasing the mAs. In another study, Rai et al. estimated the linear attenuation coefficient of X-ray photons passing a smart glass in the range of 0.874–0.617 for 90–150 kVp.

Some clinics determine the modified exposure factors based on the experience of the radiographers and by using EI as a segregate for detector dose and image quality. In the TTG technique, the glass attenuates low-energy X-ray photons and depletes them, resulting in increased image noise. Therefore, exposure factors must be increased to preserve image quality.

Brady et al.(15) determined the kVp and mAs values when using TTG according to the patient's size and FSD. Mostly, 105–110 kVp and 4.5–5.0 mAs were used. Rai et al.(17) used an adult anthropomorphic thorax phantom to perform TTG. The technique parameters used for the standard CXR were 100–125 kVp at 1–3 mAs, compared with 125 kVp at 3.2 mAs when using the TTG technique. In a study by Moirano et al.,(12) a technician determined the exposure factors for the TTG technique based on their experience and prior knowledge. They used 130 kVp, 6 mAs, and 180 cm of SID for TTG compared with 130 kVp, 6 mAs, and 180 cm of SID for standard pCXR. Schellman and Boyd(18) investigated the TTG technique by using an anthropomorphic phantom. They used 100 kVp/1.6 mAs for a typical pCXR exposure, compared with 120 kVp/5 mAs for TTG. Finally, Gange et al.(20) retrospectively reviewed 100 radiographs obtained using the TTG technique, in addition to 50 radiographs obtained using the standard CXR. For standard-sized patients, exposure factors of 86 kVp, 2.2–3.6 mAs, and 183 cm of FFD were applied for TTG.

Brady et al.(15) found the KA product value using the TTG to be 0.10 Gy·cm^2, which is similar to the established UK diagnostic reference levels (DRLs) for chest AP (0.1 Gy·cm^2) and EC DRLs for chest PA (0.12–1 Gy.cm^2). TTG resulted in an effective dose of 0.02mSv, similar to a standard CXR. McKenney et al.(16) evaluated TTG techniques by estimating the patient radiation doses and scattered AK. Rai et al.(17) reported adequate image quality when using the TTG technique at acceptable ESAK and showed no significant difference in radiation dose and image between the standard and TTG techniques. In Schellman and Boyd's study,(18) the incident AK to the phantom under TTG (67.82 μGy) was double that of the standard CXR (29.47 μGy). The values remained below the established DRLs for PA-CXR (150 μGy).(30) The image quality scores in TTG were comparable to those acquired using standard CXR. England et al.(19) reported incident AK of 76.3 μGy using the TTG technique, compared with 53.7±0.1 μGy using the standard CXR. The authors used EI as a surrogate for detector dose and image quality to maintain control of zero DI. Gange et al.(20) used EI values as a surrogate for radiation dose and image quality.

The doses administered to the patients were compared with the DRLs in CXR. Table 3 shows the internationally established diagnostic reference levels for adult CXR. Consequently, patient doses in the TTG technique are compared with established international DRLs for adult chest radiography.

Table 3.

International established diagnostic reference levels for adult CXR.

ESAK per radiograph (mGy)	KAP value per radiograph (mGy.cm^2)	Reference
0.15	100	30
0.30	**	31,32

Table 4 shows the exposure factors for standard pCXR for an average-sized adult patient. Figure 1 shows the comparison of ESAK values of adult patients measured using conventional CXR and TTG. The data presented in Table 4 are meant to provide common directions for typical exposure factors that can be expected when applying TTG and should not be used as recommended values. Typical exposures usually depend on hospital conditions, which are determined as described previously.

Table 4.

Exposure factors for conventional radiography versus the modified TTG techniques for adult patients.

Hospital	Protocol	Exposure factor	ESAK (ED)	Reference
H01	TTG	125-130 kVp; 6 mAs; 180 cm SID	Not reported	Moirano et al.(12)
	Standard	100–103 kVp; 2–2.5 mAs; 180 cm SID	Not reported	
H02	TTG	110 kVp; SID 218 cm; 4 mAs	42.94 µGy	Chan et al.(13)
	Standard	110 kVp; 168 cm SID; 0.9 mAs	37.07	
H03	TTG	105–110 kV; 4.5–5.0 mAs	(20 µSv)	Brady et al.(15)
H04	TTG	100 kVp; 3.2 mAs	38.2 µGy (7.7 µSv)	McKenney et al.(16)
	Standard	100 kVp; 1.6 mAs	28.4 µGy (7.2 µSv)	
H05	TTG	95 kV; 6.4 mAs	50.3 µGy (16.6 µSv)	McKenney et al.(16)
	Standard	95 kVp; 4 mAs	59.5 µGy (21 µSv)	
H06	TTG	125 kVp; 6.3 mAs; 180 FDD	146.3 µGy	Rai et al.(17)
	Standard	125 kVp; 3.2 mAs; 180 FDD	150.9 µGy	
H07	TTG	100 kVp; 20 mAs; 180 FDD	240 µGy	Rai et al.(17)
	Standard	100 kVp; 2.0 mAs; 180 FDD	52.8 µGy	
H08	TTG	120 kVp; 5 mAs; SID 219 cm	91.6 µGy	Schelleman and Boyd(18)
	Standard	100 kVp; 1.6 mAs; SID 219 cm	39.8 µGy	
H09	TTG	90 kV; SID 180 cm; 11.25 mAs	76.3±0.8 µGy	England et al.(19)
	Standard	90 kV; SID 180 cm; 8 mAs	53.7±0.1 µGy	
H10	TTG	110 kVp; 5.9-10.0 mAs; 183 cm FFD	157-288 µGy	Gange et al.(20)
	Standard	86 kVp; 2.2-3.6 mAs; 183 cm FFD	132-217 µGy	

*Value of incident air kerma (IAK) is converted to ESAK using (ESAK = IAK*BSF; BSF =1.35 for chest X-ray)*

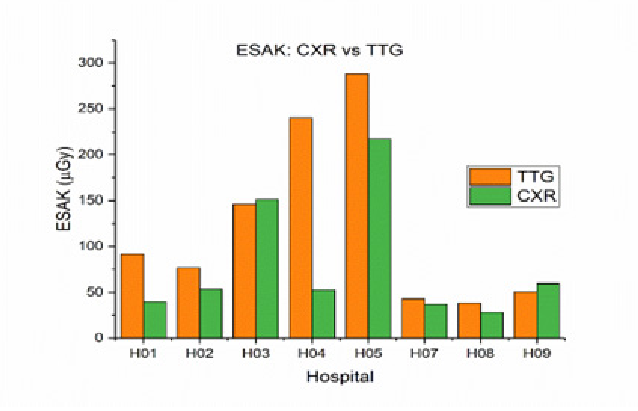

Fig. 1. *Comparison of ESAK values of adult patients measured using conventional CXR and TTG*

<u>Image Quality Issues with TTG</u>

When using the TTG technique, Moirano et al.(12) noticed that most image artifacts were motion-related, probably caused by increased exposure time, and are more noticeable in intubated hypersthene patients. Artifacts could also be caused by the glass barrier type and design; these can be mitigated by reducing the SID where possible. Furthermore, a respiratory therapist standing behind suitable shielding can ask patients to hold their breath, and using a ventilator, if necessary, could reduce the artifact. Moirano's findings are corroborated by McKenney et al.(16)

In the study by Brady et al.,(15) radiologists and radiographers assessed the TTG technique. The radiologist determined the image quality, whereas the radiographer critically assessed the techniques affecting the diagnostic quality. Both groups reported an overall good image quality when using the TTG technique. According to radiographers, under-collimation is the most problematic aspect of the through-glass technique. When the SID is too long, minor adjustments can significantly affect the collimation. According to Rai et al.,(17) glass attenuation of low-energy X-ray photons results in increased image noise, necessitating an increase in exposure factors to preserve the image quality. The authors reported adequate image quality when using the TTG technique at an acceptable radiation dose; further, they found that the difference in the image quality was not significant between the standard and TTG techniques. In pCXR, where the patient suffers from an acute condition and does not cooperate, positioning and inspiratory effort may not be optimal. As a result, TTG images were highlighted for their suboptimal positioning issues.

Schellman and Boyd(18) reported that ED patients presenting with suspected or confirmed COVID-19 could be imaged through glass with high image quality. England et al.(19) measured the signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) as physical image quality parameters. The authors reported insignificant differences in SNR between the CXR and TTG techniques. In contrast, a small reduction in CNR was observed when TTG was used, which was not apparent in the perceptual analysis. According to the authors, CNR is more sensitive than visual inspections in revealing changes in image quality.

Staff Exposure, Radiation Protection, and Safety

One of the requirements for using the TTG technique is the measurement of scattered radiation at the radiographer's location and at different points.

The TTG technique could involve different exposure categories, including medical exposure of patients, occupational exposure of workers, and, to a lesser extent, public exposure to patients' relatives and caretakers. According to the International Commission on Radiological Protection, both the public and radiation workers are subject to the principle of dose limitation. The staff should adhere to the basic radiation protection points, which involves minimizing the time and distance of exposure while shielding as practically possible. Radiology technicians, nurses, and radiologists involved in TTG and other imaging procedures must wear lead-equivalent aprons and personal dosimeters. Hence, it is ideal for hospitals to establish radiation surveillance programs. According to NCRP, the level of radiation exposure in uncontrolled areas should not exceed the recommended dose limits.(21)

Brady et al.(15) measured AK from scattered radiation using an anthropomorphic adult chest phantom. They simulated both a standard and a TTG X-ray environment using 110 kV, 5 mA, and an SID of 205 cm. The measured AK from the scattered radiation at the position of the radiographer 1m from the X-ray unit reached up to 0.06 µGy/mAs, whereas the backscattered AK from the glass was as high as 0.3 µGy. Inside the room, the AK from the scattered radiation was 0.4 µGy at 1m and 0.1 µGy at 2 m. An operator received a total dose of 0.03–0.04 mSv over one month. According to their findings, unshielded personnel consistently positioned 1m from the patient were likely to remain within the occupational dose limits. To provide maximum protection to the staff, they used a dose constraint of 1 mSv. A worker exposed to 0.5 mSv at 1m from the X-ray tube would need 2000 chest radiographs to reach 1 mSv in one year. Similarly, McKenney et al.(16) measured AK from scattered radiation in a simulated TTG technique using an anthropomorphic phantom. They found that lead aprons, mobile shields, and increased distances, where possible, helped lower staff radiation doses.

Rai et al.(17) measured backscattered radiation at 2 m from the patient. For a standard CXR, the backscatter was 0.02 µSv, compared with 0.04–0.22 µSv for the TTG CXR. At 100 kVp and 20 mAs, the maximum AK from the backscattered radiation from the glass was in the range of 0.14–0.22 µSv. In another study, Gange et al.(20) measured the AK rate of the technician standing 1.8 m (6 feet) from the pCXR and found it to be 7 µGy using the TTG technique, compared with 10 µGy during a typical CXR examination. However, the radiation entrance exposure to the technician standing 6 feet behind the radiographic unit was as high as 16 µGy. Considering the recommended yearly dose of 20 mSv for radiation workers, this limit is unlikely to be exceeded for moderate workloads per annum. According to Yeung et al., (33) there was no statistically significant increase in the number of staff receiving doses exceeding 0.01 mSv per quarter when performing TTG. Therefore, the radiation risk to radiographers was not significant.

As shown in Table 5, using the modified imaging technique, the AK rates from scatter radiation were ensured to be within the acceptable limit for staff positions inside and outside the patient's room. On average, approximately 2000–3200 X-ray radiographs could be taken per year without exceeding the public dose limit of 1mSv for staff standing at least 2 m from the X-ray machine during exposure.

Table 5.

Scatter radiation measured during TTG technique.

Study	Inside the isolation room		Outside the isolation room at the operator
	Behind the patient*	Beside the patient**	
Brady et al. (15)	0.4 µGy	**	0.3 µGy
Mckenney et al.(16)	0.16	0.212	0.26
Mckenney et al.(16)	0.008	0.15	0.02
Rai et al.(17)	0.02(0.04-0.22)	**	0.05
Schelleman and Boyd(18)	0.51 µGy	**	0.99 µGy
Gange et al.(20)	**	**	7-16 µGy

**Dosimeter measuring scatter radiation at 1 m from the phantom to mimic the location of the radiographer within the patient room.*

***Dosimeter measuring scatter radiation at 1 m from the glass window to mimic the location of pCXR operator outside the isolation room*

Conclusions and Future Directions

The current survey reviewed and reported the latest experience with TTG and summarized the implementation strategies, technical factors, and radiation doses administered directly or indirectly to patients and staff. The TTG technique may be performed in the ED or ICU to minimize the requirements for disinfection of imaging equipment and reduce cross-infection. Initially, a feasibility study was required in a simulated environment using an anthropomorphic adult chest phantom to determine the appropriate technical factors pertaining to the TTG technique, measure the scatter radiations, and determine appropriate staff positions. Some hospitals determine the aforementioned factors by relying on their staff's experience and knowledge. When imaging through a glass barrier, the X-ray photon intensity decreases owing to the increased SID, according to the inverse square law and attenuation by the glass barrier.

Thus, the TTG technique requires an increase in both kV and mA to compensate for the photon loss. The DRL values in radiography are used to ascertain that the patient dose levels remain within the recommended criterion. The optimization of protection requires practicing the basic radiation safety principles of shielding, time, and distance. Hospitals ensure this by using a lead apron and scatter radiation measurements to ascertain that exposure levels remain within the recommended dose limits.

A noticeable effect of the TTG technique is a reduction in image quality owing to the increased SID and beam hardening due to glass attenuation, which affects the image contrast. During TTG, EI is used as a surrogate for detector dose and image quality, and it should be within the recommended value.

Overall, the results of the surveyed literature could help formulate international guidelines and recommendations for the use of TTG technique for imaging COVID-19 patients. Such guidelines can help minimize the cost and time required for outpatients and accelerate pCXR examinations in suspected and confirmed COVID-19 patients, helping reduce the disease's morbidity and mortality.

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Competing Interests

The authors declare that they have no competing interests.

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