



Investigation of the Radiographer's adherence and compliance with radiation protection and infection control practices during COVID-19 mobile radiography

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ABSTRACT

Radiological staff, especially radiographers, work as front liners against the COVID-19 outbreak. This study aims to assess compliance with radiation protection and infection control practices during COVID-19 mobile radiography procedures. This cross-sectional study included 234 radiographers (females, 56%, $n = 131$; males, 44%, $n = 103$) who were asked to complete an online questionnaire consisting of demographic data, radiation protection and infection control practices during COVID-19 portable cases, and knowledge and awareness. After informed consent was completed, SPSS statistical software was used for the data analysis. The most common age group of participants ranged from 18 to 25 years old (30.3%, $n = 71$). Bachelor's degree holders were 74.4% ($n = 174$). Most radiographers (39.7%, $n = 93$) had a working experience of 1–5 years, followed by 27.8% ($n = 65$) with more than 16 years of experience. Most respondents (62.4%, $n = 146$) handled approximately 1–5 cases daily, the majority of them (56%, $n = 131$) stated affirmatively they had obtained special training to handle COVID-19, and when inquired if they had received any special allowances for handling COVID-19 suspected/confirmed cases most of them stated negative (73.9%, $n = 173$). Most participants stated that they always wear a TLD during portable cases (67.1%, $n = 157$) and a lead apron (51.7%, $n = 121$). Around 73% ($n = 171$) knew the latest information on COVID-19 and attended the COVID-19 awareness course. A significant association was found between the work experience of the radiographers and their responses to following the best practices ($p = 0.018$, $\alpha = 0.05$). Radiographers who had COVID-19 training ($\mu = 48.78$) tend to adhere more to best practices than those who have not ($p = 0.04$, $\alpha = 0.05$). Further, respondents who handled more than 16/more COVID-19 suspected/confirmed cases followed the best practices more ($\mu = 50.38$) than those who handled less ($p = 0.04$, $\alpha = 0.05$). This study revealed detailed information on radiation protection and infection control practices during COVID-19 mobile radiography. It has been observed that the participants/radiographers have good knowledge and awareness of radiation protection and infection-control practices. The present results may be used to plan future requirements regarding resources and training to ensure patient safety.

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1. Introduction

Coronavirus disease (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus. Most infected with this virus develop mild to moderate respiratory symptoms and recover without specific treatment. Some people, however, become critically unwell and require medical attention. The first instance was discovered in December 2019 in Wuhan, China (Yu et al., 2020) (Hadi et al., 2021). The disease quickly spread worldwide, resulting in the COVID-19 pandemic (Niu Y et al., 2020). COVID-19 can be identified based on symptoms and verified by RT-PCR or other contaminated secretion nucleic acid tests (Zhang et al., 2020). Chest X-ray (CXR) computed tomography (CT) and laboratory tests may be helpful in diagnosing COVID-19 in those with a high clinical suspicion of infection. Most specialist facilities, clinics and hospitals have mobile radiographic imaging devices (Osman et al., 2023). The analysis of CXR images from COVID-19 patients revealed that this test was a quick and cost-effective strategy for diagnosing the individuals in question (Chalkia et al., 2022). The number of mobile X-ray procedures increased massively during the pandemic, as they were used for diagnosis and follow-up for suspected and confirmed COVID-19 cases (Abuzaid et al., 2022).

Radiographers and radiologists are highly skilled users of imaging technologies and are involved in direct contact with COVID-19 cases (Martell et al., 2022). They were trained to use imaging for the best benefit of patients. Understanding potential concerns from ionizing radiation is an essential component of their education, as it is necessary to minimise the risk of injury from inappropriate or excessive radiation usage. The radiology profession's obligations go beyond radiation protection, including infection prevention when doing radiology examinations (Martell et al., 2022).

Consequently, radiographers had difficulty establishing an adequate distance between them, the radiation source, and the resultant scattered radiation at all times. While the International Society of Radiographers and Radiologic Technologists recommends a distance of 2 m between the patient and radiographer, studies have shown that yearly maximum permissible doses are not exceeded for mobile X-ray imaging at distances of 1 m (ISSRT, 2020). However, for COVID-19, stricter infection control measures, such as additional equipment restraints or lead-equivalent protection, have been recommended (Yeung et al., 2022).

Radiological staff, especially radiographers, working at the front line in combat of the COVID-19 outbreak. They are in direct contact with patients, bearing the responsibility and risk of infection prevention, control and radiation protection. Undertaking radiographic procedures when there is a possibility that the patient may be Covid-19 positive brings its challenges (ISSRT, 2020, Thomas et al., 2022, Society of Radiographers U., 2021).

The COVID-19 pandemic has led to the implementation of infection prevention and control (IPC) measures in healthcare settings, including radiology departments. This scoping review aimed to identify and summarise the IPC practices that have been implemented in radiology departments during the pandemic. Various studies were included in the review. The findings showed that the most common IPC measures included triaging patients, screening for COVID-19 symptoms, using personal protective equipment (PPE), environmental cleaning and disinfection, and social distancing. The review also identified challenges faced by radiology departments in implementing IPC measures, including PPE shortages, staff training and patient compliance with IPC measures (Yu et al., 2020; Naylor et al., 2022; Mc Fadden et al., 2022, Clements et al., 2020).

The aim is to study radiographers' compliance with radiation protection and infection control practices during COVID-19 mobile radiography.

2. Materials and methods

2.1. Methods

During the pandemic, a cross-sectional study was conducted among radiographers and radiological technologists who examined suspected and confirmed COVID-19 cases in Saudi Arabia. The research team, four senior radiographers, and infection control managers devised, vetted, and piloted the survey. The evaluation was conducted to ensure that the questions were displayed appropriately and comprehensibly and returned the required information. The results of the pilot research were removed from the primary investigation.

The demographic characteristics were the first section of the questionnaire (e.g., age, academic qualification, work experience, the average number of COVID-19 cases handled daily, and receiving any special training or allowance during the pandemic). The second part examined whether participants' radiation protection practices reduced radiation exposure for workers, staff, and patients. The use of thermoluminescence dosimeters (TLDs), lead aprons, thyroid collars, collimation, distance shielding, gonad shielding and the proper exposure parameters were all studied. In the third part, infection control measures were assessed, such as personal protective equipment (PPE), infection prevention, equipment disinfection, hand hygiene and following the standard documentation routine.

The survey employed a 4-point Likert scale with the following scores: (4) always, (3) often, (2) occasionally, and (1) never. The better the practice, the higher the score. By dividing the total score by the maximum possible score multiplied by 100, the score was converted to a percentage scale. As a result, the score was divided into three categories: poor adherence (less than 60%), moderate adherence (60–80%), and good adherence (more than 80%).

2.2. Data analysis

A total of 234 responses were received, of which all questionnaires were completed and therefore included in the study. The responses were collected and analyzed using the Statistical Package for Social Sciences (SPSS) and IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM. Graphs for responses were created using Microsoft Office Excel 2016 (Microsoft Corporation, CA, USA). Following the descriptive statistics for all questions, a one-way analysis of variance (ANOVA) was conducted to analyze the association between the demographics and the participants' infection control and radiation protection practices.

2.3. Ethical considerations

The Institutional Research Unit approved the research protocol. All respondents gave their informed consent after learning about the study's goals and being assured of anonymity. The participants were told that they could leave at any point during the data collection process.

3. Results

3.1. Demographic and participants' background

The responses recorded from the 234 participants are shown in Table 1. The majority were females (56%, $n = 131$); 30.3% ($n = 71$) were 18–25 years old. Nearly three-quarters of the participants had the highest qualification of a bachelor's degree (74.4%, $n = 174$), and participants with a PhD were the least (2.1%, $n = 5$).

Most radiographers (39.7%, $n = 93$) had a working experience of 1–5 years, followed by 27.8% ($n = 65$) of radiographers with more than 16 years of experience. The respondents were asked about 'the approximate number of portable COVID-19 suspected or confirmed cases that they handled daily', and most respondents stated approximately 1–5 cases (62.4%, $n = 146$). Some respondents had handled around 11–15 cases a

Table 1
Distribution of the demographic characteristics of the participants (n = 234).

Criteria	Responses	Frequency (%)
Gender	Male	103 (44.0)
	Female	131 (56.0)
Age (years)	18–25	71 (30.3)
	26–35	70 (29.9)
	36–45	53 (22.6)
	46–65	40 (17.1)
	66–75	10 (4.2)
Qualification	Diploma	25 (10.7)
	Bachelors	174 (74.4)
	Masters	30 (12.8)
	PhD	5 (2.1)
Experience	1–5 years	93 (39.7)
	6–10 years	35 (15.0)
	11–15 years	41 (17.5)
	More than 16 years	65 (27.8)
Number of Covid-19 cases handled per day	1–5	146 (62.4)
	6–10	54 (23.1)
	11–15	16 (6.8)
	More than 16	18 (7.7)
COVID-19 related training	Yes	131 (56.0)
	No	103 (44.0)
Allowances/incentives received	Yes	61 (26.1)
	No	173 (73.9)

day (6.8%, n = 16) and more than 16 cases too (7.7%, n = 18). The radiographers were also inquired 'if they had obtained special training to handle the COVID-19 confirmed or suspected cases', for which the majority of them stated affirmative (56%, n = 131) and when inquired 'if they had received any special allowances for handling COVID-19 suspected/confirmed cases', most of them stated negative (73.9%, n = 173).

3.2. Radiation protection practices during COVID-19 portable cases

This questionnaire section comprises 10 sub-questions, each gathering responses on a 4-point Likert scale. The descriptive statistics of the responses are given in Table 2.

Most participants stated that they always wear a TLD during portable cases (67.1%, n = 157) and a lead apron (51.7%, n = 121). Most participants never responded when asked whether they wore a thyroid collar (51.3%, n = 120). The respondents said they always used proper collimation (50%, n = 117) and proper SID/FFD (48.3%, n = 113). When applying gonad shielding, most participants said they sometimes applied it (35%, n = 82), and close to one-third of the participants

Table 2
Radiation protection practice frequencies.

Monitoring characteristics	Never (%)	Sometimes (%)	Most of the time (%)	Always (%)
Wearing TLD	25 (10.7)	22(9.4)	30(12.8)	157 (67.1)
Wearing lead apron	21(9.0)	57(24.4)	35(15.0)	121 (51.7)
Wearing thyroid collar	120 (51.3)	57(24.4)	26(11.1)	31(13.2)
Using proper collimation	3(1.3)	35(15.0)	79(33.8)	117 (50.0)
Using proper SID/FFD	5(2.1)	42(17.9)	74(31.6)	113 (48.3)
Apply patient gonad shielding	28 (12.0)	82(35.0)	53(22.6)	71(30.3)
Apply patient lead shielding	24 (10.3)	67(28.6)	64(27.4)	79(33.8)
Using minimum exposure time	3(1.3)	26(11.1)	93(39.7)	112 (47.9)
Using the lead apron for all co-patient/staff	16(6.8)	55(23.5)	82(35.0)	81(34.6)
Closing the room door	1(0.4)	9(3.8)	82(35.0)	142 (60.7)

(33.8%, n = 79) said they always applied gonad shielding. Most respondents stated that they always use minimum exposure time (47.9%, n = 112), provide a lead apron for all co-patient/staff (34.6, n = 81), and close the room door (60.7%, n = 234).

3.3. Infection control practices during COVID-19 portable cases

The third part of the questionnaire gathered responses through 5 sub-questions based on a 4-point Likert scale. The responses are given in Table 3. Most respondents stated that they always wear personal protective gear, facemasks, gloves, face shields, etc. (71.8%, n = 168) and maintain appropriate isolation precaution practices (64.5%, n = 151) when handling COVID-19 suspected/confirmed patients in portable radiography. The respondents also stated that they always disinfect according to infection control policies and procedures (61.1%, n = 143), maintain hand hygiene (personal cleanliness) (69.7%, n = 163), and follow standardized hospital protocols for decontaminating imaging equipment after the imaging procedure (68.8%, n = 161).

The respondents' knowledge, awareness, and information were analyzed through a series of 6 questions. The respondents were asked if they knew the latest information on COVID-19 and had attended the COVID-19 awareness course; most (73%, n = 171) stated yes. A majority of the respondents had attended the COVID-19 awareness course (73.1%, n = 171), received department support during the pandemic (52.6%, n = 123), and received hospital support during the pandemic (46.6%, n = 109).

Almost half of the respondents (51.3%, n = 120) stated that they are confident in handling COVID-19-suspected patients to a great extent. For most participants, health organizations (69.2%, n = 162) were the primary sources of information and social media, second to it (12.0%, n = 28).

3.4. Comparison of demographics and responses

A one-way ANOVA was conducted to analyze any association between the demographics and their responses regarding radiation protection and infection control practices. The 4-point Likert scale responses were scored from 1 to 4, where 1 = 'Never', 2 = 'Sometimes', 3 = 'Most of the time', and 4 = 'Always'. The lowest score of 15 meant not following proper infection control and radiation protection practices, and the highest score of 60 meant adhering to best practices.

A significant association was found between the work experience of the radiographers and their responses to following the best practices (p = 0.018, $\alpha = 0.05$). In contrast, radiographers with more than 16 years of experience ($\mu = 49.7$) and between 1 and 5 years ($\mu = 48.2$) of experience tend to follow more than the rest. The study also revealed

Table 3
Infection control practice frequencies.

Information was sought.	Never, N (%)	Sometimes, N (%)	Most of the time, N (%)	Always, N (%)
They wore personal protective gear, facemasks, gloves, face shields, etc.	6(2.6)	29(12.4)	31 (13.2)	168 (71.8)
Appropriate isolation precaution practices are maintained during portable radiography	9(3.8)	27(11.5)	47 (20.1)	151 (64.5)
Equipment disinfected according to Infection Control policies and procedures	10 (4.3)	21(9.0)	60 (25.6)	143 (61.1)
Hand hygiene (personal cleanliness)	4(1.7)	17(7.3)	50 (21.4)	163 (69.7)
Standardized hospital protocols for decontaminating imaging equipment after the imaging procedure	7(3.0)	17(7.3)	49 (20.9)	161 (68.8)

that radiographers who had COVID-19 training ($\mu = 48.78$) tend to adhere more to best practices than those who have not ($p = 0.04$, $\alpha = 0.05$). Further, respondents who handled more than 16 COVID-19 suspected/confirmed cases followed the best practices more ($\mu = 50.38$) compared to those who handled lesser ($p = 0.04$, $\alpha = 0.05$).

4. Discussion

Rapid and precise diagnostic procedures were required during the COVID-19 epidemic. It has been confirmed that medical imaging (chest radiography and computed tomography) is critical in the fight against COVID-19 (Yeung et al., 2022). The safety of patients, professionals, and the general public during medical imaging studies is critical. As the epidemic continues, medical imaging professionals must develop the knowledge and skills to ensure patient safety and up-to-date information. Several studies and papers have been published focusing on patient safety in medical imaging during COVID-19 and the obstacles and optimization solutions in radiology service during the pandemic (Abuzaid et al., 2022). During the COVID-19 epidemic, the increased use of mobile radiography necessitated greater attention to occupational and patient dosages. The International Society of Radiographers and Radiologic Technologists (ISRRT) issued a response document in April 2020 to ensure patient safety and radiation protection during medical imaging procedures in COVID-19 instances (ISSRT, 2020).

4.1. Radiation protection practices during COVID-19 mobile cases

Radiographers who work with ionizing radiation are responsible for patient and public radiation safety. Because X-rays use ionizing radiation, which can deposit energy in human cells and cause tissue changes, patient-associated risks must be minimized (Alkhorayef et al., 2020; Osman et al., 2022). Dose reduction is accomplished by reducing the radiation used to create the clinical images required to answer a medical query. The ALARA concept is crucial because it can help to avoid overexposure and unnecessary exposure. ALARA principles are based on three elements controlled by radiographers: time, distance and shielding (Abuzaid et al., 2022; Elshami et al., 2019). Results showed moderate attention to the use of proper collimation (50%, $n = 117$), minimum exposure time (47.9%, $n = 112$), and use of proper SID/FFD (48.3%, $n = 113$). Both collimation and distance must be adjusted strictly to focus on a specific part of the patient's body, limiting the radiation beam within the range defined by clinical procedures and ensuring that it matches the image detector. In addition, to reduce scattered radiation, proper collimation and distance may improve image contrast and reduce geometric distortion (Niu et al., 2020). Reducing exposure time can directly reduce the radiation dose, absorbed dose, and biological effects of ionizing radiation.

The practices that were either neglected or never used by a large proportion of the radiographers were the use of lead gloves during fluoroscopy (37.6%), wearing a thyroid collar during OT (18.3%), and wearing TLDs (15.7%). Around 62.5% wear TLD and lead aprons during the mobile radiography procedure. This result agrees with the study done by Abuzaid et al. Al, entitled 'Assessment of compliance to radiation safety and protection at the radiology department' (Abuzaid et al., 2019).

When using mobile DR equipment for examination in an area such as a fever clinic, where no dedicated diagnostic examination room is built, the persons around such an area should be informed to leave as far as possible. Additionally, there should be no other persons in the main direction of the radiation beam. When using mobile DR equipment for X-ray examination in a quarantine ward, protection measures should be taken for the patients in the adjacent beds within 2 m of the DR equipment. At the same time, irradiation beams should not be directed toward other patients. The length of the cable connecting the exposure switch should not be less than 3 m; otherwise, a remote control/delayed exposure switch has to be equipped.

4.2. Infection control practices and knowledge during COVID-19 mobile cases

Knitted constructs are considered better suited to cloth masks than woven structures due to their thicker cross-sections and high air permeability. People should be encouraged to procure a high-quality mask to help reduce the spread of SARS-CoV-2 and shield against sun exposure

(ISRRT, 2020; WHO Guidance Note., 2020). However, the types of gloves should also be carefully selected according to the objects to be protected against. The best gloves for healthcare workers are the first latex and second nitrile. Although this principle is appropriate for protection from viral infection, it is not always suitable for protecting unsealed radioactive materials (Niu et al., 2020; Amalou et al., 2020).

When the mobile DR equipment needs to be moved out of the fever or other clinics for use, the entire surface of the equipment must receive wipe disinfection and then be exposed to ultraviolet light for more than 30 min before use. The worker should wear an N95 mask or higher, a disposable fluid-resistant gown, gloves, goggles, or a visor for eye protection (ISSRT., 2020, WHO Guidance Note., 2020). Our workers wore PPE, a disposable fluid-resistant gown, gloves, goggles, or a visor for eye protection.

Being familiar with the requirements for infection control and prevention at different posts, it is necessary to know the related types of protective articles and their uses and the requirements and methods for disinfection of personnel, equipment, and places (Yeung et al., 2022). Table 4 shows that most participants have enough knowledge and awareness, and received support from their departments in attending courses and trainings during the pandemic.

4.3. Comparison of demographics and responses

A significant association was found between the radiographers' work experience and their responses to following the best practices. However, this result contrasts with the study 'Knowledge of COVID-19 infection control among healthcare workers in radiology departments in Saudi Arabia'. There was a significant association between the profession and good clinical practices in radiology departments regarding COVID-19. Such knowledge could limit the spread of COVID-19 among healthcare workers in radiology departments.

The study also highlights the importance of improving training, department design, patient triage, post-exposure patient handling, and the implementation of paperless systems to better handle COVID-19 and protect radiology staff. Additionally, a novel isolation bag device is proposed for use in CT to facilitate containment and reduce contamination in radiology departments during the COVID pandemic. Overall, this study sheds light on the crucial role of radiographers in fighting against COVID-19 and emphasizes the need for their safety and protection.

5. Conclusion

This study investigates radiographers' adherence to and compliance

Table 4
Knowledge and awareness of participants.

Information was sought.	Yes N (%)	No N (%)	Sometimes N (%)
Up to date aware of the latest information on COVID-19	171 (73.1)	28 (12.0)	35(15.0)
Attend any COVID-19 Awareness Course	171 (73.1)	42 (17.9)	21(9.0)
Get any department support during the pandemic	123 (52.6)	52 (22.2)	59(25.2)
Get any hospital support during the pandemic	109 (46.6)	68 (29.1)	57(24.4)

with radiation protection while performing mobile radiography for COVID-19 cases. The incidence of COVID-19 infection among radiology personnel is primarily due to a poor understanding of the newly emerged virus. The disease can better be handled, and the radiology staff can better be protected by improving the training, department design, patient triage, post-exposure patient handling, and implementing paperless systems. A novel isolation bag device is feasible for use in CT and might facilitate containment and reduce contamination in radiology departments during the COVID Pandemic. The present results may also be used to plan future requirements regarding resources and training to ensure patient safety.

6. Recommendations

The paper recommends improving the training, department design, patient triage, post-exposure patient handling, and implementation of paperless systems to better handle COVID-19 and protect radiology staff. The study also proposes a novel isolation bag device for use in CT to facilitate containment and reduce contamination in radiology departments during the COVID pandemic. The results of this study may be used to plan future requirements in terms of resources and training to ensure patient safety. Overall, the paper emphasizes the importance of ensuring the safety and protection of radiographers during the COVID-19 pandemic.

Author contributions

Conceptualization: M.M.A;
 Methodology: I.A.M and M.Y;
 Software: I.A.M, M.Y and A.M.A;
 Validation: M.U.K, A.M.A and H.O; Formal analysis: H.O, M.Y and S. J;
 Investigation: H.O, M.M.A, Q.T.A, A.M. and A.M.A.M.;
 Resources: H.O, M.M.A and Q.T.A; Data curation: H.O and S.S.A;
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 Visualization: S.E.L and D.A.B;
 Supervision: M.U.K and H.O; Project administration: H.O; Funding acquisition: H.O.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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