



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Knowledge of COVID-19 infection control among healthcare workers in radiology departments in Saudi Arabia

Rowa Aljondi^a, Salem Saeed Alghamdi^a, Ikhlas Abdelaziz^a, Lubna Bushara^a, Somayah Alghamdi^b, Abdullah Aljehani^c, Ali Zailae^d, Jamaan S. Alghamdi^e, Iyad Feteih^f, Mustafa Z. Mahmoud^g and Abdulrahman Tajaldeen^h

^aDepartment of Applied Radiologic Technology, Collage of Applied Medical Sciences, University of Jeddah, Jeddah, Saudi Arabia;

^bRadiology Department, King Abdulaziz University Hospital, Jeddah, Saudi Arabia; ^cRadiology Department, King Abdulaziz Hospital,

Jeddah, Saudi Arabia; ^dRadiology Department, King Saud Medical City, Riyadh, Saudi Arabia; ^eDiagnostic Radiology Technology

Department, College of Applied Medical Science, King Abdulaziz University, Jeddah, Saudi Arabia; ^fCollage of Medicine, University of

Jeddah, Jeddah, Saudi Arabia; ^gRadiology and Medical Imaging Department, College of Applied Medical Sciences, Prince Sattam Bin

Abdulaziz University, Al-Kharj, Saudi Arabia; ^hRadiological Science Department, College of Applied Medical Science, Imam Abdulrahman

Bin Faisal University, Dammam, Saudi Arabia

ABSTRACT

Radiological examinations have played a crucial role in the identification and management of COVID-19 patients. Therefore, knowledge and awareness of infection control among healthcare workers in radiology departments are important to prevent disease transmission. This study aimed to assess the knowledge and practice of infection control for COVID-19 among healthcare workers in radiology departments in Saudi Arabia. A cross-sectional, online questionnaire was administered among healthcare workers in radiology departments in Saudi Arabia in May 2020. The questionnaire consisted of demographic characteristics, profession, knowledge of infection control for COVID-19, and good practice of infection control measures for COVID-19 in radiology departments. A descriptive statistical analysis and chi-square test were performed using SPSS software. A total of 234 (91%) of healthcare workers replied that they have good knowledge about the precautions needed during the examination of positive COVID-19 cases in radiology departments, and 216 (84%) replied that they knew the necessary precautions when using portable X-ray machine. Moreover, 191 (>74%) of those surveyed agreed that wearing personal protective equipment and following the CDC sequence. There was significant association between profession and good clinical practices in radiology departments regarding COVID-19. Such knowledge could limit the spread of COVID-19 among the healthcare workers in radiology departments.

ARTICLE HISTORY

Received 3 August 2020

Accepted 23 November 2020

KEYWORDS

Knowledge; infection control; radiology department; COVID-19

1. Introduction

Coronaviruses (CoVs) are a large group of viruses that cause respiratory infections. In the past two decades, severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV) have emerged, causing several human diseases (He et al., 2020). The current coronavirus disease 2019 (COVID-19) was initially defined in Wuhan, China, in December 2019, and it has spread rapidly worldwide (Huang et al., 2020). On January 30 2020, the World Health Organization (WHO) declared COVID-19 to be public health emergency of international concern (Sohrabi et al., 2020). On March 2 2020, the Ministry of Health (MOH) confirmed the first case of COVID-19 in Saudi Arabia (Ministry of health in Saudi Arabia, 0000). There is currently no effective antiviral treatment or vaccine for COVID-19. Thus, decisive precautions and infection control measures were implemented early by the MOH in Saudi Arabia to prevent

spread of the disease within the country (Algaissi et al., 2020; Alshammari et al., 2020; Barry et al., 2020) (Ministry of health in Saudi Arabia, 0000).

COVID-19 is transmitted from person to person through respiratory droplets and contact routes (Backer et al., 2020; Organization WH, 2020a). The most common clinical symptoms are fever, cough, and shortness of breath (Chen et al., 2020; Huang et al., 2020; Michelen et al., 2020; G Zhang et al., 2020). These symptoms occur within 2–14 days after exposure based on the incubation period of COVID-19 (Backer et al., 2020). The current gold standard for the clinical diagnosis of COVID-19 is the reverse transcription-polymerase chain reaction (RT-PCR) analysis of the extract from a saliva or mucus swap sample (Corman et al., 2020; Long et al., 2020). However, previous studies have reported low sensitivity of real-time RT-PCR tests in the early detection of COVID-19 (Ai et al., 2020; Fang et al., 2020; Li et al., 2020; Yang et al., 2020). In addition, the availability of the RT-PCR test and the

long processing time are major concerns during this pandemic. Therefore, radiological chest examinations such as with X-ray and computed tomography (CT) scan have been suggested in recent studies for the identification and follow-up of suspected patients with COVID-19 (Ai et al., 2020; Fang et al., 2020; Long et al., 2020; Rubin et al., 2020; Xie et al., 2020). With the increasing number of infected patients, controlling the transmission of COVID-19 infections in radiology department is the most critical intervention.

During the COVID-19 outbreak, many healthcare workers (HCWs) have been infected with COVID-19 worldwide, mainly in China (Chu et al., 2020; Gan et al., 2020; Wang et al., 2020; Xiao et al., 2020). The reason for this transmission to HCWs is that the nature of their work puts them in close contact with infected patients during examinations and their contaminated environments (Xiao et al., 2020). Because radiological examinations play a significant role in the diagnosis and management of suspected and/or laboratory-confirmed patients with COVID-19 (Shahzeb et al., 2020; Shi et al., 2020; Zu et al., 2020), HCWs in radiology departments are expected to be at higher risk of being infected (H-W Zhang et al., 2020). During the previous MERS-CoV outbreak in Saudi Arabia, it was reported that radiologic technologists had the highest infection rate in hospital units in Jeddah that treated infected patients (Alraddadi et al., 2016). The main reasons for this high rate were that they had direct contact with infected patients while obtaining portable chest radiographs and lacked infection control knowledge (Alraddadi et al., 2016; Omrani & Shalhoub, 2015). Therefore, HCWs in radiology departments should be aware of infection control measures and trained in the use of personal protective equipment (PPE) to prevent the transmission of diseases (Yu et al., 2020).

Recently, the focus of most radiology departments is on preparedness for COVID-19 to enable their role in the diagnosis of infected patients and to maintain the optimum utilization of radiological services for the hospital as well as ensure the safety of HCWs, patients, and the population (Mossa-Basha et al., 2020; Rubin et al., 2020; Wan et al., 2020) (Ministry of health, 0000). In this regard, the WHO and Center for Disease Control (CDC) have published guidelines for HCWs about infection prevention and control of COVID-19 (Centres for Disease Control and prevention, 0000; Organization WH, 2020b). The MOH in Saudi Arabia has also defined the standard operation procedure of radiological investigations in diagnosing and/or follow-up COVID-19 patient to ensure staff, patient, and population safety (Ministry of health, 0000). Although online materials and several training courses have been offered by the WHO to increase awareness among HCWs about preventive strategies (Organization WH, 2020c) (World Health Organization, 0000), it is still unclear to what extent this knowledge

can be put into clinical practice to reduce the spread of COVID-19 infections in radiology departments. We conducted this study to assess the infection control knowledge and practice of HCWs in radiology departments regarding patients with COVID-19 in Saudi Arabia.

2. Materials and methods

An online questionnaire was designed using Question pro software to assess the knowledge of infection control for COVID-19 among HCWs in radiology departments. This survey contained 25 items and was developed utilizing WHO course materials on emerging respiratory viruses, including COVID-19 (17).

The estimation of the sample size was performed using the following formula $n = P(1 - P) Z^2/d^2$, assuming an unknown prevalence of 50%, $Z = 1.96$, $d = 0.05$, confidence level = 95% (margin of error = 5%), and 80% power of the study. The calculated sample size of this study was 256 participants. The sample size was determined according to the latest report of the General Authority for Statistics (GAS), Kingdom of Saudi Arabia, 2020.

The draft survey was distributed to five experts in different geographical regions for the comprehensive evaluation of the content domain of the questionnaire. The draft evaluation was scaled from 1 to 5 points and allowed for open commentaries. In addition, the materials utilized for developing the questionnaire were provided to allow for any necessary clarifications. The readability of the questionnaire was assessed by seven faculty members who read the questionnaire for 10 minutes and scored the ease of readability from 1 – 5 (1 very easy, 2 easy, 3 standard, 4 difficult, and 5 confusing). To assess the clarity and acceptability of the survey, a pilot survey was conducted among seven HCWs who were selected randomly. Another seven HCWs were selected randomly to assess the required time and the feasibility of answering the survey questions. These participants were not included in the study. Adjustments were made in final draft as required to ensure a good understanding of the questions and to organize them before the survey distribution. Prior to the distribution, the survey was edited to remove typographic errors and standardize the formatting. The participation period lasted 1 week, from May 24 until the end of May 2020. A URL link for the final questionnaire was created using Question pro software and distributed through e-mail and social media applications to different clinical groups in 13 different regions in Saudi Arabia.

The survey covered four sections as follows: 1) demographic and characterization of HCWs, 2) the knowledge of HCWs about infection control for COVID-19, 3) the good practice of infection control for COVID-19 during clinical investigations, and 4) the

main source of information related to COVID-19 for the participant.

The questionnaire consisted of four sections and 25 questions, and all were multiple choice and were free text. The first section referred to general demographic information, such as gender, age group, region, qualification, and years of experience in diagnostic radiology. The second section asked about the participants' employment information, including their job description, the region of their institution, and if their institution was an authorized center for dealing with COVID-19. This section also included questions related to the participants' knowledge of infection control in diagnostic radiology. The third section contained questions about the participants' knowledge of the good practice of infection control measures when working with patients with COVID-19. This included questions related to following the guidelines for the center for disease control and prevention (CDC) sequence for the 'donning and doffing' of personal protective and equipment (PPE). The last section addressed the participants' source of COVID-19 information. All data were inserted into an Excel spreadsheet (Microsoft Office) for analysis.

3. Inclusion and exclusion criteria

The participants included male and female (Saudi and non-Saudi) employees in 13 regions of Saudi Arabia. The age of the participants ranged from 20 to 60 years. Other HCWs at hospitals such as lab technologists, pharmacists, and dentists were excluded from this study.

4. Statistical analysis

A descriptive cross-sectional design was adopted for this study. Descriptive statistics and graphical presentations of the survey data were expressed as frequencies and percentages. Comparisons of categorical data between groups were performed using Pearson's chi-square analysis or an exact analysis when expected cell counts were less than five. In all analyses, $P < 0.05$ was considered significant. All statistical analyses were performed using Package for Social Science (SPSS) statistical software, version 22.

5. Ethical considerations

During the study, the confidentiality of personal information was maintained by keeping the participants' information anonymous. Electronic informed consent was obtained from each participant on the first page of the survey. All participants were asked to answer the questions honestly. The participation of HCWs in this survey was completely voluntary and not compensated. This study followed the declaration of Helsinki principles revised in 2013. Moreover, it followed the

checklist for reporting the results of internet E-surveys (CHERRIES) guidelines (19).

6. Results

A total of 1314 questionnaires were distributed, and 256 participants completed the questionnaire. Of those who responded, 34 were radiographers (13%), 160 were radiologic technologists (63%), and 62 were radiologists (24%) (Table 1); 101 were female (39%), and 155 were male (61%) (Table 1). The age of most of the participants ranged from 21 to 50 years, representing 95% of the sample, of which 104 (41%) had more than 10 years of experience, 53 (21%) had 1–5 years of experience, and 59 (23%) had 6–10 years of experience (Table 1). Overall, most of the responses were from the MOH, totaling 132 (52%), and the other responses, totaling 124 (48%), were from different five health sectors. Most of the responses, totaling 180 (70%), were from centers authorized for treating COVID-19 that deal directly with patients with COVID-19 (Table 2). In addition, 205 (80%) of the participants reported receiving frequent training about infection prevention and control at their health institutions (Table 2).

7. Knowledge of HCWs about COVID-19 infection control practices

Most of the responses (163, 64%) were 'yes' for the question about having previous experience in dealing with a pandemic/epidemic (Table 2). A total of 234 (91%) of the HCWs replied that they had knowledge of the precautions needed during the investigation of positive COVID-19 cases in radiology departments, and 216 (84%) reported having such knowledge when using a portable X-ray machine (Table 3). Moreover, for CT and MRI units, 172 (67%) of the radiology staff

Table 1. Sociodemographic characteristics of healthcare workers (N = 256).

Characteristic	Participants, n (%)	
Gender	Male	155(61)
	Female	101(39)
Age	21–25	46(18)
	26–30	75(29)
	31–40	77(30)
	41–50	46(18)
	51–60	10(4)
	Above 60	2(1)
Current degree	Higher diploma	34(13)
	BSc	143(56)
	MSc	41(16)
	PhD	38(15)
Profession/Specialty of work	Radiographer	34(13)
	Radiologic Technologist	160(63)
	Radiologist	62(24)
Years of experience	Internship	11 (4)
	Less than 1 year	29 (11)
	1–5 years	53 (21)
	6–10 years	59 (23)
	More than 10 years	104 (41)

Table 2. Healthcare workers' perception of patients with corona virus disease 2019 (COVID-19) (N = 256).

Statement	Yes, n (%)	No, n (%)
Is your organization an authorized facility for COVID-19 patients?	180(70)	76(30)
Do you deal directly with COVID-19 patients?	134(52)	122(48)
Do you have previous experience in dealing with a pandemic/epidemic?	163(64)	93(36)
Have you received some form of training about infection prevention and control?	205(80)	51(20)

members stated they knew how to prepare the types of disinfectants, including the medium level and high level types, for disinfecting the sectional imaging rooms (Table 3). The responses to the question about the types of contact and spray precautions needed during a radiological examination for patients with COVID-19 revealed that 199 (77%) participants knew the precaution protocols. Because facial protection instruments are vital during routine X-ray exams and in some radiology departments they are not available because of their high cost, most of the participants (159, 62%) stated they knew how to complete the exams without them (Table 3).

The statistical analyses revealed there was a significant association between profession and knowledge of COVID-19. A majority of radiologic technologists agreed that they knew about the types of disinfectants and their use for the radiology equipment ($p = 0.001$). Moreover, they reported having sufficient knowledge about the types of contact and spray precautions needed during the radiological examination of an infected patient ($p = 0.046$) and the precautions needed to perform a routine X-ray examination if the safety materials were unviable ($p = 0.001$) (Table 3).

8. The good practice of infection control of COVID-19 during clinical investigations

Overall, a high percentage of 223,(87%) of the participants responded that they followed infection control measures and precaution policies before and after each exam in their radiology department. More than 169 (66%) of the HCWs stated that they followed the rules by screening the patients at the radiology front desk and taking the appropriate precautions before, during, and after each radiology exam (Table 4). Moreover, 149 (58%) participants stated that putting on a surgical mask would be helpful to prevent COVID-19 transmission. Most of the radiographic technologists replied that they were aware of the importance of following the CDC sequence for PPE, and 191 (>74%) agreed that wearing PPE and following the CDC sequence can prevent the spread of COVID-19 from infected patients to radiology staff (Table 4). There

were significant associations between profession and good clinical practices of infection control regarding COVID-19 in the radiology department ($p < 0.05$).

9. Participants' main source of information about COVID-19

This section asked the participants about their sources of information about 1) COVID-19 in general and 2) preventing the transmission of COVID-19 among professionals in radiology departments. Official media platforms and their websites (e.g., TV, radio, and newspapers) received the most responses 51(20%) about the primary source for information on the two points. Periodical medical meetings in the organization, internal newsletters, colleagues, and international organizations such as the WHO accounted for 46 (<18%) responses about the primary source of general information and information about preventing the COVID-19 pandemic (Figure 1).

10. Discussion

To the best of our knowledge, this is the first study to assess the knowledge and practice of COVID-19 infection control among HCWs in radiology departments in Saudi Arabia. The results of the present study indicated that there is a good knowledge of infection control measures with patients with COVID-19 among HCWs in radiology departments. In addition, there was a significant association between HCWs' profession and their knowledge of COVID-19 and good clinical practices of infection control measures. The most common sources of COVID-19 information and prevention policies were official media platforms and the websites of the hospital/MOH.

The findings of the current study demonstrate that the majority of the respondents knew the required infection control precautions needed during radiological examinations of suspected and/or positive COVID-19 cases and when using a portable unit. In the previous MERS-CoV epidemic in Saudi Arabia, HCWs had less knowledge about MERS-CoV infection control (Alsaifi & Cheng, 2016; Nour et al., 2015; Rabaan et al., 2017). In another study, Alraddadi et al (Alraddadi et al., 2016) reported that the highest infection rate was among radiographic technicians because of their lack of infection control knowledge while imaging infected patients. As a sign that a lesson was learned from the previous epidemic in Saudi Arabia, we found that most HCWs in radiology departments had attended a training course about infection prevention and control to improve their knowledge. In addition, the majority of the surveyed HCWs were working in an authorized facility for patients with COVID-19; therefore, radiology departments followed infection control measures and precaution policies for each examination.

Table 3. Association between healthcare worker's professions and their knowledge of coronavirus disease 2019 (COVID-19) (N = 256).

Question and response	Profession	Strongly Agree n(%)	Agree n(%)	Disagree n(%)	Strongly Disagree n(%)	Total	p value
I have knowledge about the precautions required during the investigation of suspected/positive COVID-19 cases at the radiology department	Radiographer	18 (53)	12 (35)	3 (9)	1 (3)	34	0.616
	Radiologic Technologist	65 (41)	83 (52)	7 (4)	5 (3)	160	
	Radiologist	24 (39)	32 (52)	5 (8)	1 (1)	62	
I have knowledge about the precautions required during the investigation of suspected/positive COVID-19 cases when using a portable unit	Total	107	127	15	7	256	0.278
	Radiographer	17 (50)	10 (29)	5 (15)	2 (6)	34	
	Radiologic Technologist	64 (40)	75 (47)	16 (10)	5 (3)	160	
I have knowledge about the types of disinfectants (Middle-High types) and how to prepare and use them for disinfecting the radiology equipment (especially CT and MRI)	Radiologist	18 (29)	32 (51)	10 (16)	2 (4)	62	0.001*
	Total	99	117	31	9	256	
	Radiographer	16 (47)	8 (24)	8 (24)	2 (6)	34	
I have knowledge about the types of contact and spray precautions needed during radiological examinations for COVID-19 cases	Radiologic Technologist	38 (24)	81 (51)	34 (21)	7 (4)	160	0.046*
	Radiologist	11 (17)	18 (29)	23 (37)	10 (17)	62	
	Total	65	107	65	19	256	
If eye protective glasses or face protective instruments are unavailable, I have knowledge about the precautions needed to do a routine X-ray examination	Radiographer	14 (41)	15 (44)	3 (9)	2 (6)	34	0.001*
	Radiologic Technologist	46 (29)	83 (52)	27 (17)	4 (3)	160	
	Radiologist	14 (23)	27 (43)	16 (26)	5 (8)	62	
I have knowledge about those who have received thorough and specialized training from the infection control department and are responsible for the disinfection of radiology departments rooms and equipment	Total	74	125	46	11	256	0.001*
	Radiographer	14 (41)	12 (35)	6 (18)	2 (6)	34	
	Radiologic Technologist	40 (25)	79 (49)	35 (22)	6 (3)	160	
I have knowledge about those who have received thorough and specialized training from the infection control department and are responsible for the disinfection of radiology departments rooms and equipment	Radiologist	8 (13)	19 (30)	26 (42)	9 (15)	62	.057
	Total	59	100	72	25	256	
	Radiographer	15 (44)	11 (32)	5	3	34	
I have knowledge about those who have received thorough and specialized training from the infection control department and are responsible for the disinfection of radiology departments rooms and equipment	Radiologic Technologist	42 (26)	79 (49)	34	5	160	0.001*
	Radiologist	14 (23)	25 (40)	19 (31)	4 (6)	62	
	Total	71	115	58	12	256	

Pearson's chi-square test, *Significant at p < 0.05 (bolded)

Table 4. Association between healthcare worker's professions and good practices regarding coronavirus disease 2019 (COVID-19).

Question and response	Profession	Strongly Agree n(%)	Agree n(%)	Disagree n(%)	Strongly Disagree n(%)	Total	p value
In my department, we follow infection control measures and precaution policies before and after each exam	Radiographer	20 (59)	12 (35)	1 (3)	1 (3)	34	0.170
	Radiologic Technologist	66 (42)	73 (46)	18 (11)	2 (1)	159	
	Radiologist	21 (33)	31 (49)	8 (13)	3 (5)	63	
Your radiology department performs screening at the radiology front desk for out-patients to assure safety	Total	107	116	27	6	256	0.001*
	Radiographer	20 (59)	6 (18)	7 (21)	1 (3)	34	
	Radiologic Technologist	45 (28)	63 (40)	37 (23)	14 (9)	159	
A surgical mask is appropriate to prevent the spread of COVID-19	Radiologist	11 (17)	24 (38)	22 (35)	6 (10)	63	0.627
	Total	75	94	66	21	256	
	Radiographer	8 (24)	11 (32)	11 (32)	4 (12)	34	
For every patient regardless of the infectious state, we should wear the personal protective equipment (PPE) recommended for use in suspected COVID-19 patients in a healthcare setting	Radiologic Technologist	35 (22)	60 (38)	36 (23)	28 (18)	159	0.045*
	Radiologist	10 (16)	25 (40)	20 (32)	8 (13)	63	
	Total	53	96	67	40	256	
I have knowledge about the Center for Disease Control and Prevention (CDC) sequence for 'donning and doffing' of personal protective and equipment (PPE)	Radiographer	14 (41)	12 (35)	3 (9)	5 (15)	34	0.779
	Radiologic Technologist	66 (42)	68 (43)	18 (11)	7 (4)	159	
	Radiologist	24 (38)	23 (37)	14 (22)	2 (3)	63	
Radiology housekeepers perform a deep cleaning of all radiology offices and radiology workstations at the end of each day	Total	104	103	35	14	256	0.001*
	Radiographer	12 (35)	14 (41)	6 (18)	2 (6)	34	
	Radiologic Technologist	53 (33)	67 (42)	31 (19)	8 (5)	159	
Radiology housekeepers perform a deep cleaning of all radiology offices and radiology workstations at the end of each day	Radiologist	14 (22)	31 (49)	15 (24)	3 (5)	63	0.001*
	Total	79	112	52	13	256	
	Radiographer	16 (47)	8 (24)	5 (15)	5 (15)	34	
Radiology housekeepers perform a deep cleaning of all radiology offices and radiology workstations at the end of each day	Radiologic Technologist	52 (33)	65 (41)	30 (19)	12 (8)	159	0.001*
	Radiologist	8 (13)	22 (35)	23 (37)	10 (16)	63	
	Total	76	95	58	27	256	

Pearson's chi-square test, *Significant at p < 0.05 (bolded)

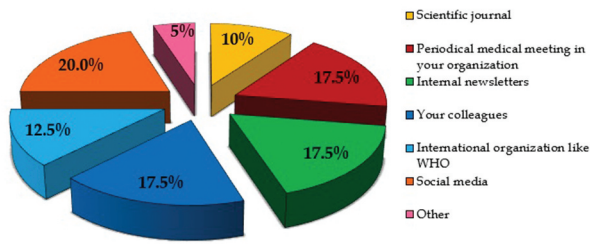


Figure 1. The participant's primary sources of general information about COVID-19 (they could select more than one answer).

We also analyzed the association between profession and HCWs' knowledge of COVID-19 infection control in clinical practice in radiology departments. The results showed that the majority of radiographic technologists agreed that they knew about the types of disinfectant used for the radiology equipment, especially for CT and MRI scans. They also had sufficient knowledge about the precautions needed to perform a routine X-ray examination when eye protective glasses or face protective instruments were unavailable in the radiology department. This critical knowledge among radiographic technologists in our study could be explained by their work experience in dealing with different imaging modalities, clinical training for imaging patients with COVID-19, and previous experience with the MERS-CoV pandemic in Saudi Arabia. In our study, most of the surveyed HCWs were radiographic technologists, their age ranged from 25 to 50 years old, and they had more than 10 years of experience in the field. These factors could explain their sufficient knowledge of infection control. This is in line with the findings from a previous study in Saudi Arabia that indicated that age, specialty, and work experience were significantly associated with infection control knowledge of MERS-CoV among HCWs (Nour et al., 2015). Similarly, Ayinde et al (Ayinde et al., 2020) and Giao et al (Giao et al., 2020) reported that profession was significantly associated with HCWs' knowledge of COVID-19. This sufficient knowledge had a positive impact on HCWs' attitudes toward COVID-19 prevention (Ayinde et al., 2020; Giao et al., 2020).

The present study revealed good practices of infection control among radiographic technologists during the outbreak compared with other HCWs in the radiology department. We found that the majority of the radiographic technologists reported wearing the recommended PPE for each radiological examination regardless of the patient's infection status during this pandemic. This good practice indicates their high level of knowledge about the appropriate use of PPE such as isolation gowns, surgical masks, and gloves while imaging patients to protect against the new virus. These findings agree with those from a study in China showing that professional categories and work experience

significantly influenced HCWs' practices regarding COVID-19 (Zhou et al., 2020).

The results of our study also showed that most of the HCW professions agreed that their radiology departments followed the COVID-19 infection control measures and precaution policies before and after each exam. These infection control measures included screening each out-patient at the front desk of the radiology department and performing a deep cleaning of all radiology offices and workstations. These guidelines were in line with recent recommendations for infection control of COVID-19 in radiology departments (Kooraki et al., 2020; Mossa-Basha et al., 2020; Nasir et al., 2020; Wan et al., 2020; Yu et al., 2020). Thus, the sufficient COVID-19 knowledge and good practice of control measures by HCWs in radiology departments found in this study are likely related to the protection-associated materials and policies of the MOH that have aided the frontline HCWs in Saudi Arabia during this pandemic (Ministry of health, 0000). As a result, HCWs in radiology departments were more confident in their knowledge of and ability to protect against the virus.

We found that the majority of the respondents obtained their information about COVID-19 and preventive procedures through official media platforms such as TV, radio, and newspapers and their hospital and MOH websites. This finding is consistent with previous studies that assessed HCWs' knowledge and perceptions of COVID-19 (Bhagavathula et al., 2020; Giao et al., 2020; Saqlain et al., 2020). Although there is a vast amount of information currently available on the internet, a major concern during this pandemic is the worldwide spread of misinformation causing xenophobia (Bhagavathula et al., 2020). Thus, information regarding COVID-19 and prevention strategies on the MOH and hospital websites should be updated regularly to ensure the delivery of correct information to HCWs. To effectively control the spread of the disease within the country, educational training programs must be offered to all HCWs in hospitals to increase their existing knowledge.

The major strength of the present study is that our findings indicate that HCWs possess important knowledge during this outbreak and demonstrate that the major infection control procedures are followed in radiology departments in Saudi Arabia. Another strength of this study is that it included participants who are working in radiology departments during this pandemic in different regions in Saudi Arabia. However, this study has some limitations that must be considered when interpreting the results, including there has been limited research on COVID-19 infection control for comparison. It remains unclear how many HCWs have been infected with COVID-19 in radiology departments. Further analyses and data are needed to understand the specific situation of HCWs who have been infected

during their work (Xiao et al., 2020). Moreover, additional studies on infection control expanded to include general HCWs in Saudi Arabia, including nurses, physicians, and doctors in other departments, are needed. The information obtained from such studies could help to design appropriate interventions at the national level.

11. Conclusion

There is a good knowledge and practice of infection control among HCWs in radiology departments in Saudi Arabia. The radiology staff responses showed that they are following infection control measures and precaution policies before and after each radiology exam in the department. Such knowledge could limit the spread of COVID-19 among the HCWs in radiology departments.

Acknowledgments

The authors thank Dr. Adnan Al-Homaidan, President of the University of Jeddah, and the Vice-President for Graduate Studies and Scientific Research, Dr. Obaid Al-Modaf, for their support and encouragement of research related to COVID-19. In addition, the authors would like to thank the College of Applied Medical Sciences and the Department of Medical Imaging and Radiation Sciences in the University of Jeddah for their full support. We thank all those who participated in the survey for providing essential information.

Disclosure statement

The authors declared that there is no conflict of interest.

Funding

The authors have no funding to report.

References

- Ai, T., Yang, Z., Hou, H., Zhan, C., Chen, C., Lv, W., Tao, Q., Sun, Z., & Xia, L. (2020). Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: A report of 1014 cases. *Radiology*, 0033-8419, 200642. doi:10.1148/radiol.2020200642
- Algaissi, A. A., Alharbi, N. K., Hassanain, M., & Hashem, A. M. (2020). Preparedness and response to COVID-19 in Saudi Arabia: Building on MERS experience. *Journal of Infection and Public Health*, 13(1876-0341), 834-838. <https://doi.org/10.1016/j.jiph.2020.04.016>
- Alraddadi, B. M., Al-Salmi, H. S., Jacobs-Slifka, K., Slayton, R. B., Estivariz, C. F., Geller, A. I., Al-Turkistani, H. H., Al-Rehily, S. S., Alserehi, H. A., & Wali, G. Y. (2016). Risk factors for middle east respiratory syndrome coronavirus infection among healthcare personnel. *Emerging Infectious Diseases*, 22, 1915. <https://doi.org/10.3201/eid2211.160920>
- Alsahafi, A. J., & Cheng, A. C. (2016). Knowledge, attitudes and behaviours of healthcare workers in the kingdom of Saudi Arabia to MERS coronavirus and other emerging infectious diseases. *International Journal of Environmental Research and Public Health*, 13(11), 1214. <https://doi.org/10.3390/ijerph13121214>
- Alshammari, T. M., Altebainawi, A. F., & Alenzi, K. A. (2020). Importance of early precautionary actions in avoiding the spread of COVID-19: Saudi Arabia as an example. *Saudi Pharmaceutical Journal*, 28(1319-0164), 898-902. <https://doi.org/10.1016/j.jsps.2020.05.005>
- Ayinde, O. O., Usman, A. B., Posi, A., & Gbolahan, A. (2020). A cross-sectional study on Oyo State health care worker's knowledge, attitude and practice regarding corona virus disease 2019 (COVID-19). *Advances in Infectious Diseases*, 10(3), 6. <https://doi.org/10.4236/aid.2020.103002>
- Backer, J. A., Klinkenberg, D., & Wallinga, J. (2020). Incubation period of 2019 novel coronavirus (2019-nCoV) infections among travellers from Wuhan, China, 20-28 January 2020. *Eurosurveillance*, 25(5), 2000062. <https://doi.org/10.2807/1560-7917.ES.2020.25.5.2000062>
- Barry, M., Ghonem, L., Alsharidi, A., Awadh, A., Al-Shahrani, F., & Naif, H. (2020). Coronavirus disease 2019 (COVID-19) pandemic in the kingdom of Saudi Arabia: Mitigation measures and hospitals preparedness. *Journal of Natural Science and Medicine*, 3(3), 1-11. doi:10.4103/JNSM.JNSM_29_20
- Bhagavathula, A. S., Aldhaleei, W. A., Rahmani, J., Mahabadi, M. A., & Bandari, D. K. (2020). Novel coronavirus (COVID-19) knowledge and perceptions: A SURVEY ON HEALTHCARE workers. *MedRxiv*. 2(6), 1. doi:10.2196/19160
- Centres for Disease Control and prevention. <https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-guidance-management-patients.html>
- Chen, N., Zhou, M., Dong, X., Qu, J., Gong, F., Han, Y., Qiu, Y., Wang, J., Liu, Y., Wei, Y., Xia, J., Yu, T., Zhang, X., & Zhang, L. (2020). Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: A descriptive study. *Lancet*, 395(10223), 507-513. [https://doi.org/10.1016/S0140-6736\(20\)30211-7](https://doi.org/10.1016/S0140-6736(20)30211-7)
- Chu, J., Yang, N., Wei, Y., Yue, H., Zhang, F., Zhao, J., He, L., Sheng, G., Chen, P., & Li, G. (2020). Clinical characteristics of 54 medical staff with COVID-19: A retrospective study in a single center in Wuhan, China. *Journal of Medical Virology*, 92(7), 807-813. <https://doi.org/10.1002/jmv.25793>
- Corman, V. M., Landt, O., Kaiser, M., Molenkamp, R., Meijer, A., Chu, D. K., Bleicker, T., Brunink, S., Schneider, J., & Schmidt, M. L. (2020). Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. *Eurosurveillance*, 25(3), 2000045. <https://doi.org/10.2807/1560-7917.ES.2020.25.3.2000045>
- Fang, Y., Zhang, H., Xie, J., Lin, M., Ying, L., Pang, P., & Ji, W. (2020). Sensitivity of chest CT for COVID-19: Comparison to RT-PCR. *Radiology*, 296(2), 200432. <https://doi.org/10.1148/radiol.2020200432>
- Gan, W. H., Lim, J. W., & David, K. (2020). Preventing intra-hospital infection and transmission of COVID-19 in healthcare workers. *Safety and Health at Work*, 11(2), 241-243. <https://doi.org/10.1016/j.shaw.2020.03.001>
- Giao, H., Han, N. T. N., Van Khanh, T., Ngan, V. K., Van Tam, V., & Le An, P. (2020). Knowledge and attitude toward COVID-19 among healthcare workers at District 2 Hospital, Ho Chi Minh City. *Asian Pacific Journal of Tropical Medicine*, 13(6), 260-265. doi:10.4103/1995-7645.280396
- He, F., Deng, Y., & Li, W. (2020). Coronavirus disease 2019 (COVID-19): What we know? *Journal of Medical Virology*, 92(0146-6615), 719-725. <https://doi.org/10.1002/jmv.25766>
- Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., Hu, Y., Zhang, L., Fan, G., Xu, J., & Gu, X. (2020). Clinical features of patients infected with 2019 novel coronavirus in

- Wuhan, China. *The Lancet*, 395(10223), 497–506. [https://doi.org/10.1016/S0140-6736\(20\)30183-5](https://doi.org/10.1016/S0140-6736(20)30183-5)
- Kooraki, S., Hosseiny, M., Myers, L., & Gholamrezanezhad, A. (2020). Coronavirus (COVID-19) Outbreak: What the department of radiology should know. *Journal of the American College of Radiology*, 17(4), 447–451. <https://doi.org/10.1016/j.jacr.2020.02.008>
- Li, Y., Yao, L., Li, J., Chen, L., Song, Y., Cai, Z., & Yang, C. (2020). Stability issues of RT-PCR testing of SARS-CoV-2 for hospitalized patients clinically diagnosed with COVID-19. *Journal of Medical Virology*, 92 (107), 903–908. doi:10.1002/jmv.25786
- Long, C., Xu, H., Shen, Q., Zhang, X., Fan, B., Wang, C., Zeng, B., Li, Z., Li, X., & Li, H. (2020). Diagnosis of the coronavirus disease (COVID-19): RRT-PCR or CT? *European Journal of Radiology*, 126, 108961. <https://doi.org/10.1016/j.ejrad.2020.108961>
- Michelen, M., Jones, N., & Stavropoulou, C. *In patients of COVID-19, what are the symptoms and clinical features of mild and moderate cases?* Centre for Evidence-Based Medicine Retrieved 16 2020 <https://www.cebm.net/covid-19/in-patients-of-covid-19-what-are-the-symptoms-and-clinical-features-of-mild-and-moderatecase/>
- Ministry of health. <https://www.moh.gov.sa/Ministry/MediaCenter/Publications/Documents/Radiology-Departments-Preparedness.pdf>
- Ministry of health in Saudi Arabia. <https://www.moh.gov.sa>
- Mossa-Basha, M., Meltzer, C. C., Kim, D. C., Tuite, M. J., Kolli, K. P., & Tan, B. S. (2020). Radiology department preparedness for COVID-19: Radiology scientific expert panel. *Radiology*, 296(2), 200988. <https://doi.org/10.1148/radiol.2020200988>
- Nasir, M. U., Roberts, J., Muller, N. L., Macri, F., Mohammed, M. F., Akhlaghpour, S., Parker, W., Eftekhari, A., Rezaei, S., & Mayo, J. (2020). The role of emergency radiology in COVID-19: From preparedness to diagnosis. *Canadian Association of Radiologists Journal*, 296(2), 0846537120916419.
- Nour, M. O., Babilghith, A. O., Natto, H. A., Al-Amin, F. O., & Alawneh, S. M. (2015). Knowledge, attitude and practices of healthcare providers towards MERS-CoV infection at Makkah hospitals, KSA. *International Research Journal of Medicine and Medical Sciences*, 3(4), 103–112.
- Omrani, A., & Shalhoub, S. (2015). Middle East respiratory syndrome coronavirus (MERS-CoV): What lessons can we learn? *Journal of Hospital Infection*, 91(3), 188–196. <https://doi.org/10.1016/j.jhin.2015.08.002>
- Organization WH. (2020a). *Modes of transmission of virus causing COVID-19: Implications for IPC precaution recommendations: Scientific brief, 27 March 2020*. World Health Organization.
- Organization WH. (2020b, March 19). *Infection prevention and control during health care when novel coronavirus (nCoV) infection is suspected Interim guidance*. World Health Organization.
- Organization WH. (2020c, April 6). *Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages: Interim guidance*. World Health Organization.
- Rabaan, A. A., Alhani, H. M., Bazzi, A. M., & Al-Ahmed, S. H. (2017). Questionnaire-based analysis of infection prevention and control in healthcare facilities in Saudi Arabia in regards to middle east respiratory syndrome. *Journal of Infection and Public Health*, 10(5), 548–563. <https://doi.org/10.1016/j.jiph.2016.11.008>
- Rubin, G. D., Ryerson, C. J., Haramati, L. B., Sverzellati, N., Kanne, J. P., Raouf, S., Schluger, N. W., Volpi, A., Yim, J., & Martin, I. (2020). The role of chest imaging in patient management during the covid-19 pandemic: A multinational consensus statement from the fleischner society. *Chest*, 158(1), 106–116. <https://doi.org/10.1016/j.chest.2020.04.003>
- Saqlain, M., Munir, M. M., Ur Rehman, S., Gulzar, A., Naz, S., Ahmed, Z., Tahir, A. H., & Mashhood, M. (2020). Knowledge, attitude, practice and perceived barriers among health-care professionals regarding COVID-19: A cross-sectional survey from Pakistan. *Journal of Hospital Infection*, 105 (0159-6701), 419–423. <https://doi.org/10.1016/j.jhin.2020.05.007>
- Shahzeb, M., Khan, A., & Muhammad, A. (2020). Detection of coronavirus disease (COVID-19) using radiological examinations. *Journal of Pure and Applied Microbiology*, 14. doi:10.22207/JPAM.14.SPL1.28
- Shi, H., Han, X., Jiang, N., Cao, Y., Alwalid, O., Gu, J., Fan, Y., & Zheng, C. (2020). Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: A descriptive study. *The Lancet Infectious Diseases*, 20(4), 425–434. [https://doi.org/10.1016/S1473-3099\(20\)30086-4](https://doi.org/10.1016/S1473-3099(20)30086-4)
- Sohrabi, C., Alsafi, Z., O'Neill, N., Khan, M., Kerwan, A., Al-Jabir, A., Losifidis, C., & Agha, R. (2020). World Health Organization declares global emergency: A review of the 2019 novel coronavirus (COVID-19). *International Journal of Surgery*, 76, 71–76. doi:10.1016/j.ijsu.2020.02.034
- Wan, Y.-L., Schoepf, U. J., Wu, C. C., Giovagnoli, D. P., Wu, M.-T., Hsu, -H.-H., Chang, Y.-C., Yang, C.-T., & Cherng, W.-J. (2020). Preparedness and best practice in radiology department for COVID-19 and other future pandemics of severe acute respiratory infection. *Journal of Thoracic Imaging*, 35(4), 239–245. <https://doi.org/10.1097/RTI.0000000000000529>
- Wang, D., Hu, B., Hu, C., Zhu, F., Liu, X., Zhang, J., Wang, B., Xiang, H., Cheng, Z., & Xiong, Y. (2020). Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. *Jama*, 323(11), 1061–1069. <https://doi.org/10.1001/jama.2020.1585>
- World Health Organization. <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/training/online-training>
- Xiao, J., Fang, M., Chen, Q., & He, B. (2020). SARS, MERS and COVID-19 among healthcare workers: A narrative review. *Journal of Infection and Public Health*, 13(6), 843–848. <https://doi.org/10.1016/j.jiph.2020.05.019>
- Xie, X., Zhong, Z., Zhao, W., Zheng, C., Wang, F., & Liu, J. (2020). Chest CT for typical 2019-nCoV pneumonia: Relationship to negative RT-PCR testing. *Radiology*, 296 (2), 200343. <https://doi.org/10.1148/radiol.2020200343>
- Yang, Y., Yang, M., Shen, C., Wang, F., Yuan, J., Li, J., Li, J., Zhange, M., Wang, Z., Xing, L., & Wei, J. (2020). Laboratory diagnosis and monitoring the viral shedding of 2019-nCoV infections. *MedRxiv*. <https://doi.org/10.1101/2020.02.11.20021493>
- Yu, J., Ding, N., Chen, H., Liu, X.-J., He, W.-J., Dai, W.-C., Zhou, Z.-G., Lin, F., Pu, Z.-H., & Li, D.-F. (2020). Infection control against COVID-19 in departments of radiology. *Academic Radiology*, 27(5), 614–617. <https://doi.org/10.1016/j.acra.2020.03.025>
- Zhang, G., Zhang, J., Wang, B., Zhu, X., Wang, Q., & Qiu, S. (2020). Analysis of clinical characteristics and laboratory findings of 95 cases of 2019 novel coronavirus pneumonia in Wuhan, China: A retrospective analysis. *Respiratory Research*, 21(1), 74. <https://doi.org/10.1186/s12931-020-01338-8>
- Zhang, H.-W., Yu, J., Xu, H.-J., Lei, Y., Pu, Z.-H., Dai, W.-C., Lin, F., Wang, Y.-L., Wu, X.-L., & Liu, L.-H. (2020). Corona virus

international public health emergencies: Implications for radiology management. *Academic Radiology*, 27(4), 463–467. doi:[10.1016/j.acra.2020.02.003](https://doi.org/10.1016/j.acra.2020.02.003)

Zhou, M., Tang, F., Wang, Y., Nie, H., Zhang, L., You, G., & Zhang, M. (2020). Knowledge, attitude and practice regarding COVID-19 among health care workers in

Henan, China. *Journal of Hospital Infection*, 105(2), 182–187. <https://doi.org/10.1016/j.jhin.2020.04.012>

Zu, Z. Y., Jiang, M. D., Xu, P. P., Chen, W., Ni, Q. Q., Lu, G. M., & Zhang, L.-J. (2020). Coronavirus disease 2019 (COVID-19): A perspective from China. *Radiology*, 296(2), 200490. doi:[10.1148/radiol.2020200490](https://doi.org/10.1148/radiol.2020200490)