Abstract

Introduction: Worldwide, reports and experiences indicate that there has been extensive re-organisation within diagnostic imaging and radiotherapy departments in response to the COVID-19 pandemic. This was necessary due to changes in workload and working practice guidelines that have evolved during the pandemic. This review provides a comprehensive summary of the global impact of the COVID-19 pandemic on radiography practice, service delivery and workforce wellbeing.

Methods: A systematic review methodology was adopted to obtain data from primary studies of qualitative, quantitative, and mixed methods designs from databases (PubMed, Science Direct, Cumulative Index of Nursing and Allied Health Literature [CINAHL], and SCOPUS: all 2020 to present). The included articles were subjected to information extraction and results-based convergent synthesis.

Results: The electronic database search yielded 10420 articles after removal of duplicates. Of these, 31 articles met the final inclusion criteria with some (n=8) fully focussed on radiotherapy workforce and service delivery. The pandemic impact on radiography practice is broadly themed around: training, communication, and information dissemination; infrastructure, technology, and clinical workflow; and workforce mental health and well-being.

Conclusions: Globally, most radiographers received inadequate training for managing COVID-19 patients during the initial acute phase of the pandemic. Additionally, there were significant changes to clinical practice, working patterns and perceived increase in workload due to surges in COVID-19 patients and the consequent strict adherence to new infection protocols. These changes, coupled with fear emanating from the increased risk of the workforce to contracting the infection, contributed to anxiety and workplace-related stress during the pandemic.

Implications for practice: Local pandemic response strategies must be appropriately developed from standard protocols in readiness for safe clinical practice and well-being management training of practitioners.

Keywords: Radiography, Radiotherapy, COVID-19, Personal-protective equipment, Workplace-related stress, Well-being

Introduction

In the initial acute phase of the pandemic, chest imaging emerged as one of the key diagnostic and monitoring tools for patients with COVID-19.[1-6] Consequently, the diagnostic radiology workforce came under extreme pressure with the surge in patient numbers.[7-14] Diagnostic imaging modalities employed for direct COVID-19 patient management (general X-ray [CXR] including mobile systems) and computed tomography (CT) were perceived to have been under increased procedural pressure while other elective/non-urgent diagnostic and screening services were paused in some settings globally.[7,9,10,15,16] Staff were reassigned to modalities with anticipated increase in pressure such as CXR and CT.[7,9,14] Worldwide, reports and experiences indicate that there has been extensive re-organisation within radiology and radiotherapy departments to conform with the COVID-19 guidelines to effectively manage the anticipated pandemic-related workload increases while keeping workflows safe.[1,16-19] In some settings, additional radiography practice modifications were required to reduce cross-infection, such as X-raying through room windows[20,72,73] with both the digital image receiver/cassette and mobile X-ray machine secured with layers of polythene sheets.[21,22]

Clinical radiotherapy practice was indirectly impacted globally with several reports[23-28] indicating a decline in patient volumes, although almost all departments were operational during the pandemic. The rapidly evolving situation[29] resulted in the regular release of recommendations from national and international authorities including the International Society of Radiographers and Radiological Technologists (ISRRT), National Cancer Research Institute (NCRI - UK), European Society for Radiotherapy and Oncology (ESTRO) and the American Society for Radiation Oncology for safe clinical care of cancers.[30-33,60] In line with these recommendations, radiotherapy departments underwent resource and technical re-organisation to allow the continuation of daily cancer care provision.[23-28,34,61,62] The recommendations included the implementation of strict hygiene protocols to guarantee the safety of cancer patients, many of whom are generally immunocompromised and at increased risk of COVID-19 complications, and of staff administering the treatments. Additionally, strict triage systems and the use of hypofractionation protocols designed for specific cancers were rapidly implemented[30-33] to allow cancer care continuation during the pandemic. For example, a recent study[23] reported a substantial increase in bladder, oesophageal and rectal cancer radiotherapy during the pandemic, potentially due to reduced surgical capacity. Adoption and

implementation of these protocols were largely influenced by institutional and/or national practices and resource availability.[8,34-37]

The nature of clinical radiography practice requires working in close proximity to patients for radiotherapy treatment or diagnostic imaging. The need for adequate personal protective equipment (PPE) for safe practice became critical during the pandemic.[9-11,38-40,76] A recent prospective study among frontline healthcare workers (HCW) from the United Kingdom (UK) and the United States of America (USA),[41] found that HCW are approximately three times at risk for contracting the infection compared to the general population. This further highlights the need for appropriate PPE in all clinical settings. Reports of perceived inadequate availability of PPE during phases of the pandemic in different countries and settings have been noted.[7-9,14,42,43] Fear of contracting the infection was widely reported among the radiography workforce across all resource settings.[7-10,12-14,40,42,44] This contributed poorly to the mental health (including workplace-related stress and anxiety) and general well-being of all HCWs, including the radiography workforce.[7-10,12-14,40,45-49]

The body of evidence reporting the impact of the pandemic on radiography practice is diverse and variable in terms of its scope (see Tables 1 and 2). This systematic review aims to integrate available evidence to provide a comprehensive summary of the global impact of the COVID-19 pandemic on diagnostic and therapeutic radiography practice. This will provide a reference resource for policy formulation and recommendations for radiography education and training.

Methods

A mixed-method systematic review methodology[17,68,69,70,71] was adopted to obtain data from primary studies of qualitative, quantitative, and mixed methods designs in accordance with the Cochrane Collaboration guide[50] whilst also utilising an adapted version of the Preferred Reporting Items for Systematic Review (PRISMA: see Fig. 1) statement.[53] The PRISMA adaptation include our inability to register the search protocol of this systematic review *a priori*. This was due to the quickly evolving nature of the pandemic, the urgency, and the necessity of generating robust findings to inform COVID-19 policy for safe practice. Taken together, this methodologically inclusive approach is deemed appropriate to broaden the

conceptualisation and synthesis of available evidence on the topic. Ethical approval is not required for literature reviews.

Eligibility Criteria

Articles were included if they were published in English and explored the impact of the COVID-19 pandemic on diagnostic radiography and/or radiotherapy practice in relation to changes in workload and service delivery, staff well-being, infection control protocols and other relevant pandemic-related changes. Opinion reports, preprints, commentaries, literature reviews and primary studies with a multidisciplinary focus outside of radiography practice were excluded.

Sources

The following database records: PubMed, Science Direct, CINAHL (Cumulative Index of Nursing and Allied Health Literature, and SCOPUS were identified and searched to ensure all relevant studies are captured. A manual search of google scholar and the "*COVID-19 article collection*" of key radiography journals (including, *Radiography*, *Journal of Medical Imaging & Radiation Sciences (JMIRS)*, *Journal of Medical Radiation Sciences (JMRS)* and *Radiologic Technology*) was conducted for relevant publications. In addition, the reference list of relevant primary studies and review articles were also searched for other relevant publications that fulfil the eligibility criteria.

Search Strategy

A systematic search strategy (certified as satisfactory by an expert librarian) was employed to identify studies in each of the databases independently. The MeSH (Medical Subject Heading) was used to identify and develop keywords for the literature search. Using this search strategy, an independent electronic literature search was carried out by two researchers (NAM/WE) from November, 2020 to January 31st 2021 to identify relevant articles. A further search was conducted on June 29th 2021 to update the results. Boolean operators (OR, AND) and keywords/MeSH terms combinations: ["Radiography" OR "Medical Radiation Science" OR Radiologic Technologist" OR "Radiotherapy" OR "Radiation Therapist" OR "Imaging" OR "Radiographer well-being" OR "workplace stress" AND "COVID-19" OR "pandemic"] were

employed for the search. To increase the sensitivity to the databases and minimise the risk of missing relevant studies, the search combinations were refined to include appropriate subject headings, abbreviations and/or truncated syntax in accordance with the specifications of each database. A combination of Microsoft Excel 2019 for Mac and the RefWorks (ExLibris, ProQuest) referencing software was used to manage the screening process and search outputs.

Study selection and data extraction

In accordance with the predetermined search strategy, the final inclusion and quality of included studies were assessed by three members of the research team (NAM/WE/BOB) after the initial independent review of titles, abstracts, and full text. In addition, the lead investigator (TNA), reviewed the screening decisions for consistent application of the predetermined criteria at all stages of the screening exercise. Due to the diverse nature of the study designs, and to ensure a consistent critical appraisal of the relevant studies, the Quality Assessment Tool for Studies with Diverse Designs (QATSDD)[51] was employed to evaluate the studies. Any differences in quality assessment scores were discussed and consensus opinion achieved among the research team. As previously[52], studies were categorised as *high quality* if an aggregate score in excess of 70% is achieved, *moderate quality* for those scored between 50-70%, and *low quality* for those scored less than 50%. These aggregate quality scores were not a part of the article exclusion criteria. The omission of studies with low aggregate scores could potentially limit the global essence of the review considering that some findings relate specifically to certain geographical regions. All the included studies were subjected to a data extraction process that included the completion of a template with fields to capture the study methods, aims and outcomes (the findings and conclusions drawn).

Data Synthesis Approach

A results-based convergent synthesis design strategy[17,68,69,70,71] was employed to integrate findings from included studies of varied designs. Briefly, this strategy involve the independent analyses and presentation of findings from the included studies in a tabular format (See Table 1 and 2). The findings are then integrated to generate summary outcomes using textual

narrative synthesis after qualitising the quantitative component of the findings.[17,68,69,70,71] The synthesised findings/outcomes broadly provide a global overview of the pandemic impact on clinical radiography practice as highlighted in the aim of the study. This approach is deemed appropriate as it allows a robust and reproducible synthesis of existing and current evidence.

Results

The electronic database search yielded 10420 articles after removal of duplicates from the following records: PUBMED (n=5806), CINAHL (n=749), SCOPUS (n=2484), Science Direct (n=8212) and manual searches (n=73). After the first and second screening exercises based on titles and abstracts, 6243 and 4092 articles were excluded, respectively. Following this exercise, 85 articles were retained for full-text assessment of eligibility. Figure 1 details the search procedure using an adapted PRISMA chart.[53] Full-text screening based on the predetermined strategy resulted in 35 articles being included in the review. Further articles (n=4) were excluded at a consensus during the data extraction and article summary generation stages of the review process. Figure 1 details the reasons for article exclusion. Thirty-one articles met the final inclusion criteria with some (n=8) fully focused on radiotherapy workforce and service delivery. Quality scores ranged from low to high (40.5 to 84.6%). Of note, the included studies comprise of four previous publications[7,8,10,14] from our research team that fulfilled both the search criteria and the critical appraisal exercise (using the QATSDD tool).

***********INSERT FIGURE ONE HERE************

The articles identified for this literature review encompass a broad spectrum of clinical radiography professionals with a global geographic representation from low- and middle-income countries (LMIC) and high-income countries (HIC). In this review, the term "radiographer" refers to diagnostic radiographers or technicians, therapeutic radiographer/radiotherapist, and medical imaging technologists and/or radiation therapy professionals depending on the region where the included primary studies were conducted. Additionally, our findings represent perspectives from radiographers at private radiology/oncology/radiotherapy centres, private hospitals, public hospitals, and other off-

site clinical facilities. See Table 1 and 2 for the study characteristics including the geographical spread of the included studies, methodological approaches adopted, and summary of the findings.

***********INSERT TABLE ONE & TWO HERE************

Three broad themes emerged across varied clinical settings globally: Theme 1 - training, communication, and information dissemination; Theme 2 - infrastructure, technology, and clinical workflow; and Theme 3 - workforce mental health and well-being. The term "mental health" is employed as an umbrella terminology in this context to describe known and specific mental health and well-being disruptors such as stress, anxiety, emotional/psychological dilemma, burnout (emotional exhaustion and depersonalisation) emerging from the review synthesis.

Discussions

Our findings highlight prior knowledge to indicate that radiography practice varies widely across different settings and among countries, often due to differences in both expert human and physical resource availability.[8,34-37,61,74] As medical imaging has played an important role in both the diagnosis and management of COVID-19 patients, the pandemic has highlighted existing global discrepancies in radiography resource availability.[35,37,61,74] The findings suggest that the knowledge-base of radiographers about the pandemic has improved over time. For example, Kotian and colleagues[11] reported relatively low knowledge of COVID-19 among India's radiography workforce at the initial stages of the pandemic (March, 2020), similar to the baseline findings reported among their Irish counterparts at approximately the same period of the pandemic.[9] Available longitudinal data[9] to-date from the Irish radiography workforce showed improvements and a feeling of preparedness for new practices, protocols, and procedures after a 6-week follow-up among 56% of respondents relative to an initial 33%. Similarly, diagnostic radiographers in Singapore have demonstrated resilience and improvements over the past year to transition through the numerous clinical practice

challenges.[75] These improvements are attributable to improved communication, training, and public campaigns on the pandemic. [7-10,74,75]

Theme 1: Training, Communication, and Information Dissemination

Reports from varied settings indicate that there was none or limited training about COVID-19 infection control, prevention and patient management approaches within the radiology and radiotherapy departments in the initial acute phase of the pandemic.[7-9,42] For instance, in Ghana, 73.1% of radiographers who participated in a study by Akudjedu and colleagues[8] contended that they were not given any prior training and the necessary communication/information to manage COVID-19 patients at the onset of the pandemic. Education regarding appropriate infection control processes is essential in the safe management of the pandemic within radiography departments.[10] In part, the lack of training and information was due to the rapid and unexpected evolution of the global pandemic.[7,8,26,36] Lack of understanding about appropriate infection control procedures during the pandemic is linked to reported fear and anxiety across the radiography workforce from several settings[7-10,40] and feeling of a lack of preparedness.[23,26,28,42,43] This is consistent with findings reported in a large, multidisciplinary cohort of HCW (including radiographers) in China.[47,48]

Ruiz and colleagues[40] argued that understanding the science of what PPE is needed to mitigate transmission is essential information. As COVID-19 was a novel version of the coronavirus, it took the scientific community time to understand its transmission and recommend universal pandemic precautions that minimise transmission. That period of learning did play into the time in which there was uncertainty and fear regarding infection control and transmission. Foley and colleagues[9] reported that almost 50% of respondents in their study were inadvertently exposed to positive cases without appropriate PPE due to poor communication protocols within the healthcare services. Once the World Health Organisation and related healthcare authorities became clear on their advice, quick and clear communication, and dissemination regarding the process for infection control and emergency response protocol were impactful for mitigating fear and returning power to the healthcare professional. Repeatedly throughout the literature, a theme that uncertainty causes stress and clarity leads to confidence, in other words, knowledge is power is

demonstrated clearly.[7-11,34,36,42,44] With emerging clarity on the process for infection, a trend of reported increase in knowledge and compliance with these infection control procedures are being observed[28,34,36] due to appropriate communication within healthcare units including the radiography departments.

Theme 2: Infrastructure, Technology, and Clinical Workflow

Globally, radiographers have reported a perceived increase in imaging workload volume during the pandemic, particularly for chest X-ray and CT. [1-6,8] Similarly, the radiotherapy workforce also faced increase in treatment of some specific cancers with radiotherapy during the pandemic[23], likely due to reduced surgical capacity.

Repeatedly, radiographers state that changes to operations and procedures occurred during the pandemic.[7,8,12,14,26] In some cases, there were staff redeployments and extended shift hours to cover the increased imaging demand.[8,12-14,45] For example, in the national UK survey, 12.5% of respondents were redeployed mostly to CT and general X-ray from departments responsible for elective imaging which were paused to create extra capacity[7]. Another example from a large Singapore radiography service, was the implementation of a new 12-hour working shift system as a pandemic strategy to manage clinical workflows, which reflected poorly on radiographer well-being.[45] Adapting to the "new way of work", did not only affect professional work dynamics, but it also affected home/family routines and well-being of radiographers.[12] Further adding to workplace-related stress, Ossama and colleagues[13] share that a shortage of medical imaging professionals further exacerbated stressors related to clinical workflow changes. However, the workforces' positive attitude, resilience and dedication to their profession, and initiation of unique coping strategies helped to mitigate these challenges.[12,26,75,77] Notwithstanding, there was a reported decline in patient volume (about 60%) and staff numbers (57%) in some departments due to the COVID-19 pandemic in relation to family care responsibilities (29%), staff COVID-19 illness (26%) and staff redeployment to other non/clinical areas (13%).[49]

Infrastructural and technical resource needs included access to COVID-19 testing for healthcare workers, adequate availability of related PPE and supply chain, and standardised policy support for infection control in relation to the local settings, training needs, and

consistency of enforcement protocols.[9,43,75-77] In some cases, where appropriate, information technology was used to support the workforce with research and the conduct of some of their clinical duties remotely. For example, some therapeutic radiographers were completing their contouring assignments remotely. Of note, these new clinical initiatives including the use of information technologies to enhance remote working in clinical radiotherapy follow-up consultations and planning are not universal.[8,12,13,21,34,42,61,62,75,77,78] Further highlighting the need for adaptation of established global strategies for use within local settings.

Theme 3: Workforce Mental Health and Well-being

Despite the major impact of the COVID-19 pandemic on healthcare services, and in the face of uncertainties and changes in clinical work patterns, radiology personnel along with other healthcare professionals have continued to provide committed clinical services.[54-56] The healthcare workforce has to balance strict measures to protect both patients, colleagues, and the general public from contracting COVID-19, while not compromising on the access, availability and quality of healthcare service.[57,58] These demands have placed a toll on the healthcare workforce worldwide.

The global radiography workforce populations that responded to the various surveys included in this review reported burnout symptoms, emotional/psychological dilemma, anxiety, and workplace-related stress resulting from fear of contracting the virus, increase and/or changes to clinical workload and workflow.[7-9,12,23,75,77] Ruiz et al[40] and Maraga et al[46] documented that radiographers reported fear about infecting their own family members, patients, and other co-workers particularly at the onset of the pandemic. Additionally, radiographers observed that their own work-related stress was transferred to their family, partners, and friends.[7,8,14,40,42,44,46,48] Some redeployed radiographers also reported being stressed due to the need to adjust to new working environments and technologies.[7,75,77] Anxiety from these stressors was a commonly reported theme.[5-9,24,25,46,75,77] In the Irish study of radiographers, 40% of respondents reported burnout symptoms due to the COVID-19 crisis and 30% reported considering changing jobs or retiring since the COVID-19 outbreak.[9] Consequently, some radiographers considered the potential for career change or early retirement as a result of working conditions.[9] These findings are consistent to those reported in other national surveys from the UK, Middle East, Australia and Africa.[7,8,10,12-14] The psychological and well-

being impacts of the pandemic are striking. There have been recommendations[7-9,12,23,75,77] for the establishment of both system and institution level intervention mechanisms to support radiographer well-being and workforce resilience and to address mental health implications.

Limitations

This study is potentially limited by the inclusion of only primary research published in English thereby missing grey literature and studies published in other languages. However, the reports included in this review are diverse, representing low, intermediate, and higher resource settings, and multiple and varied healthcare systems. We would therefore anticipate the themes addressed to be generalisable. There is large heterogeneity associated with the methodological approaches and designs of the included studies which may be considered a limitation to the synthesis of the findings. However, a standardised synthesis approach and critical appraisal tool was employed to assess the quality of included studies to gauge the weighting to be placed on study recommendations that informed our discussions. We acknowledge that our search protocols were not published *a priori* as recommended for the conduct of systematic reviews. This was mainly due to the quickly evolving nature of the pandemic, the urgency, and the necessity of generating robust findings to inform COVID-19 policy for safe practice.

Conclusions

This review provides a global snapshot of the pandemics' impact on clinical radiography practice across different settings of varied resource availability. Worldwide, most radiographers received inadequate training to specifically manage COVID-19 patients during the initial acute phase of the pandemic. Additionally, there were significant changes to clinical practice (e.g., implementation of hypofractionation and protection procedures), working patterns (e.g., implementation of new 12-hour working shift systems) and perceived increase in workload due to the surge in COVID-19 patients and the consequent strict adherence to infection prevention and control measures. These changes and personal fear of the virus contributed to anxiety and workplace-related stress during the pandemic. It has also highlighted the challenges and the dynamics of clinical workflows and the coping mechanisms adopted during the various stages of the pandemic globally.

Recommendations for future service planning

Following the current global pandemic, radiography departments will require extensive re-organisation and re-structuring using key lessons from the pandemic in readiness for post-COVID service delivery. Our findings suggest a number of best practice recommendations including:

i. ***Development and implementation of post-pandemic working protocols:*** Revision of existing and/or establishment of new protocols in line with lessons from the pandemic is crucial. Protocols for future pandemic response or other types of crisis events are essential considerations for all radiology and radiotherapy departments moving forward. Local pandemic response strategies must be developed from standard protocols in readiness for safe practice during emergencies. This is necessary to mitigate the burden of extra workload and anxiety in relation to redeployment and the heightened risk of an infection in an attempt to balance radiographer safety, well-being, and patient care.

ii. ***Continuous professional development activities*****:** These should include simulated case scenarios of pandemics in relation to infection prevention and control, efficient communication, and information dissemination approaches during crisis events. Other activities in relation to efficient management and/or adaptation of diagnostic imaging protocols and mental health and well-being training will be critical.

iii. ***Resource Acquisition*****:** At a departmental and/or institutional level, a robust supply chain for resource acquisition, including appropriate PPE and other clinical consumables, should be ensured.

iv. ***Hybrid Workforce:*** Some changes to conventional workforce planning and practice are proposed. These include promotion of a limited form of role hybridisation[63] or adoption of a form of regulated staff rotation system across various modalities as a departmental workforce development strategy to enhance the redeployment experience of practitioners when necessary.

v. ***Remote Working:*** Relative to radiotherapy service delivery, remote working in diagnostic radiography has been very limited during the pandemic. Thus, implementation of the emerging remote scanning technologies (e.g., virtual

cockpit technology) will improve access to imaging services in more settings while enabling flexible radiographer deployment across multiple locations at a single time.

Figure Titles

Figure 1: PRISMA Flow Diagram- Search Strategy

Table Titles

Table 1: Summary of relevant research studies focusing on diagnostic radiography workforce.

Table 2: Summary of relevant radiotherapy/radiation oncology workforce studies.

Table Legends

Table 1: *Study coordinated from the United Arab Emirates with a multinational participation (United Arab Emirates, Oman, Kingdom of Saudi Arabia, Turkey, Sudan, Bahrain, India, Kuwait and Jordan); **Study coordinated from the United kingdom with a multinational participation (the rest of Europe, Africa, Oceania and North America); ø Study quality was determined using the Quality Assessment Tool for Studies with Diverse Designs (QATSDD) tool (Sirriyeh et al. 2012); PACS = Picture Archiving and Communications System; œ = findings are applicable to the radiotherapy/radiation oncology workforce.

Table 2: *Study coordinated from Ghana with multinational participation from Ghana, Algeria, Egypt, Kenya, Namibia, Nigeria, South Africa, Zambia. ø Study quality was determined using the Quality Assessment Tool for Studies with Diverse Designs (QATSDD) tool[51]; PACS = Picture Archiving and Communications System. **Study coordinated from the Netherlands with a multinational participation from the European Society for Radiotherapy and Oncology (ESTRO) membership with response mainly from Italy, Germany, Spain, The Netherlands, Switzerland, The United Kingdom, Belgium with a total of less than 5% response from other European countries.

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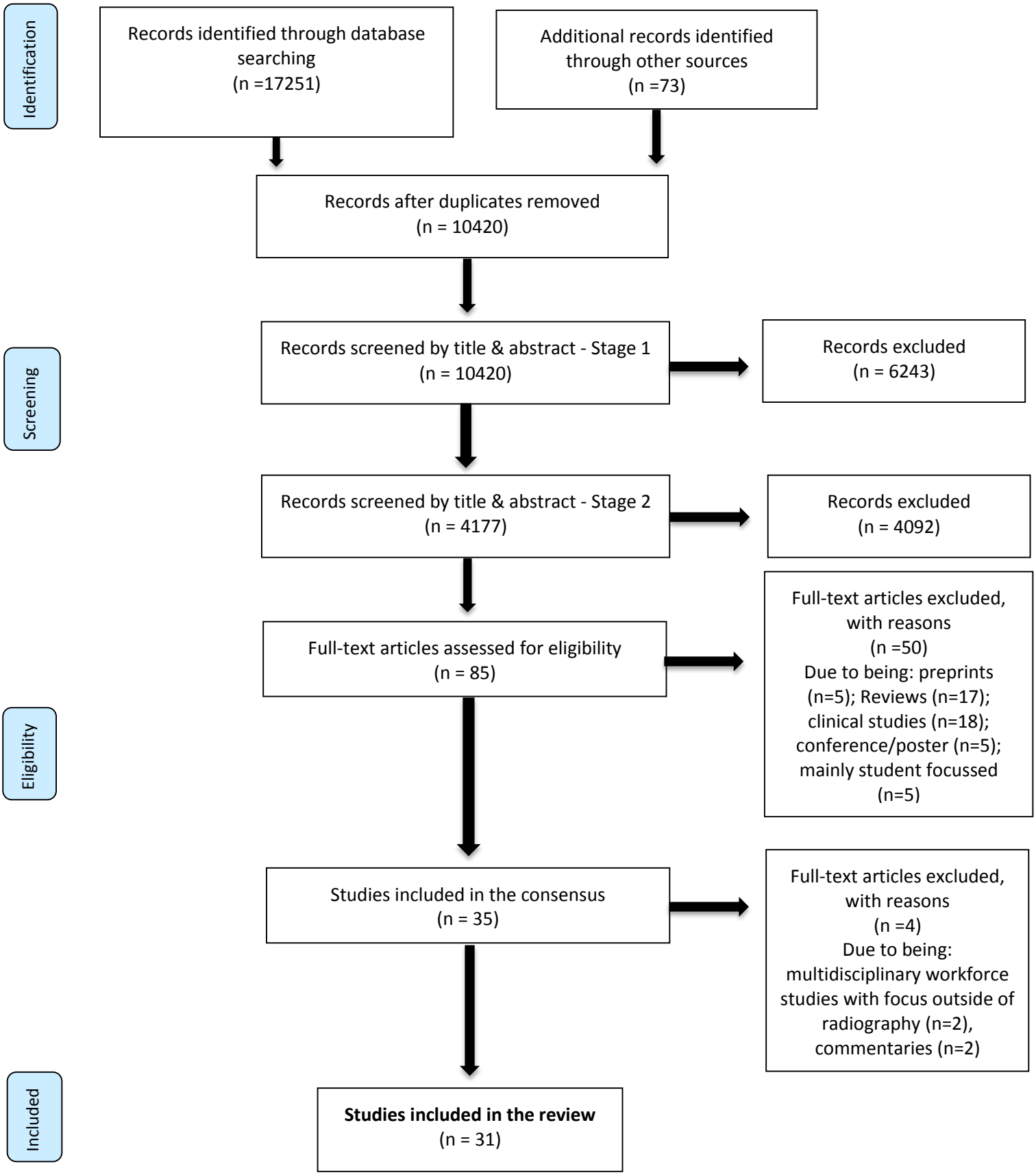
Figure 1: PRISMA Flow Diagram- Search Strategy



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Paper No.	Study Reference & Journal	Methods				Study Aim (s)	Study Outcomes		Study Quality Grading ø
		Country/ Continent of study	Sample/Study Site Characteristics	Study Design & Analysis approach	Study period & Duration or operational details of centres		Key findings	Key Conclusions	
1 œ	Akudjedu et al. 2020b BJR Open	United Kingdom, Europe	Diagnostic Radiographers (n=412, 78.9%) Therapy Radiographers (110, 21.1%) Total Sample Size = 522	Online survey Cross-sectional (one time-point) observation design Mixed methods data analysis approach	March 25th – April 26th, 2020 Survey Opened for 6 weeks	To assess the impact of the pandemic on radiography practice in the United Kingdom.	Fear of contracting the infection and perceived inadequate personal protective equipment (PPE) were identified as key contributors to workplace stress during the study period. Compared to the therapeutic workforce, a significantly higher proportion of the diagnostic workforce identified fear of being infected as a major stressor.	This survey has demonstrated changes to clinical practice, in particular to working patterns, service delivery and infection prevention and control were key contributors to workplace-related stress during the pandemic.	High
2	Akudjedu et al. 2020c Radiography	Ghana, Africa	Radiographers = 134	Online survey Cross-sectional (one time-point) observation design Quantitative data analysis approach	March 26th - May 6th, 2020 Survey opened for 22 days	To assess the radiographers' perspective on the impact of the pandemic on their wellbeing and imaging service delivery in Ghana.	Of the respondents, 75.4% (n = 101) reported to have started experiencing high levels of workplace-related stress after the outbreak. Three-quarters (n = 98, 73.1%) of respondents reported limited access to any form of psychosocial support systems at work during the study period.	Majority of the workforce started experiencing coronavirus-specific workplace-related stress after the outbreak. Albeit speculative, low patient confidence and fear of contracting	Moderate

							Half (n = 67, 50%) of the respondents reported a decline in general workload during the study period while only a minority (n = 18, 13.4%) reported an increase in workload due to COVID-19 cases.	the COVID-19 infection on hospital attendance contributed to the decline in general workload during the study period. In order to mitigate the burden of workplace-related stress on frontline workers, including radiographers, and in keeping to standard practices for staff mental wellbeing and patient safety, institutional support structures are necessary in similar future pandemics.	
3 œ	Akpaniwo et al. 2020 European Journal of Medical and Health Sciences	Nigeria, Africa	Radiographers = 107	Online survey Cross-sectional (one time-point) observation design	March 26th - April 30th, 2020. Survey opened for ~30 days	To assess the level of preparedness of the radiography sector in Nigeria.	Following the outbreak of COVID-19, 86% of the respondent's report that there have been changes in the departmental procedures. Sixty-seven percent said "no" to the availability of an appointment system, guidelines	Department managers have made some effort at improving working procedures for radiographers after the outbreak of the COVID-19 pandemic.	Moderate

				Quantitative data analysis approach			to reduce human to human contact (57%) and auditing for suspected COVID-19 cases (58.9%). Only 16 (15%) of the respondents had received emergency training towards the fight against COVID-19. Of these, 6 (37.5%) were trained in patient care, only 1 (6.3%) on emergency response while 9 (56.3%) received training in limiting human to human transmission.	However, a lot of areas requires urgent attention. These include development of appointment systems, provision of guidelines to reduce transmission, auditing for suspected COVID-19 cases, provision of dedicated imaging equipment for suspected and confirmed cases of COVID-19 in the departments and also in isolation centres, and the immediate setting of isolation centres where there are none. Need for emergency training should be organised for all radiographers, some of whom should be made part of the COVID-19 team in all isolation centres	

4	Aljondi et al. 2020 Journal of Radiation Research and Applied Sciences	Saudi Arabia, Asia	Radiographer = (n=34, 13.0%) Radiologic Technologist = (n=160, 63.0%) Radiologist = (n=62, 24.0%) Total Sample size = 256	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	May 24th - 31st May, 2020. Survey opened for ~7 days	To assess the knowledge and practice of infection control for COVID-19 among healthcare workers in radiology departments in Saudi Arabia.	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 Centre for Disease Control (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.	High
5 œ	Elgyoum et al. 2020 Archives of the Balkan Medical Union	Sudan, Africa	Diagnostic Radiographer = (n=80, 65.8%) Sonographer = (n=33, 27.5%) Radiology Nurse = (n=6, 5.0%) Radiologist = (n=1, 0.8%) Therapy	Online survey Cross-sectional (one time-point) observation design Quantitative data analysis approach	March - April, 2020. Survey opened for ~30 days	To evaluate the knowledge and practice of standard measures of infection prevention controls among the staff of the radiology departments in Sudan.	A total of 68.3% of the study group knew the guidelines established by the World Health Organisation (WHO) to deal with COVID-19 patients or suspected cases. 65% of the respondents had previous training in hand hygiene and about 75% of them had sufficient knowledge in hand hygiene, observed during their routine clinical practices. 69.2% of respondents used portable imaging equipment to limit	The radiology departments staff in Sudan is fairly aware of SICPs. They are strictly following standard guidelines for infection, prevention and management of COVID-19 issued by WHO.	Low

			Radiographer = (n=1, 0.8%) Total Sample size = 121				the transportation of COVID-19 patients and 69.2% were aware that the patients were wearing a surgical mask when entering and leaving the radiology department		
6 œ	Elshami et al. 2020 Radiography	Multinational*	Radiographers = (n=835, 92.5%) Advanced practitioners = (n=13, 1.4%) Radiologists = (n=21, 2.3%) Radiology Assistants = (n=8, 0.9%) Radiology Residents = (n=9, 1.0%) Radiology Nurse = (n=8, 0.9%) Others = (n=9, 1.0%) Total Sample size =903	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	May 22nd - June 2nd, 2020 Survey opened for ~12 days	To investigate the response of the radiology workforce to the impact of the coronavirus disease 2019 (COVID-19) pandemic on professional practice in India and eight other Middle Eastern and North African countries. It further investigated the levels of fear and anxiety among this workforce during the pandemic.	58% had completed training on infection control required for handling COVID-19 patients. A large proportion (79.5%) of the respondents strongly agreed or agreed that personal protective equipment (PPE) was adequately available at work during the pandemic. The respondents reported experiences of work-related stress (42.9%), high COVID-19 fear score (83.3%) and anxiety (10%) during the study period.	There was a perceived workload increase in general X-ray and Computed Tomography imaging procedures because they were the key modalities for the initial and follow-up investigations of COVID-19. Most radiology workers were afraid of being infected with the virus. Fear was predominant among workers younger than 30 years of age and also in temporary staff. Anxiety occurred completely independent of gender, age, experience,	High

								country, place of work, and work status. It is important to provide training and regular mental health support and evaluations for healthcare professionals, including radiology workers, during similar future pandemics.	
7 œ	Foley et al. 2020 Insights into Imaging	Republic of Ireland, Europe	First Time-point = 370 Radiographers Second Time-point = 266 Radiographers	Online surveys Longitudinal (two time-point) design Mixed methods data analysis approach	Early March, 2020 (1st Time-point). Late May, 2020 (2nd Time-point). Both Surveys opened for 2 weeks.	To describe the early experience of radiographers in Ireland to the impact of COVID-19 using two electronic surveys distributed 6 weeks apart.	Three quarters of radiographers (77%) reported having adequate personal protective equipment (PPE) available to them. However, almost half of the radiographers were inadvertently exposed to COVID-19-positive patients without appropriate PPE, largely attributed to poor communication and testing. Anxiety levels while initially high, reduced substantially 6 weeks into the crisis period. However, obvious distress was noted amongst some respondents. Forty percent of radiographers reported burnout symptoms due to	Clear communication regarding changing protocols and importantly patients' infectious status are essential to safeguard healthcare workers and to minimise unnecessary anxiety and distress. Attention is required to staff mental health including the identification of burnout symptoms to prevent long-term negative consequences of the pandemic on	High

							the COVID-19 crisis and 30% reported considering changing jobs or retiring since the COVID-19 outbreak.	radiography services.	
8	Harris et al. 2021 Journal of Medical Imaging & Radiation Sciences	Multinational**	Diagnostic Radiographers working in CT during the pandemic = 180	Online survey Cross-sectional (one time-point) observation design Mixed methods data analysis approach	June 29th - August 16th, 2020. Survey opened for ~6 weeks	To assess changes to service delivery, working practices and decision-making role of radiographers working in CT departments during the pandemic.	Service delivery changes included social distancing, restriction of referrals to those considered time-critical and dedicated COVID-19 scanners. Working practices were impacted by a need to implement PPE, although variation in PPE worn for different scenarios was seen. Half of the radiographers were routinely reviewing asymptomatic outpatient images for common COVID-19 signs, despite 63.5% of respondents not receiving formal training. Ad hoc patient pathways were in place in 90.5% of cases with 35% indicating that this was radiographer-led. CT staff had experienced anxiety, fatigue, and low morale, but praised teamwork.	This study has demonstrated that despite variance in practice, radiographers play a key role in identifying and triaging high-risk patients. Radiographers were able to reduce the risk of transmission through social distancing, designated scanners, and PPE.	High

9 œ	Hasford et al. 2020b Health & Technology	Ghana, Africa	Diagnostic Radiographer = (n=95, 65.5%) Medical Physicist = (n=26, 17.9%) Radiological Technician = (n=16, 11.0%) Sonographer = (n=5, 3.40%) Therapy Radiographer = (n=3, 2.10%) Total Sample size = 145	Online survey Cross-sectional (one time-point) observation design Quantitative data analysis approach	Not reported	To assess the level of knowledge on SARS-COV-2 infection prevention, transmission, and symptoms of COVID-19, as well as perceptions regarding prevention of SARS-COV-2 infection among allied radiation medicine professionals.	Overall, the extent of knowledge among allied radiation medicine professionals on the symptoms of COVID-19, transmission and control of SARS-COV-2 infection in radiation medicine facilities were all adequate, with weighted average indices of 3.8, 4.1 and 4.4 respectively. However, overall perception of the respondents regarding the use of radiation medicine procedures in management of COVID-19 was diverse, with weighted index of 3.5. The facts about COVID-19 that were identified to be most known were shortness of breath being a serious symptom of the disease and fever being a common symptom. The extent of knowledge on the fact that "SARS-COV-2 infection can be transmitted through small droplets from the nose or mouth of an infected person" was almost excellent, with weighted average index of 4.9. Also, the thinking that provision of hand washing, and	The study shows that some aspects of the awareness of radiation medicine professionals on COVID-19 pandemic are adequate and others need critical improvement to help reduce spread of the disease.	Moderate

							sanitizing facilities is a measure for controlling the infection was almost perfectly shared among the respondents. Computed tomography was perceived by majority of the respondents as the most preferred imaging modality for screening patients for COVID-19		
10	Huang et al. 2020a Medical Science Monitor	China, Asia	Technicians (Radiographers) = (n=245, 41.7%) Doctors = (n=223, 38.0%) Radiology Nurse = (n=119, 20.3%) Total Sample size =587	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	February 7th - February 9th, 2020. Survey opened for ~2 days	To assess the resilience level of medical staff in radiology departments during the outbreak of COVID-19 and to explore factors related to it to provide a basis for more effective risk assessment and psychological intervention.	There was a significant negative correlation between perceived stress and resilience (r=−0.635, P<0.001). According to multivariate analysis, the total perceived stress score (β=−1.318, P<0.001), gender (β=−4.738, P<0.001), knowledge of COVID-19 (β=2.884, P=0.043), knowledge of COVID-19 protective measures (β=3.260, P=0.042), and availability of adequate protective materials (β=−1.268, P=0.039) were independent influencing factors for resilience.	The resilience level of the medical staff in the radiology departments during the outbreak of COVID-19 was generally low, particularly regarding toughness. More attention should be paid to resilience influence factors such as high perceived stress, female gender, lack of understanding of COVID-19 and protective measures, and lack of protective materials, and targeted	High

								interventions should be undertaken to improve the resilience level of the medical staff in the radiology departments during the outbreak of COVID-19.	
11	Huang et al. 2020b Medical Science Monitor	China, Asia	Technicians (Radiographers) = (n=245, 67.3%) Radiology Nurse = (n=119, 32.7%) Total Sample size =364	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	February 7th - February 9th, 2020. Survey opened for ~2 days	To understand the prevalence of psychological anxiety and identify risk and protective factors contributing to anxiety.	Some participants reported mild (n=63), moderate (n=19), or severe (n=3) anxiety. Multiple linear regression analysis showed that age, job position, availability of protective materials, signs of suspected symptoms, and susceptibility to emotions and behaviours of people around them were identified as risk factors for anxiety, whereas psychological resilience was identified as a protective factor.	Anxiety level of health care workers in the radiology department with a high exposure risk to COVID-19 was high in the early stage of the outbreak, although the majority remained within normal limits. Timely assessment and effective intervention measures can improve the mental health of these at-risk populations.	High
12	Itani et al. 2021 Healthcare	Lebanon, Asia	Radiographers = 212	Online survey	December 3rd – 17th , 2020.	To highlight the experiences and evaluate factors associated with	Despite applying an adapted safety protocol, institutions are neither providing free RT-PCR	This study highlighted the different ways the pandemic has	High

				Cross-sectional (one time-point) design Quantitative data analysis approach	Survey opened for 14days	stress from contracting the virus from the workplace among Lebanese radiographers.	testing to their staff nor showing adequate support for infected staff members, thus causing distress about contracting the virus from the workplace. Aggravated by the deteriorating economic situation that affected the radiographers financially, they additionally suffer from severe occupational physical and mental burnout.	impacted radiographers: physically, psychologically, and financially. Regardl ess of that, they used their free time during the lockdown for skill/knowledge development and have performed many recreational activities.	
13 œ	Kotian et al. 2020a Health & Technology	India, Asia	Radiographer = (n=126, 22.9%) Radiography Teaching Staff = (n=35, 6.4%) Radiography students = (n=320, 58.2%) Radiography interns = (n=64, 11.6%) Administrators = (n=5, 0.9%)	Online Survey Cross-sectional (one time-point) design Quantitative Data Analysis approach	March 31st - April 5th, 2020 Survey opened for ~7 days	To investigate the knowledge and understanding of medical imaging professionals (MIP) about COVID-19.	Regarding COVID-19, most of the participants answered correctly (95.5%) on symptoms, (84.4%) time interval for visible symptoms, (98.0%) transmission and (44%) airborne transmission respectively. A significant proportion of MIPs (36.4%) had poor knowledge about wearing multiple masks as an effective measure against coronavirus infection. Most of the respondents (48.5%) incorrectly considered X-ray as the reliable method of diagnosis for suspected COVID-19 patients. 44.6% of the respondents lacked	Our findings suggest that MIPs, have poor knowledge, attitudes, and appropriate practices towards COVID-19 during the rapid rise period of the COVID-19 outbreak. However, the MIPs had good knowledge about the symptoms and general awareness on COVID-19.	Moderate

			Total Sample size = 550				knowledge about the steps involved in hand washing technique which is one of the most important safety practice methods in medical imaging to prevent spread of infection.	it is crucial and critical to improve the knowledge and understanding of MIPs.	
14	Lewis and Mulla, 2020 Radiography	South Africa, Africa	Diagnostic Radiographers = 60	Online survey Cross-sectional (one time-point) and purposive design Qualitative data analysis approach	Not reported	To explore diagnostic radiographers' experiences of COVID-19 in Gauteng.	Thematic analysis revealed three themes: new workflow and operations, effect on radiographer well-being and radiographer resilience.	Besides experiencing a shift in their professional work routine and home/family dynamics, diagnostic radiographers' well-being has also been impacted by COVID-19. Adapting to the "new way of work" has been challenging yet their resilience and dedication to their profession, providing quality patient care and skill expertise is their arsenal to combat these challenges. They have experienced changes to staff	Moderate

								allocations and work-hours as well as the implementation of stringent infection control and social distancing measures. Moreover, they face mental, physical, emotional and financial challenges.	
15 œ	Maraqa et al. 2020 Journal of Primary care & Community Health	Palestine, Asia	Doctors = (n=211, 49.1%) Other healthcare workers including radiographers = (n=219, 50.9%) Total Sample size =430	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	March 29th - April 15th, 2020. Survey opened for ~16 days	To assess the level of stress perceived by healthcare workers and possible associated factors during the COVID-19 outbreak in Palestine.	Most respondents (74.0%) reported high-stress levels during the outbreak. Fear of transmitting the virus to family was the most stressful factor (91.6%). HCWs who did not have training on the outbreak response were more likely to have high-stress levels (OR = 2.7 [95% CI = 1.7-4.4], *P* < .001). Those with high stress reported being disappointed (OR = 2.4 [95% CI = 1.5-3.6], *P* < .001), and strongly considered taking sick leave (OR = 3.9 [95% CI = 1.9-7.9], *P* < .001).	Health Care Workers (HCWs) are under tremendous stress, given the ongoing COVID-19 pandemic. Understanding the psychological impact of the outbreak on HCWs and the activities that mitigate the stress is crucial to guide policies and interventions that can maintain psychological well-being.	High
16	Ooi et al. 2020 Radiography	Singapore, Asia	Diagnostic Radiographers = 48	Online survey	The online survey was opened for one	To explore the radiographers' perspectives of	Radiographers experienced fatigue and appreciated the longer rest days	The findings indicate that the extended shift	High

				Cross-sectional (one time-point) observation design Mixed methods data analysis approach	week in 2020 (month not reported). Data was obtained from Picture Archiving and Communication System (PACS) and Departmental Sick Leave Management Record between February and June in the years 2019 and 2020.	the new shift [12-h shift consisted of the day (9am-9pm) and night (9pm-9am)] and the impact of shift patterns on radiographers' wellness and work performance compared to the original three shift patterns [morning (8am-2pm), afternoon (2pm–9pm) and night (9pm-8am)].	associated with the 12-h shift. Additionally, the sick leave rates and image reject counts were more favourable with the 12-h shift pattern.	hours are effective during a pandemic but may result in radiographer burnout during a prolonged outbreak. Studying these variables will provide an effective starting point in understanding the efficacy and applicability of a 12-h shift system during pandemic periods	
17	Ooi et al. 2021 Proceedings of Singapore Healthcare	Singapore, Asia	Radiographer = (n=97, 63.4%) Radiology nurse = (n=34, 22.2%) Support Staff (Assistant practitioners etc) = (n=22, 14.4%)	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	July 13th - August 12th, 2020. Survey opened for ~30 days	To identify the knowledge, attitude, perceptions (KAPs) of HCWs with direct patient contact in Singapore, with regard to workplace preparedness at a single-site radiology	Radiology HCWs self-reported significantly better knowledge of infection control measures and positive work attitudes. Those who had received the flu vaccine had significantly better perceptions of working during the pandemic. Suggested improvements included better organisational structure	The findings indicate favourable KAPs among radiology HCWs in Singapore with regard to workplace preparedness during the pandemic, but efforts towards sustainability must be considered.	High

			Total Sample size = 153			department during the COVID-19 pandemic.	and more resources, better staff compliance and vigilance, better education, and a clearer focus on staff wellbeing.	Formulating policies to nurture motivated and resilient HCWs during a pandemic is advocated to foster a resilient workforce that is prepared for the next pandemic.	
18	Ossama et al. 2020 The Sapporo Medical Journal	Saudi Arabia, Asia	Diagnostic Radiographer = (n=66, 42.86%) Radiologist = (n=88, 57.14%) Total Sample size = 154	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	Not reported	To holistically evaluate the perception and knowledge of radiology team members as regards COVID-19 infection and its related aspects.	Participants had good knowledge about the new Saudi Ministry of Health (MOH) guidelines for the radiology department teams during the COVID-19 pandemic. Their overall perception and practice regarding the protective measures was very high. Approximately, 62% of them do believe that personal precautions are sufficient for protection against this infection. The commonest cause of stress among the radiology technicians was the shortage of their numbers (68.2%). This was expressed as elevated workload, imposed pressure with a higher perception of increased	Radiology team members within the Eastern Province area were highly acquainted with the MOH guidelines for dealing with COVID-19 pandemic. They are also fully oriented with the self-precautionary measures during the pandemic. Although the participants' number is slightly limited, it may highlight the need for further studies with higher participants' number to give a realistic view of the radiologists	Low

							liability to contract infection.	and their team when dealing with biological hazards such as this pandemic.	
19 œ	Pereira et al. 2021 Radiography	Portugal, Europe	Radiographers = 386	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	April 16th - 26th, 2020. Survey opened for ~10 days	To assess the impact of the COVID-19 pandemic on the incidence of burnout among Portuguese radiographers.	A total of 43.5% and 45.5% of subjects had a high level of emotional exhaustion and depersonalization, respectively, and 59.8% experienced low personal accomplishment. Altogether, 23.3% of study participants were at high risk of burnout in the three dimensions assessed and 77.2% in at least one.	The findings showed that radiographers were at high risk of developing burnout in the COVID-19 pandemic setting. Health institutions should actively monitor these professional's mental health and develop restorative strategies that enable their emotional wellbeing, preventing absenteeism and increasing patients' quality of care.	High
20 œ	Ruiz et al. 2020 Radiography	Spain, Europe	Radiographers = 546	Online surveys Observational, cross-sectional (one time-point) design	May 5th – June 1st, 2020. Survey opened for ~4 weeks	To determine radiographers' perceptions of threat-related with possible exposure to COVID-19 and	The results showed a high level of a perceived threat from COVID-19, furthermore we observed a high level of threat about the possibility of infecting family members, patients,	COVID-19 pandemic is perceived as a serious threat, being especially concerned about the threat of	High

				Quantitative data analysis approach		the possibility to spread the infection between family, patients and co-workers.	and co-workers. Furthermore, females have a higher level of a perception of threat to spread infection between patients and co-workers, than males.	spreading the infection to family, co-workers, and patients. The perception of risk depends partly on professionals' gender and family responsibilities. Our findings suggest that it is recommended that healthcare professionals receive formation to reinforce and improve their emotional competencies for coping successfully with potentially stressful situations like COVI19 pandemic.	
21 œ	Shanahan & Akudjedu, 2021 Journal of Medical Radiation Sciences	Australia, Australia	Diagnostic Radiographers (n=177, 81.2%) Therapy Radiographers (41, 18.8%) Total Sample Size = 218	Online survey Cross-sectional (one time-point) observation design Mixed methods data analysis approach	June 24th - July 15th, 2020. Survey opened for 22 days	To assess the perceptions of Australian dia gnostic radiographers and radiation therapists on the impact of the COVID-19 pandemic on their practice.	Changes in work hours ($p < 0.001$) and workload ($p= 0.022$) were experienced due to COVID-19. Diagnostic radiographers reported increased procedural pressure on mobile radiography, computed tomography and general radiography. For radiation therapists, most pressure was reported on	COVID-19 has resulted in changes to clinical working patterns and service delivery. PPE shortages as well as increased workplace-related stress were identified. Workplaces should seek to mitigate	High

							simulation and linear accelerator. PPE was in short supply at the start of the pandemic, and at the time of the study, shortages were identified for all PPE items. There was no difference in PPE supply reported by diagnostic radiographers and radiation therapists except for hand sanitiser (p=0.003). Respondents experienced increased personal stress (61.4%) and anxiety (58.2%) at work due to COVID-19. In addition, their work caused increased stress to their family, partners or friends (57.4%).	the pandemic impact through provision of adequate PPE for safe practice as well as implement strategies to support and enhance staff well-being.	
22	Yasin et al. 2021 Radiography	United Kingdom, Europe	Diagnostic Radiographers = 16	Online survey Cross-sectional (one time-point) observation design Mixed methods data analysis approach	March 23rd - June 21st, 2020. Survey opened for ~13 weeks during the first wave and direct comparison was made to the same period in 2019.	To investigate the physical and mental demands of mobile x-ray imaging on radiographers during the first wave of the COVID-19 pandemic, within a local NHS Trust.	Three key themes emerged from the data. These include mental health challenges/work morale in Radiology, demand of mobile imaging and departmental and Trust-wide mental health support. Results indicate a high demand in mobile imaging which has made a significant difference in the working life of some radiographers.	The COVID-19 pandemic has significantly affected the mental health of a proportion of radiographers at this Trust. Results indicate high workload and demand in mobile imaging has made a significant difference to the working life of	Moderate

								radiographers, specifically the ones who were relatively newly qualified.	
23 œ	Zervides et al. 2020 Radiography	Cyprus, Europe	Therapy Radiographers and Nuclear Medicine = (n=4, 3.9%) Diagnostic Radiographers = (n=97, 96.1%) Total Sample Size = 101	Online surveys Observational, cross-sectional (one time-point) design Quantitative data analysis approach	May 12th - May 23rd, 2020. Survey opened for 11 days	To assess the insight of radiographers on how the COVID-19 pandemic has affected their work routine and if protective measures are applied.	The results showed that there are statistically significant differences regarding the working hours, the feeling of stress, the work effectiveness, the average examination time, the presence of a protocol used among the different workplaces of the participants; a private radiology centre, a private hospital or a public hospital, Also, statistically significant differences were observed in the decontamination methods used for equipment (p-value 0.007), for air (p-value 0.04) and when decontamination takes place (p-value 0.00032) among the different workplaces of the participants. Nonetheless, the majority of radiographers believe that their workplace is sufficiently provided with PPE, cleaning supplies, equipment, and with	There are protocols regarding protective measures against COVID-19, and the radiographers are adequately trained on how to face an infectious disease outbreak. However, work is needed in order to develop protocols that reassure the safety of patients and medical personnel while managing the excess workload effectively. This study indicates the importance of applying protective measures and protocols in the radiology departments in order to minimise	Moderate

							cleaning personnel and are optimistic regarding the adequacy of these provisions in the next three months.	the spread of the virus.	

Table 1: Summary of relevant research studies focusing on diagnostic radiography workforce. *Study coordinated from the United Arab Emirates with a multinational participation (United Arab Emirates, Oman, Kingdom of Saudi Arabia, Turkey, Sudan, Bahrain, India, Kuwait and Jordan); **Study coordinated from the United kingdom with a multinational participation (the rest of Europe, Africa, Oceania and North America); ø Study quality was determined using the Quality Assessment Tool for Studies with Diverse Designs (QATSDD) tool (Sirriyeh et al. 2012); PACS = Picture Archiving and Communications System; œ = findings are applicable to the radiotherapy/radiation oncology workforce.

Paper No.	Study Reference & Journal	Methods				Study Aim (s)	Study Outcomes		Study Quality Grading ø
		Country/ Continent of study	Sample/Study Site Characteristics	Study Design & Analysis approach	Study period & Duration or operational details of centres		Key findings	Key Conclusions	
1	Achard et al. 2020 Journal of the European Society for Therapeutic Radiology and Oncology	Switzerland, Europe	22 Swiss Radiation Oncology Departments.	Online surveys Observational, cross-sectional (one time-point) design Quantitative data analysis approach	April 7th – April 24th, 2020 Survey Opened for 17 days	To better understand the early impact of the COVID-19 pandemic on radiotherapy practice in Switzerland.	Approximately half (45%, 10/22) of the Swiss radiation-oncology departments had been confronted with patients diagnosed with COVID-19, with 73% of the centres (16/22) experiencing a reduction of their daily activity. 18% of the departments suffered from staff shortage (4/22), with COVID-19 infection among staff members observed in 5 out of 22 centres (23%,) and part/full-time shift of collaborators in a COVID-19 unit imposed Dedicated IT solutions for the COVID-19 crisis were implemented in all institutions. Remote access to the treatment planning workstations was available	Dedicated IT solutions were implemented in all radiation-oncology departments. Use of hypofractionation for breast, rectal cancer and palliation was increased. Remote consultations were offered whenever possible in all centres.	Low

							for staff members in (91%) centres and allowed for majority of the teams (81%) to practice split staffing.		
2	Caravatta et al. 2020 BMC Radiation Oncology	Italy, Europe	Single Radiotherapy/Radiation Oncology Centre in Central Italy (Chieti – Abruzzo Region). Equipped with two Linear Accelerators (LINAC) and simulation computed tomography (Simul CT). Radiography Workforce: 14	Comparative study Quantitative data analysis approach	The centre operates two daily shift patterns between 8.00 am and 8.30 pm. Time period for which the centre's activity is being compared: ordinary routine conditions, within the period March 9th – May 4th, 2019. Full lockdown phase I of the COVID-19 emergency, March 9th – May 4th, 2020.	To compare the centre's treatment and management activities under ordinary routine conditions and full lockdown phase I of the COVID-19 emergency.	The centres operational capacity during both periods were similar and no cases of COVID-19 positivity recorded either in patients or in healthcare professionals.	During both phases of the COVID-19 emergency, the planned model used in our own experience guaranteed both continuity in radiotherapy treatments whilst neither reducing workload nor interrupting treatment and, as such, it ensured the safety of cancer patients, hospital environments and staff.	Moderate
3	Carvalho et al. 2020	Brazil, South America	Single Radiotherapy Department of a tertiary	Comparative study	An analysis of the first two-month period (April and May	To report the impact of the COVID-19 pandemic on	A 10% reduction in the number of treated patients and a 26% reduction in the number of sessions was	There was a decrease in the number of treated patients in our	Moderate

	Clinics		public/university hospital Equipped with 10 Linear Accelerators (LINAC) and one high dose-rate brachytherapy machine.	Quantitative data analysis approach	2020) after the implementation of established policies was carried out, and this period was compared with the same period in 2019.	patient attendance at a radiotherapy department two months after the implementation of specific policies regarding the pandemic.	observed. The main impact was a decrease in the treatment of benign diseases and gastrointestinal tumours, with a general increase in breast cancer treatments. Eighteen (1.7%) patients were confirmed as having COVID-19 during radiotherapy in April and May 2020, three of whom were hospitalized, and one patient died because of COVID-19. Among the 18 patients, 12 had their treatments interrupted for at least 15 days from symptom appearance.	radiotherapy department, with a greater decrease in the total number of sessions. This indicated, overall, a smaller number of fractions/patients treated, despite our efforts to maintain the treatment routine. We had several patients who were infected with COVID-19 and one related death during treatment in the first few months of the pandemic in São Paulo, Brazil.	
4	Hasford et al. 2020a Health & Technology	Multinational*	12 radiotherapy centres in 8 African countries*	Comparative study Quantitative data Analysis approach	Not reported	To analyse safety measures and practices being put in place in some radiotherapy (RT) centres in the Africa region to ensure that radiotherapy	The study shows that use of personal protective equipment, provision of hand washing and sanitizing facilities, social distance observance, restrictions for patient care-givers, provision of isolation unit meant for holding suspected COVID-19 cases, existence of working protocols, and COVID-19 safety education for staff are	Strict adherence of the safety measures is highly essential to contain the spread and prevent infection of the disease to patients, care-givers and staff of the radiotherapy departments	Low

						services are continually delivered at optimally safe levels while reducing COVID-19 infection spread between patients, care-givers and within the workforce.	fully complied with by the surveyed radiotherapy centres. A greater portion of the centres, are however, without radiotherapy facilities solely dedicated for suspicious and confirmed COVID-19 cases.	across the African region.	
5	Jereczek-Fossa et al. 2020 Radiotherapy & Oncology	Italy, Europe	125 Directors of Radiotherapy/Radiation Oncology Departments (this included senior/superintendent radiographers)	Online surveys Observational, cross-sectional (one time-point) design	April 6th – 16th, 2020 Survey opened for 10 days	To identify strategies that Italian Radiotherapy (RT) facilities have implemented to face this unprecedented emergency.	Nevertheless, despite the entity of the pandemic in Italy, the total number of positive patients and units of personnel in quarantine was relatively low. This fact can be ascribable to efficacy of triage procedures and, more in general, to all adopted measures. On the other hand, despite the reasonably higher probability of coming into contact with positive patients, the facilities in Lombardy had, on average, less PPE in use than the Italian average. Working from home could replace could represent a	This survey showed rapid reaction by the Radiation Oncology Departments to the COVID-19 crisis, demonstrating that use of information technologies, RT prioritization and implementation of hypofractionation and protection procedures allowed balancing between cancer patient care and safety while	Moderate

							valid tool for some office based tasks such as remote contouring and planning or scientific writing. Telephonic triage is effective at minimising infection spread, thus, telemedicine, allows more flexibility for both clinicians and patients.	safeguarding the healthcare staff.	
6	Malicki et al. 2020 Reports of Practical Oncology and Radiotherapy	Poland, Europe	Single Radiotherapy/Radiation Oncology Centre - Greater Poland Cancer Centre (GPCC)	Observational study Quantitative data analysis approach	Radiotherapy patient volume during the 10-week period from March 15th - May 22nd, 2020 at the peak of the pandemic restrictions, compared to the usual number of patients treated prior to the pandemic.	To assess the impact of precautionary measures implemented in response to the COVID-19 pandemic on the performance of a radiation oncology departments in given cancer centre in Poland.	The number of patients treated with radiotherapy during the study period decreased due to precautionary measures. After five weeks, the number of radiotherapy treatments began to increase. Just over half of the radiotherapy patients (53.5%) treated at the GPCC reside in the city of Poznan or in one of the ten surrounding counties where COVID-19 incidence was low and reached at the end of the study period cumulative number of cases n = 204.	The precautionary measures were effective Real-Time Quantitative Reverse Transcription Polymerase Chain Reaction (qRT-PCR) tests were performed in 1545 individuals (patients and hospital staff) revealing four staff members and no patient with a positive PCR result. Immunoglobulin testing was performed in 1132 individuals (patients and hospital staff). A total of 63	Moderate

								individuals were positive for antibodies.	
7	Slotman et al. 2020 Radiotherapy & Oncology	Multinational**	Directors/Heads of 139 Radiotherapy/Radiation Oncology Departments who are members of the ESTRO (this included Senior/superintendent radiographers)	Online survey Cross-sectional (one time-point) design Quantitative data analysis approach	6^{th} - 20^{th} May, 2020 Survey opened for ~2 weeks	To evaluate the impact of COVID-19 on radiation oncology departments in Europe.	All departments were operational. In 58% of them, treatment of some new patients was deferred to a later date. A decline in patient volume was noticed in 60% of the departments. A reduction in staff occurred in 57% of the departments, mainly due to the impact of the COVID-19 pandemic on family care responsibilities (29%), staff COVID-19 illness (26%) and staff transfer to other clinical areas (13%).	Telemedicine was used in 78% of the departments, and 60% reported a decline in patient volume. Use of protective measures was implemented on a large scale, but shortages of personal protective equipment were present in more than half of the departments.	Low
8	Spencer et al. 2021 The Lancet Oncology	United Kingdom, Europe	Population-based dataset relating to all radiotherapy delivered for cancer in the English NHS	Comparative study Quantitative data analysis approach	Changes in mean weekly radiotherapy courses, attendances (reflecting fractions), and fractionation patterns following the start of the UK lockdown were compared with corresponding	To assess the impact of the pandemic on radiotherapy activity in England	In 2020, mean weekly radiotherapy courses fell by 19·9% in April, 6·2% in May, and 11·6% in June compared with corresponding months in 2019. A relatively greater fall was observed for attendances (29·1% in April, 31·4% in May, and 31·5% in June). A greater reduction in treatment courses between 2019 and 2020 was seen for patients aged 70 years or older compared with those	Radiotherapy activity fell significantly but use of hypofractionated regimens rapidly increased in the English NHS during the first peak of the COVID-19 pandemic. An increase in treatments for some cancers suggests that radiotherapy	High

					months in 2019 overall, for specific diagnoses, and across age groups. Data relating to all radiotherapy delivered for cancer in the English NHS, from Feb 4th, 2019 - June 28th, 2020.		aged younger than 70 years (34·4% *vs* 7·3% in April).	compensated for reduced surgical activity.	

Table 2: Summary of relevant radiotherapy/radiation oncology workforce studies. *Study coordinated from Ghana with multinational participation from Ghana, Algeria, Egypt, Kenya, Namibia, Nigeria, South Africa, Zambia. ᵠ Study quality was determined using the Quality Assessment Tool for Studies with Diverse Designs (QATSDD) tool (Sirriyeh et al. 2012); PACS = Picture Archiving and Communications System. **Study coordinated from the Netherlands with a multinational participation from the European Society for Radiotherapy and Oncology (ESTRO) membership with response mainly from Italy, Germany, Spain, The Netherlands, Switzerland, The United Kingdom, Belgium with a total of less than 5% response from other European countries.