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Research Article

# Computed tomography during the COVID-19 pandemic: A survey of changes to service delivery, working practices and decision-making role of radiographers

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## ABSTRACT

**Introduction:** During the COVID-19 pandemic, Computed Tomography (CT) departments have established additional acute capacity whilst maintaining essential services. The purpose of this study was to investigate the changes in service delivery, working practices and decision-making role of diagnostic radiographers during the pandemic.

**Methods:** We conducted an electronic cross-sectional survey of diagnostic radiographers working in CT during the COVID-19 pandemic. The survey was open for 6-weeks, with radiographers from all geographical regions encouraged to respond. The questionnaire explored social distancing, patient scheduling and departmental organisation; PPE usage; recognition and escalation of COVID-19 changes, patient management pathways and any training. Additionally, we sought the personal perspectives of radiographers through free text comments.

**Results:** Following exclusions, 180 responses were analysed. Service delivery changes included social distancing (59.4%; n= 107), restriction of referrals to those considered time-critical (63.3%; n=114) and dedicated COVID-19 scanners (66.1%; n=119). 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.

**Conclusions:** Radiographers were able to reduce the risk of transmission through social distancing, designated scanners, and PPE. This study has demonstrated that despite variance in practice, radiographers play a key role in identifying and triaging high-risk patients.

## RÉSUMÉ

**Introduction :** Pendant la pandémie de COVID-19, les services de tomodensitométrie (TDM) ont mis en place une capacité aigüe supplémentaire tout en maintenant les services essentiels. Le but de cette étude était d'examiner les changements dans la prestation de services, les pratiques de travail et le rôle décisionnel des radiographes de diagnostic pendant la pandémie.

**Méthodologie :** Nous avons mené une enquête électronique transversale auprès des radiographes de diagnostic travaillant dans le domaine de la tomodensitométrie pendant la pandémie de COVID-19. L'enquête a été ouverte pendant 6 semaines, les radiographes de toutes les régions géographiques étant encouragés à y répondre. Le questionnaire portait sur la distanciation sociale, la programmation des patients et l'organisation du service, l'utilisation des EPI, la reconnaissance et l'escalade des changements liés au COVID-19, les voies de prise en charge des patients et toute formation. En outre, nous avons cherché à connaître le point de vue personnel des radiographes par le biais de commentaires libres.

**Résultats :** Après exclusions, 180 réponses ont été analysées. Les changements apportés à la prestation des services comprenaient la

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distanciation sociale (59,4 % ; n= 107), la restriction des aiguillages à ceux considérés comme critiques en termes de temps (63,3 % ; n=114) et des scanners COVID-19 dédiés (66,1 % ; n=119). Les pratiques de travail ont été affectées par la nécessité de déployer des EPI, bien que l'on ait constaté des variations dans les EPI portés pour différents scénarios. La moitié des radiographes examinaient systématiquement les images des patients ambulatoires asymptomatiques pour détecter les signes communs de la COVID-19, bien que 63,5 % des répondants n'aient pas reçu de formation officielle. Des parcours ad hoc pour les

patients étaient en place dans 90,5 % des cas, avec des indications à l'effets qu'ils étaient dirigés par des radiographes dans 35% des cas. Le personnel de TDM a ressenti de l'anxiété, de la fatigue et une baisse de moral, mais a loué le travail d'équipe.

**Conclusion :** Les radiographes ont pu réduire le risque de transmission par la distanciation sociale, la désignation de scanners et l'EPI. Cette étude a démontré que malgré la variance des pratiques, les radiographes jouent un rôle clé dans l'identification et le triage des patients à haut risque.

*Keywords:* Computed tomography; Diagnostic radiography; Radiographers; COVID-19; Pandemic

## Introduction

The COVID-19 pandemic continues to dominate world-wide, with 136,508,474 cases of COVID-19 and 2,536,888 deaths reported internationally as per April 15 2021 [1]. The resultant health crisis has evolved through several stages since the international community lockdowns were initiated in March 2020. In the UK, an unforeseen acute stage was followed by temporary easing of restrictions, prior to the introduction of staged tiers as the number of regional positive cases crept up to critical levels. At the point of writing, multiple coronavirus vaccines have received authorisation worldwide. However, precautions remain in place as the mass vaccination programme will take a significant length of time to complete, and the efficacy of vaccines against all variants is unknown. The majority of COVID-19 cases are asymptomatic or mild enough to be treated at home. However, the World Health Organisation (WHO) states that approximately 5% of confirmed cases are severe enough to require robust treatment strategies and intensive care [2]. The main causes of mortality include respiratory distress syndrome, organ failure, septic shock and severe pneumonia [2]. The acute phase was characterised by a period of rapid learning and adaptation by all work sectors, but particularly healthcare organisations who were required to identify, treat, and reduce risk for patients at risk of COVID-19 [3]. Guidance on infection control and personal protective equipment (PPE) was provided internationally [4] and reflected at country level, such as that relevant to organisations in England [5]. However, messages changed regularly in line with developing scientific knowledge. Concerns around advice and availability of PPE for UK healthcare workers during the acute phase were also well documented [6–11].

Imaging has played a critical role in the diagnostic pathway of COVID-19 [12]. Evidence-based guidance on the use of imaging has been provided throughout the pandemic with chest X-rays recommended as a primary tool for diagnosis and follow-up of coronavirus pneumonia progression, alongside polymerase chain reaction (RT-PCR) testing [13,14]. Chest X-rays have the versatility of being performed outside of the imaging department at the patient bedside but required carefully devised local standard operating procedures [13]. Although, Computed Tomography (CT) is an accurate and well-accepted

test for patients with severe respiratory distress, it was advocated that CT was not performed as a screening tool but reserved for moderate to severe features of COVID-19 [6] based on monitoring progression [15] and potential for acute thromboembolic disease [16]. Cases would need risk/ benefit analysis by clinicians and radiologist authorisation [15] as CT scanning requires the patient to attend the imaging department. Patient transfer to CT in these cases is often complex and resource intensive and requires carefully coordinated decontamination of CT facilities following COVID-19 positive cases.

The impact of the pandemic on diagnostic imaging departments has been extensive. The emergency has demanded that modalities establish additional capacity and processes for COVID-19 related inpatient workload, including the segregation of patients considered to be WHO classified as probable, suspected, or confirmed [3], from those considered to be at low risk of having the infection. Within their means, imaging departments have also attempted to pragmatically maintain safe, clinically essential non-COVID-19 services, and more recently to restore elective outpatient capacity to pre-pandemic levels. It is acknowledged that throughout the pandemic asymptomatic, but COVID-19 positive, patients may be attending imaging departments for a diagnostic workup of different pathologies; therefore, the necessary precautions may not have been undertaken [12].

The purpose of this study was to investigate the changes that have been made by the CT department within diagnostic imaging and their impacts on service delivery, working practices and decision-making role among diagnostic radiographers. The aim was to ascertain the types of scans accepted during the pandemic, whether departments were using dedicated COVID-19 scanners, and if they could ensure social distancing during care. The working practices surveyed related to radiographer PPE for high-risk versus low-risk COVID-19 cases, and provision of facemasks for patients. Based on the risk of community transmission by asymptomatic patients, we asked radiographers if they review outpatient CT images for signs of COVID-19 pneumonia. We sought to understand their decision making and autonomy within patient pathways as well as the underpinning training provided to support independent practice. Diagnostic radiographers have been steered by a range of

learning opportunities [17] and research [12,18] on the characteristic imaging appearances of this new pathology. However, there are wider aspects of clinical governance, the duty of care to patients and education still to be learned from the experiences of radiographers in preparation for future pandemics.

## Materials/ methods

We conducted an electronic cross-sectional survey of diagnostic radiographers (radiologic technologists) working in CT during the COVID-19 pandemic. The survey was to be completed on an individual basis to try to gain a wide range of experiences and perspectives of those working within the CT scanning environment however, the size of the population of interest eligible to participate was unknown.

The survey was developed by a clinical and academic team of radiographers based in the North of England and delivered via JISC Online Surveys (Bristol, UK). The questionnaire consisted of 16 questions in 6 sections utilising a combination of fixed response, free text, and scenarios to explore role expectations within the three main aspects of service delivery, working practices and decision-making of radiographers (survey questions are available from the corresponding author). Specific areas of interest were social distancing, patient scheduling and departmental organisation; PPE routines for different clinical situations and mandatory facemasks for patients; and the review and management of asymptomatic patients. Additionally, radiographers were given the opportunity to provide their personal views and experiences of the pandemic through free text comments. Respondents were asked to provide their geographical location to identify their distribution, however this was the only identifiable information collected. All responses were treated confidentially. Participant information was provided on the first page of the survey with contact details provided for comments or questions, including those related to eligibility to participate. Ethical approval for this study was obtained prior to study commencement (EC26228).

As this is the first known survey of its kind, the authors performed internal and external checks to ascertain the reliability (consistency) and validity of questions with a small number of CT radiographers. At the time of the survey, the COVID-19 pandemic was expected to be of high salience to respondents and facts were expected to be well remembered. The questionnaire was also piloted with radiographers prior to distribution for question wording, coherence, and usability of the survey platform. Modifications were made in line with suggestions to minimise response bias. The survey was opened for 6 weeks between 29 June 2020 and 16 Aug 2020. Using snowball sampling, the link to the online survey was promoted through global networks, professional special interest groups, and social media. As this was a personal invitation, respondents were asked to share survey details with CT colleagues both within their own department and at other institutions to avoid selection bias. The survey was not limited to UK-practicing radiographers and as such was open to respondents from any geographical region, although

Table 1  
Geographic location of the respondents.

Region	Number (%)
UK	152 (84.4)
England	120 (78.9)
East	11 (9.2)
London	2 (1.7)
Midlands	27 (22.5)
North East	4 (3.3)
North West	22 (18.3)
South East	6 (5.0)
South West	14 (11.7)
Yorkshire & the Humber	34 (28.3)
Northern Ireland	6 (3.9)
Scotland	13 (8.6)
Wales	13 (8.6)
International	28 (15.6)
Total	180

advertisement in the international context was predominately limited to social media. A number of updates and reminders to participate were posted on social media to maximise response. Upon survey closure, all electronic response data was exported into Microsoft Excel<sup>®</sup> (Microsoft Corporation, USA) for data validation and analysis. Descriptive and textual analysis, which represent the perspectives and experiences, have been reported. Statistical analysis was undertaken using social science statistics (<https://www.socscistatistics.com/>) including Chi-squared test of association between variables. In hypothesis testing (that the variables are independent), a p-value 0.05 has been considered significant and 0.01 highly significant.

## Results

### Demographic data

A total of 186 responses were received within the 6-week timeframe. Following assessment for eligibility, completeness, and appropriateness of replies, 180 questionnaire sets were included in the final analysis. Respondents were primarily UK based (84.4%; n=152) however, the experiences of radiographers from the rest of Europe (2.8%; n=5) and Africa (1.7%; n=3) as well as Medical Radiation Technologists (MRTs) in North America (1.1%; n=2) and Oceania (10.0%; n=18) were also received (Table 1). For those responses from the UK, the largest proportion was received from England (78.9%; n=120), although all areas of the UK were represented, as were all four home nations.

### Service delivery

The large majority of respondents were providing CT services in public hospitals (95.0%; n=171) with some sub-types and specialties specifically stated (Figure 1). Additionally, 5 respondents (2.8%) were based in private clinics and two respondents (1.1%) were supporting imaging through the pandemic on mobile CT vans. The institution type was not stated in 2 cases (1.1%). Institutions were providing inpatient

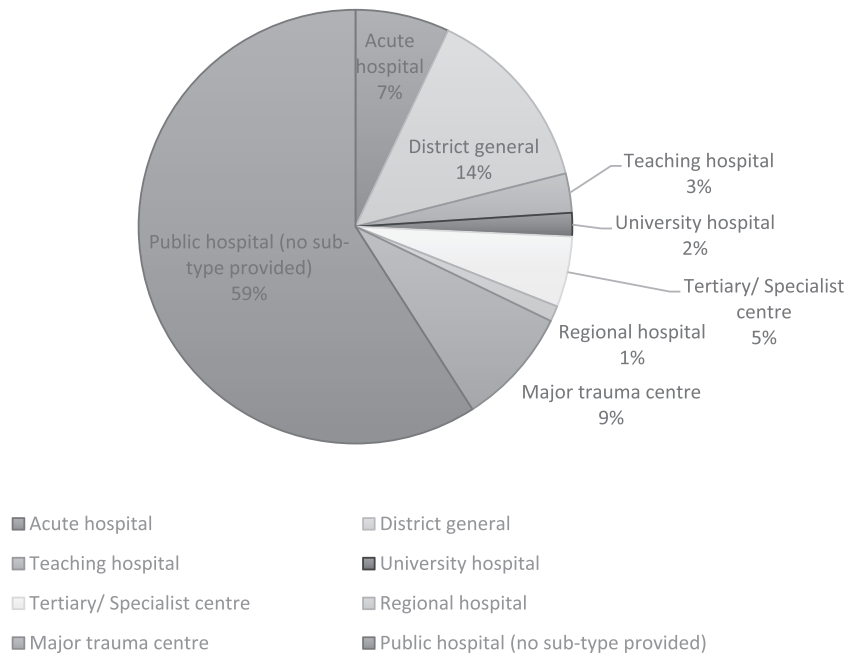


Figure 1. Public hospital types in which respondents were providing CT services.

only (4.4%; n=8) or outpatient only services (2.8%; n=5), but mostly a combination of both (92.8%; n=167).

All respondents were aware of the need to implement social distance measures for patients attending for CT imaging, with 107 (59.4%) of radiographers stating that their department had successfully fulfilled the requirements. A further 73 (40.6%) radiographers indicated that their department had been able to partially facilitate social distancing for CT patients but were limited by the confines of physical space. To negate issues around workload and waiting room availability, most respondents indicated that they had introduced restrictions on the numbers or type of patients. This mostly affected routine outpatient appointments. Sites had used different methods to reduce patient numbers with the most common approach described by respondents being to scan only those deemed as emergencies, urgent, time critical or those on a cancer pathway (suspected or follow-up), with decisions made by consultant radiologists (63.3%; n=114). The restrictions in place seemed to change in response to the stage of the pandemic in their geographical location. Some (8.9%; n=16) respondents stated that restrictions had been in place at the height of the pandemic but that all elective (outpatient) appointments were being reintroduced. Five radiographers (2.8%) specifically indicated that specialist CT examinations, such as cardiac scans and CT colonography services had been suspended locally, whereas 34 respondents (18.9%) had continued to scan all outpatients during the emergency. Almost a third of the latter were MRTs based in hospitals and clinics within Australasia where the only restrictions in place were to reduce the number of outpatient appointments available (to allow time for cleaning), and to limit relatives attending for scans.

Where possible, another strategy was to perform outpatients on one dedicated scanner, termed a “cold” or “green” scanner,

leaving other “hot” or “red” scanners to perform COVID-19 related work. Most respondents (66.1%; n=119) stated that they had the facilities to provide a separate CT scanner for patients who were suspected or confirmed COVID-19 positive. In four of these cases (3.4%), multiple scanners may have been available on one site within the organisation but not necessarily on all sites, or available all times of the day. The remaining respondents described the mixing of patients with different infection status on scanners (15.6%; n=28); or had only one scanner available (17.2%; n=31) making it impossible to have a dedicated COVID-19 scanner. However, two MRTs working in private clinics in Australasia (1.1%) indicated that they had not scanned any COVID-19 positive patients. Again, a small number of respondents from UK sites indicated that plans for scanner utilisation originally put in place to reduce the risk of transmission had been relaxed after a brief time period or were never followed.

#### Working practices

We asked radiographers working in the CT setting what PPE they would use for different patient scenarios. In the case of caring for patients with a confirmed COVID-19 positive swab test the majority of respondents (55.0%; n=99) were required to wear disposable single gloves, plastic apron, surgical mask, and eye protection (Table 2). However, a percentage of respondents also highlighted lower precautions with disposable single gloves, plastic apron and surgical mask being worn but omission of other face protection (15.0%; n=27), and conversely higher precautions being taken with the use of disposable single gloves, fluid-resistant gown (full arms), FFP3 mask and full-face visor (21.1%; n=38). In asymptomatic patients not suspicious for COVID-19, the commonest

Table 2

Practice for the use of personal protective equipment (PPE) use by individuals.

Level of PPE worn by radiographer	Number (%)	
	COVID-19 +ve Swab test	No COVID-19 swab test*
No PPE worn	0 (0)	10 (5.6)
Surgical mask	0 (0)	2 (1.1)
Disposable single use gloves and surgical mask	0 (0)	6 (3.3)
Disposable single use gloves and plastic apron	0 (0)	2 (1.1)
Disposable single use gloves, plastic apron and surgical mask	27 (15.0)	92 (51.1)
Disposable single use gloves, plastic apron, surgical mask and eye/ face protection	99 (55.0)	66 (36.7)
Disposable single use gloves, plastic apron, and FFP3 mask	1 (0.6)	0 (0)
Disposable single use gloves, plastic apron, FFP3 mask and eye/ face protection	10 (5.6)	1 (0.6)
Disposable single use gloves, Fluid-resistant gown, surgical mask and eye protection	1 (0.6)	(0)
Disposable single use gloves, Fluid-resistant gown, FFP3 mask and eye/ face protection	38 (21.1)	(0)
Disposable single use gloves, Fluid-resistant gown, FFP3 mask and eye protection and disposable surgical hat	1 (0.6)	1 (0.6)
Not scanning COVID-19 +ve patients	3 (1.7)	0 (0)
Total	180 (100)	180 (100)

\* This includes asymptomatic patients attending for outpatient CT appointments who may, or may not have been screened prior to the appointment.

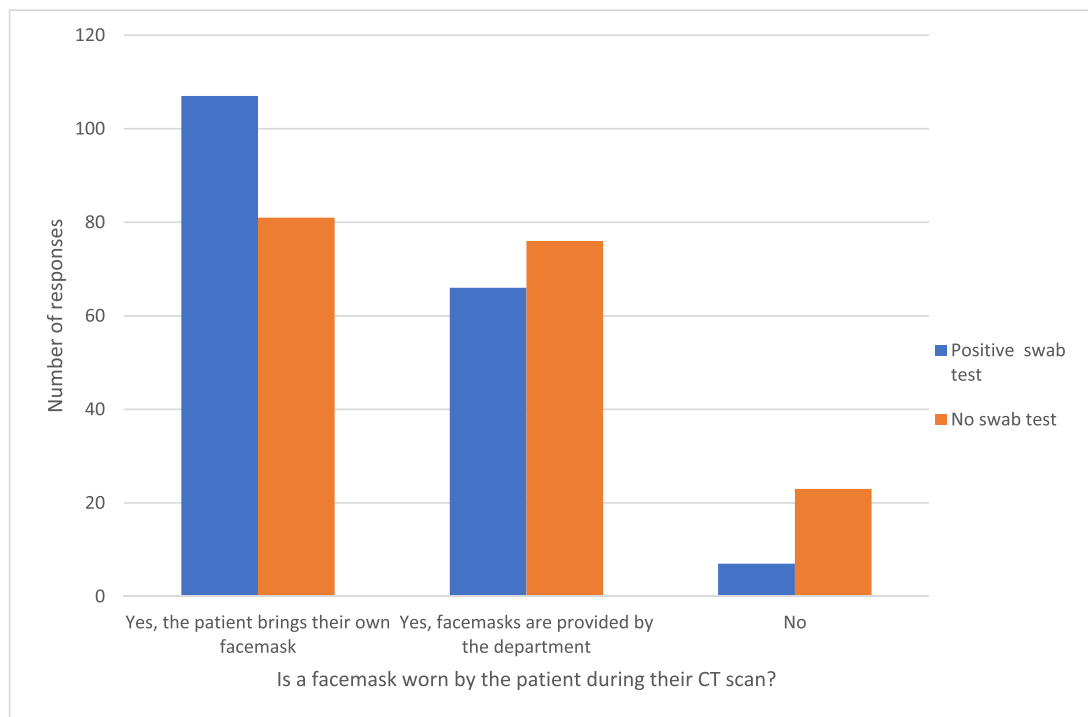


Figure 2. Respondent's experience of patients wearing face masks during CT appointments.

approach was to wear disposable single gloves, plastic apron, and surgical mask (51.1%, n=92), however 5.6% (n=10) people stated that they wore no PPE in this scenario.

Additionally, survey participants were asked whether the patients they had cared for during the pandemic had worn a facemask during their CT scan and whether their department provided masks if the patient had not brought their own (Figure 2). Regardless of their COVID-19 infection status, most patients wore a facemask. However, differences in the use, and provision, of face coverings were demonstrated between

patients confirmed to have a positive swab test for COVID-19 and asymptomatic patients attending from home (no positive swab test). The 152 responses from UK radiographers (84.4%; n= 152/180) were evaluated against non-UK radiographers (15.6%; 28/180) for the use of facemasks for patients demonstrated highly significant differences in the scenario of patients attending from home with no obvious symptoms ( $X^2 = 7.4$ ;  $p < 0.01$ ). The number of asymptomatic patients not wearing facemasks in non-UK diagnostic imaging providers was much larger than would be expected if the variables were independent.

## Radiographer decision-making role

Radiographers were asked whether they were responsible for the initial review of CT images acquired, recognition of the various imaging features (and stages) of COVID-19 pneumonia and to escalate or coordinate onward referral in line with agreed patient pathways. There was a slightly greater proportion of radiographers that indicated they were expected to review and recognise unexpected changes of the visible lung parenchyma consistent with COVID-19 (53.3%; n=96), compared to those who were not (46.7%; n=84). Where radiographers were deemed to have the autonomy to recognise ground glass changes on CT imaging, 17.7% (n=17) of respondents stated that they had received in-house training from radiologists to do so, and 18.8% (n=18) had completed limited training in the form of studying sample images or been directed to free online resources. However, a greater proportion (63.5%; n=61), stated that they had received no formal training and were either self-taught, or a senior radiographer or radiologist was available for advice.

Where radiological COVID-19 related changes were identified on CT imaging during outpatient appointments 88.9% (n=160) of respondents highlighted that their first action would be to contact the supervising radiologist, or another clinician (3.3%; n=6), immediately to discuss the case. Only a single individual stated that they would not take any action. The remaining respondents spoke in terms of obtaining a formal report for the examination. Approximately a third (33.9%; n=40) confirmed that they would prioritise the scan for immediate report, whilst 4.4% (n=8) would have allocated the exam for reporting as usual either with, or without, a courtesy call to the radiologist. Respondents were further asked if they were expected to discuss the COVID-19 findings on the CT scan with the patient, in line with an agreed departmental pathway. Only 6.7% (n=12) of respondents indicated that they would be the person responsible for this conversation. Many (65.0%; n=117) were not expected to speak to the patient with this action undertaken by the supervising radiologist. The remaining respondents (28.3%; n=51) stated that they would only break the news to the patient if asked to do so by the radiologist, or if the radiologist or a more senior member of the CT team was not available. A chi-square test of independence was performed to examine the relationship between respondent's location (UK versus non-UK) and the expectation to identify and manage COVID-19 findings with patients. The relationship between these two variables was highly significant for image review ( $X^2 = 10.7$ ,  $p < 0.01$ ) and significant for communication ( $X^2 = 4.3$ ,  $p < 0.05$ ) with UK radiographers more likely to be expected to perform these roles.

In the majority of cases (62.2%; n=112), the next step was to send the patient home with advice to isolate and/or to refer for a test. A smaller number of radiographers (20.0%; n=36) organised admission of the patient to the emergency department or a ward. However, 8.3% (n=15) stated that they would send the patient home with no advice and 9.4% (n=17) were honest enough to admit that they did not know what

they would do beyond seeking clinician advice. Just under half of the respondents (47.2%; n=85) had not experienced finding common COVID-19 signs on CT scans carried out in the outpatient setting, however of the 52.8% (n=95) that had experienced this situation, 26.3% (n=25/95) of radiographers had escalated CT findings on more than 5 occasions (Figure 3). Again, a statistical significance was demonstrated between geographic location (UK vs non-UK) ( $X^2 = 5.7$ ,  $p < 0.05$ ) with 32.1% (n=9) of non-UK radiographers and 56.6% (n=86) of UK radiographers having managed a similar experience.

## Radiographer perspectives

Several radiographers offered additional insights into their personal experience of CT practice during the pandemic. Many comments were made as to the level of PPE continuously changing, concerns for stock levels and anxieties about patients not being compliant with the wearing of masks.

*"Instructions for PPE changed daily during the first few weeks, until complete understanding of the virus spread was realised. Daily update on Trust [hospital] website were helpful."*<sup>R155</sup>

*"Frustration at continually changing advice dependent on level of PPE available."*<sup>R82</sup>

*"Whilst some patients are very compliant with the wearing of masks, we find that many are not, and these are not worn correctly due to discomfort."*<sup>R20</sup>

*"The most stressful part of the role was at the beginning, when rules on PPE kept changing. We knew we were potentially being exposed to COVID 19 through asymptomatic patients, however initially we were not allowed to wear a mask for all patients, only suspected and confirmed cases."*<sup>R144</sup>

The trials of working in CT environments during the pandemic were also highlighted:

*"...we have been expected to cover additional shifts and overtime. It has been truly exhausting and still is! Morale is at an all-time low. We feel really under appreciated by management and the trust as a whole"*<sup>R4</sup>

*"...We all performed 'red cleans' to try increase patient flow. Impossible to social distance in control rooms/whilst working in general"*<sup>R45</sup>

*"we have had to learn how to take swabs because we are expected to take swabs of each other every 10 days"*<sup>R59</sup>

*"... Some colleagues extremely stressed and nervous about covid and restricting their patient contact therefore feel I've done more patient facing than others"*<sup>R27</sup>

*"We have changed everyone's working pattern including assistants on night shifts with a Radiographer and increased weekend staff pattern"*<sup>R67</sup>

Many radiographers commented on how frightening and tiring the experience was but also praised the team.

*"It's been extremely challenging, especially as I've been self-isolating away from family during the main duration of the pandemic"*<sup>R23</sup>

*"It was great how we all adapted to the situation and changed working practice. The return to a new normal will be more stressful and care must be taken not to overwork staff"*<sup>R33</sup>

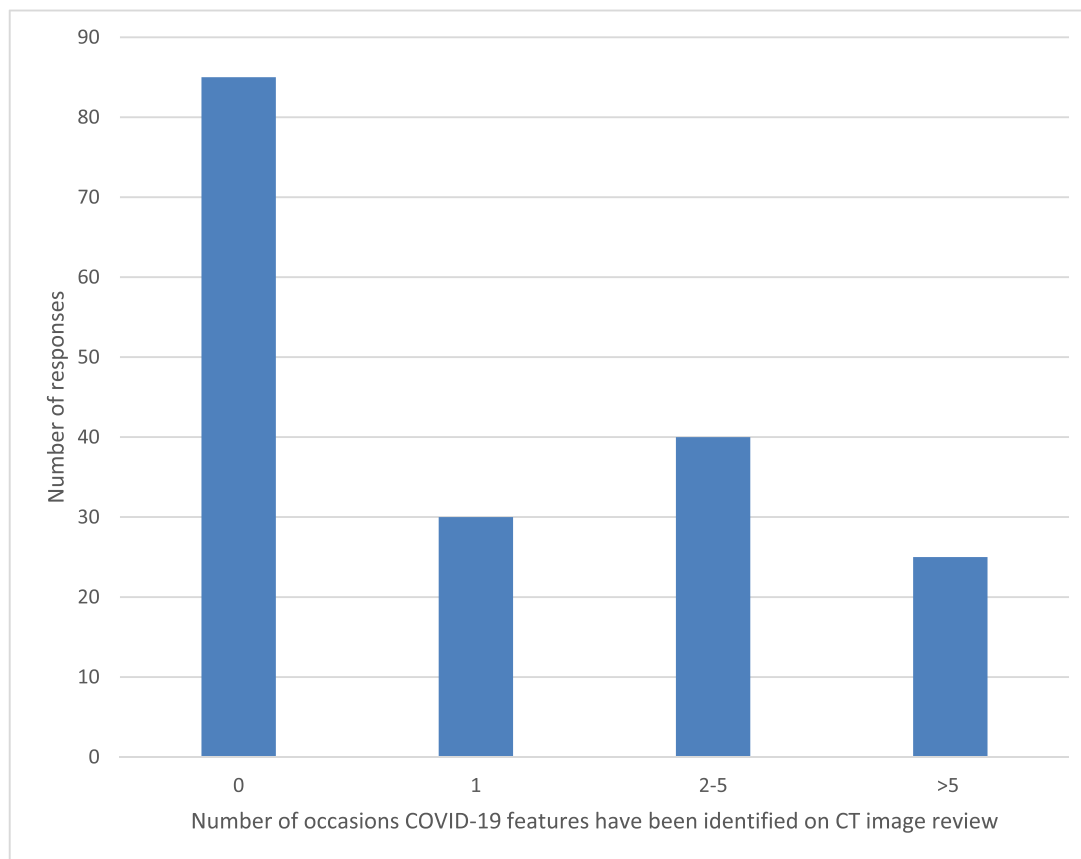


Figure 3. Experience of identifying changes consistent with COVID-19 pneumonia on CT image review.

*“Grateful to be part of the Radiology team and doing our bit to help”<sup>R68</sup>*

*“It has been hard but a huge learning curve. I feel that my Trust was pretty well prepared”<sup>R57</sup>*

*“The support we have received from our Radiologist Chest consultants in particular has been invaluable. They have ensured we have not been overwhelmed with an increase in demand to screen for covid via CT”<sup>R101</sup>*

## Discussion

Twelve-months after the novel coronavirus, COVID-19 emerged in Wuhan, China, the global pandemic continues to affect our everyday lives. Daily increases in the number of positive cases, hospital admissions and death toll are reported worldwide, and widespread disruption ensues as healthcare organisations adapt to, and try to navigate the “new normal.” The United States of America (USA) has been worst affected, reporting the highest number of cases and deaths among all nations to date [1,19], followed by Asia, Europe (including the UK), and Africa. Oceania has reported the least number of deaths at 1,290 as of April 15, 2021 [1]. Survey responses were received from the above areas except for Asia although, the large majority of respondents (and resultant data) were UK centric. All respondents to the survey were radiographers delivering CT services during the pandemic within either pub-

lic hospitals, private clinics or mobile provision. Variation in demand and workload were seen between small hospital clinics who had scanned very few, to no, COVID-19 positive patients, and larger public hospitals who were imaging an array of trauma, acutely unwell and emergency inpatients as well as CT outpatients on urgent, time critical and cancer pathways. The clinical practices, COVID-related workload, and access to PPE communicated by the survey respondents appeared to reflect international statistics for community transmission [1,20].

A RT-PCR test is considered the gold standard diagnostic investigation for COVID-19 [21], however, owing to issues around result turnaround times, and multiple false negative results, imaging studies such as X-ray and CT have been integral to patient triage throughout the pandemic [22]. The survey highlighted differences in the utilisation of CT between organisations. International guidelines [13–15, 20,23–25] have been clear that owing to poor sensitivity in asymptomatic patients and early stages of the virus, CT should not be used as a first-line diagnostic tool or screening test. Due to the higher radiation burden and risks of transmission, CT should be used sparingly for hospitalised symptomatic patients with specific clinical indications. In line with UK guidance [15], clinical decisions on the justification of CT procedures appear to have been made on a local level with some respondents indicating that CT had been reserved for those cases where infection status had been confirmed and a consultant level discussion had



highlighted a clear clinical management need. Whilst others described wide CT utilisation based on standard criteria which had increased workload and pressure on the service and staff.

There is no international consensus as to which patients requiring CT procedures should be treated as COVID-19 positive until proven otherwise. The majority of guidelines are clear for acute emergency inpatients, suggesting that equipment and staff should be protected from possible infection through testing and risk assessment [20]. However, the recommendations, and organisational level processes are less clear for asymptomatic non-hospitalised patients despite the recognised risk of unintentional transmission by those with a false negative RT-PCT or chest X-ray, or those who have not been tested prior to their elective appointment [2,18,22].

Global studies [26-29], have demonstrated that during lockdowns diagnostic imaging departments experienced a reduction in activity, either through a documented fear of the public to access healthcare services during the pandemic [26], or a decision to defer non-urgent outpatients [26] and re-focus resources on COVID-19 related activities [27]. This has been highlighted as an unprecedented move by diagnostic imaging departments [28] made to allow for social distancing of hospital visitors, cleaning between appointments and to protect staff [29]. The survey demonstrated that regardless of region, CT departments had reduced capacity for non-urgent outpatient procedures at the start of the pandemic when departments were first reacting to the emergency. However, a large majority of respondents emphasised that initial limitations were either not followed or quickly relaxed. This may be due to different perceptions of what is classed as time-critical workload, concerns over significant backlogs and service recovery, financial implications, or fears of the adverse health outcomes in patients delaying care [26] particularly in chronic long-term conditions and oncology.

The corona virus spreads via the respiratory route [19], contact with bodily fluids or from contaminated surfaces and it is suggested that both staff and patients are protected from the risk of transmission [14]. All respondents expressed that they would wear some level of PPE in both scenarios outlined in the survey, with the minimum consisting of a disposable apron, mask, and single use gloves. A single respondent stated that a surgical cap was worn, which is recommended in countries with more stringent PPE protocols [14]. Since the survey was closed, guidance has been updated to include the use of goggles or face shield for all staff [14]. For the purposes of establishing who is a contact, this includes CT control rooms where staff cannot observe social distancing measures. Despite attempts to clarify PPE advice for imaging teams [32], the survey reinforced previous studies [33] that have shown that radiographers felt confused with regards to the correct level of PPE required in different patient scenarios. Although a resource intensive measure, the survey confirmed that daily organisational level updates [34] for staff were seen as beneficial to understand changes to PPE and infection control guidance.

Although organisations have stringently worked to develop local policy and procedures for individuals with known or suspected COVID-19 infection moving between departments [40], the rapidity of such policy may have required a top-down approach. Within the limitations of the survey, radiographers highlighted that some of their organisations had been able to establish recommendations for social distancing of patients and carers and provide a dedicated scanner for patients confirmed or suspected to have COVID-19 [13]. However, approximately a third of those who responded to the survey were unable to avoid the mixing of workload. In some cases, this was due to only having one scanner on site, and radiographers had taken on the responsibilities of disinfecting the equipment and scan room to maintain throughput. It is well publicised that some diagnostic imaging services have been underfunded over previous years [30] and the COVID-19 pandemic has enforced the need to reassess equipment provision and constrained department designs, which in most cases will not have been updated for decades. This will be important moving forwards, particularly in areas such as CT, as services attempt to work through the backlog of patients whilst maintaining standard infection prevention and control precautions [35]. However, it has been warned that any capital investment must be supported by an increase in diagnostic imaging staff numbers [31], who as confirmed by this, and other studies [11,33,36-39], are on the verge of burnout.

Since the start of the pandemic, radiographers have been encouraged to familiarise themselves with the characteristic imaging appearances of COVID-19 pneumonia based on the benefits of early recognition to patient management [2,12,17,40]. Understandably, during diagnostic procedures such as CT, the focus has been to identify acute imaging appearances in patient groups deemed to be high-to medium risk. However, the perceived minimal risk pathway of outpatients attending hospitals for planned diagnostic tests [35] can be problematic when CT images demonstrate unexpected indeterminate COVID-related changes. Although imaging findings are non-specific and may overlap with other infections [40], there is a need for radiographers to review the image set, which may only include the lung bases. Recognising the features of acute or chronic COVID-19 infection, and escalating CT image appearances allows correlation with clinical presentation, history of contact and any recent travel [40]. The process can be facilitated by appropriate training of radiographers. The survey indicated a mixed response as to the provision of training on relevant CT image appearances and the subsequent autonomy to act and confidence in decision-making. Although, no radiographers had received formal education, in-house training provided by local radiologists had been well received. Unfortunately, a substantial proportion of radiographers indicated that they had been provided with little support in this area and were self-taught through online resources.

There is also an obligation to inform the patient before they leave the imaging department, even if they are not demon-

strating symptoms, so that they are aware of their potential infection risk and can take precautions to protect others. Where social distancing measures were not possible during the CT appointment any other potential contacts must be informed and advised, and staff must perform thorough cleaning of the department. Most radiographers highlighted that ad hoc contingency plans were in place to organise formal testing or arrange admission for further medical review. However, this process appeared to be primarily managed by the supervising radiologist. A single department indicated that an agreed pathway was in place that empowered radiographers to routinely perform image review and liaise with the patient regarding the outcomes and next steps. This framework was supported by documentation such as patient letters, information leaflets and frequently asked questions. The absence of protocols around this clinical scenario may reflect the low incidence in clinical practice [41]. However, other research supports the importance of acknowledging and managing asymptomatic patients or those who present with non-classic symptoms [12], which can only be achieved through locally developed and agreed schemes of work.

There are some limitations to the study, although the survey sought responses from both UK international respondents, the response rate was comparatively low to other similar surveys [11]. The mode of advertisement and limited engagement in social media in some geographical regions or language barriers may have contributed to this. The majority of responses were received from UK CT radiographers, which should be considered when interpreting the generalisability of findings. As responses were anonymous, the only demographic information collected was their country of residence. Therefore, we are unable to say whether multiple responses were obtained from radiographers within the same organisation and whether this has resulted in an element of response bias. The information presented reflects individual's experiences at a point of time in the pandemic; it is unknown whether these are based on standard operating procedures established on an organisation or site level. Pathways for escalation and management of incidental COVID-19 related image changes were not requested; therefore, this information is limited. However, this may reflect the fact that this situation has not been experienced by many radiographers worldwide. The findings represent the evolving practice of CT staff in the acute and early recovery phases of the pandemic and do not necessarily reflect current government or professional body guidance at the time of publication.

## Conclusion

This study has shown that CT radiographers have experienced the COVID-19 pandemic differently and adapted to changes made to meet clinical demand. To different degrees, these adjustments include limitations to service delivery (patient numbers, referral type, and examination range), availability of equipment and staff, implementation of infection

control working practices and respect of a new invisible pathology. Most CT radiographers were able to reduce the risk of transmission through the incorporation of social distancing in waiting rooms, workflow through designated scanners, deep-cleaning, and PPE (for radiographers and patients). Although radiographers had expressed that there had been frustration around changing PPE guidance at the start of the pandemic, the need to perform swab tests, encourage patients to wear the face mask correctly and significant changes to working patterns, there was also a sense of comradery and achievement in how they had adapted to this unprecedented situation.

Despite the evolution of the pandemic, and the roll out of international vaccine programmes, asymptomatic patients and those with only mild symptoms present a particular threat to community transmission. This study has demonstrated that despite variance in practice, CT radiographers are likely to be the first health care professionals with responsibility to review images for radiological evidence of COVID-19 pneumonia and play a key role in identifying and triaging high-risk patients. If trained and supported through a clinical governance structure, CT radiographers are ideally placed to competently recognise the acute and chronic appearances of COVID-19 in the asymptomatic outpatient setting, and to manage the patient in line with current guidance. This can include clinical correlation, providing public health advice, and arranging onward referral if necessary. Dependent on the knowledge, experience, and autonomy of the radiographer, this may be performed collaboratively with radiology colleagues or independently following clear patient management pathways embedded in local (and national) protocols. Radiographers in areas such as CT continue to embrace the challenges presented although further research is required to understand in-depth how we support radiographers to be fully prepared for the next pandemic.

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