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Diagnostic utility of additional whole-chest CT as part of an acute abdominal pain CT imaging pathway during the COVID-19 pandemic

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AIM: To evaluate the diagnostic utility of additional whole-chest computed tomography (CT) in identifying otherwise unheralded COVID-19 lung disease as part of an acute abdominal pain CT imaging pathway in response to the COVID-19 pandemic.

MATERIALS AND METHODS: Consecutive patients (n=172) who underwent additional whole-chest CT via a COVID-19 acute abdominal pain CT imaging pathway between 27 March and 3 May 2020 were evaluated in this retrospective single-centre study. Chest CT examinations were graded as non-COVID-19, indeterminate for, or classic/probable for COVID-19. CT examinations in the latter two categories were further divided into one of three anatomical distributions (lung base, limited chest [below carina], whole chest [above carina]) based on location of findings. Reverse transcriptase-polymerase chain reaction (RT-PCR) results and clinical features of COVID-19 were assessed to determine if COVID-19 was clinically suspected at the time of CT referral.

RESULTS: Twenty-seven of the 172 (15.7%) patients had CT features potentially indicative of COVID-19 pneumonia, 6/27 (3.5%) demonstrating a classic/probable pattern and 21/27 (12.2%) demonstrating an indeterminate pattern. After correlation with clinical features and RT-PCR 8/172 (4.7%) were defined as COVID-19 positive, of which only 1/172 (0.6%) was clinically unsuspected of COVID-19 at the time of CT referral. All COVID-19 positive cases could be identified on review of the lung base alone.

CONCLUSION: Whole-chest CT as part of an acute abdominal pain CT imaging pathway has a very low diagnostic yield for our cohort of patients. All COVID-19-positive patients in our cohort were identified on review of the lung bases on the abdominal CT and this offers an alternative imaging approach in this patient group.

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Introduction

In December 2019, China reported a cluster of pneumonia cases in Wuhan, which was later discovered to be caused by SARS coronavirus 2 (SARS-CoV-2) and was given the name COVID-19. COVID-19 spread rapidly around the globe and on 11 March 2020, the World Health Organization (WHO) declared a global pandemic. To date, there have been over 4 million cases worldwide, with over 215,000 confirmed cases and over 31,000 deaths in the UK alone[1,2]

After exposure to the virus, there is an asymptomatic incubation period lasting on average 5–6 days, but this can be up to 14 days.[3] Fever, dry cough, and myalgia are the most frequently occurring symptoms.[4] Among atypical COVID-19 presentations, gastrointestinal symptoms including abdominal pain, diarrhoea, and nausea have been reported.[5]

The typical imaging characteristics of COVID-19 have been well documented in the literature. Chest radiography demonstrates bilateral, peripheral pulmonary infiltrates, and on thoracic computed tomography (CT), the most common appearance is multifocal, subpleural, ground-glass opacification with a basal predominance. Interlobular septal thickening and consolidation are also commonly present.[6,7]

In March 2020, the *Lancet* published a Chinese study by Lei *et al.*[8] demonstrating poor post-surgical outcomes in 34 COVID-19 positive patients who had undergone planned surgery during their incubation period. Concerns regarding reported increased intensive care unit (ICU) admission and mortality rates in this study prompted some surgical societies to issue guidelines on preoperative patient care. In the UK, this included the Intercollegiate General Surgical Guidance on COVID-19, which recommended all patients presenting acutely or requiring emergency surgery and undergoing CT of the abdomen and pelvis, should also undergo CT of the whole thorax.[9] This was supported by the Royal College of Radiologists and incorporated into the British Society of Thoracic Imaging (BSTI) and British Society of Gastrointestinal and Abdominal Radiology (BSGAR) decision tool for chest imaging in patients undergoing CT for acute abdominal pain.[10,11] The rationale proposed for justifying additional imaging in this cohort of patients is that the chest CT findings, in conjunction with a low probability of COVID-19, might assist the surgical decision to pursue conservative or operative patient management.

To date, there has been no published data to assess the role of whole-chest CT as part of an acute abdominal pain imaging pathway to identify otherwise unheralded COVID-19 lung disease. Furthermore, review of the literature reveals variation in the sensitivity of thoracic CT in COVID-19 positive patients during the incubation period. The study by Inui *et al.* had the largest sample size (76 asymptomatic patients) and reported 54% sensitivity.[12] Smaller studies with sample sizes ranging from three to 26 patients demonstrated higher sensitivities from 65–71%.[13–15]

The UK has reportedly now passed the peak of the first wave of coronavirus cases. The post-peak phase may potentially last for 6–18 months[16,17] and is predicted to be characterised by declining disease prevalence and public health efforts to prevent future peaks. It is therefore necessary to re-assess and rationalise imaging pathways put in place earlier in the pandemic to ensure they remain appropriate and sustainable. This is especially important as elective imaging, and consequently radiology departmental activity, begins to return to pre-pandemic levels.

The principal aim of this retrospective study is to evaluate the diagnostic utility of additional whole-chest CT in identifying otherwise unheralded COVID-19 lung disease as part of an acute abdominal pain imaging pathway in response to the COVID-19 pandemic. The secondary aim is to evaluate potential alternative CT approaches for this cohort of patients.

Materials and method

Patients

This retrospective study was assessed by the Health Research Authority and local research and development Committee as not requiring ethics approval and written informed consent was waived for all cases.

Inclusion criteria for this retrospective study were defined as patients who had presented to University Hospital Southampton between 27 March to 3 May 2020 as an emergency with acute abdominal pain and, subsequently, undergone CT chest, abdomen, and pelvis according to the Intercollegiate General Surgical Guidance, RCR guidance and BSTI/BSGAR decision tool.[9,10] Patients were identified as suitable for inclusion based on review of the referral details of all abdominal CT examinations performed on the day lists contained within University Hospital Southampton's radiology information system (RIS) and picture archive and communication system (PACS). Patients who underwent chest CT examinations for alternative indications not related to the COVID-19 abdominal CT imaging pathway were excluded from the analysis. In total, 172 patients were identified.

CT acquisition

CT was acquired using one of two machines: Siemens Definition Edge (128 sections), with a reference care tube potential of 120 kV, reference care dose of 65 mAs, field of view (FOV) of 360 mm, and collimator width 1.25 mm or GE Discovery CT750 HD (128 sections), fixed tube voltage 120 kV and variable tube current range 100–650 mAs, FOV of 451 mm, and collimator width of 1.25 mm. The protocol used for both machines was undertaken after intravenous contrast medium using spiral CT of the whole chest (lung apices to diaphragms) in addition to a portal venous phase CT of the abdomen and pelvis.

Data collection

For each patient, the anonymised chest CT images were reviewed independently by two radiologists with a combined chest CT experience of 16 years (A.A. and D.I. with 11 and 5 years of experience, respectively). Any differences between the two reviewers were resolved through joint consensus.

Based on the BSTI CT reporting criteria for COVID-19, all chest CT examinations were graded into three categories: normal/non-COVID-19, indeterminate, classic/probable for COVID-19 infection (examples shown in Figs 1–3).[18] Patients with classic/probable CT findings of COVID-19 were classified as positive cases, whereas patients with indeterminate CT findings of COVID-19 were correlated with clinical features and reverse transcriptase-polymerase chain reaction (RT-PCR) results (if performed) to determine COVID-19 positive status as per the BSTI diagnostic algorithm.[18]

CT examinations were further subdivided based on whether this diagnosis could be achieved by imaging review at three distinct anatomical regions (Figs 1 and 2); at the lung bases (defined as lung parenchyma only visible on the abdomen and pelvis component of the acquired CT), limited lower chest (defined as lung parenchyma visible from the lung bases to the level of the carina), or whole chest (defined as complete craniocaudal extent of lung parenchyma from lung bases to apices).

Patient demographics (gender and age) were identified from University Hospital Southampton's IS. For each study, using the documented dose–length product (DLP), the total radiation dose and dose resulting from the chest CT component was recorded based on a CT chest k factor of 0.014.

Analysis of electronic patient records and the clinical details provided on the electronic referral for CT were examined for all cases where CT examinations were graded as either indeterminate or classical/probable for COVID-19. This gave a summary of the patient's symptoms and investigation results, including the RT-PCR swab (if performed), which was recorded to ascertain the COVID-19 status of the patient at the time of the CT study. Based on these details, patients were categorised retrospectively as either (1) clinically suspected or (2) clinically unsuspected at the time of CT referral.

Data interpretation

Continuous data were represented using the mean and standard deviation (SD) whilst categorical variable were represented using percentages.

Results

Baseline characteristics

From 27 March to 3 May 2020, 172 patients underwent additional CT of the thorax as part of a new COVID-19 acute abdominal CT protocol in a single university hospital (Table 1). The mean age was 57.8 years with a near equal number of men and women (85 female, 87 male). In total, 95 (55.2%) of patients had RT-PCR testing.

CT findings

Twenty-seven of the 172 (15.7%) patients had CT features of COVID-19 pneumonia, 6/27 (3.5%) demonstrating a classic/probable pattern and 21/27 (12.2%) demonstrating an indeterminate pattern (Table 2). All patients who had a classic/probable pattern of COVID-19 pneumonia had RT-PCR testing. Fourteen of the 21 (66.7%) patients who had an indeterminate pattern of COVID-19 pneumonia had RT-PCR testing, but all 21 had clinical correlation for features of COVID-19 infection. After correlation of CT findings with clinical features and RT-PCR testing, 8/172 (4.7%) patients were classified as COVID-19 positive (Table 3).

Location of COVID-19 pneumonia CT-positive findings

All cases with a classic/probable pattern of COVID-19 pneumonia on CT (n=6) were visible at the lung bases, meaning the diagnosis could have been confirmed without an additional CT (Table 4). Those with indeterminate CT findings (n=21) were visible at the lung bases in 66.7% of

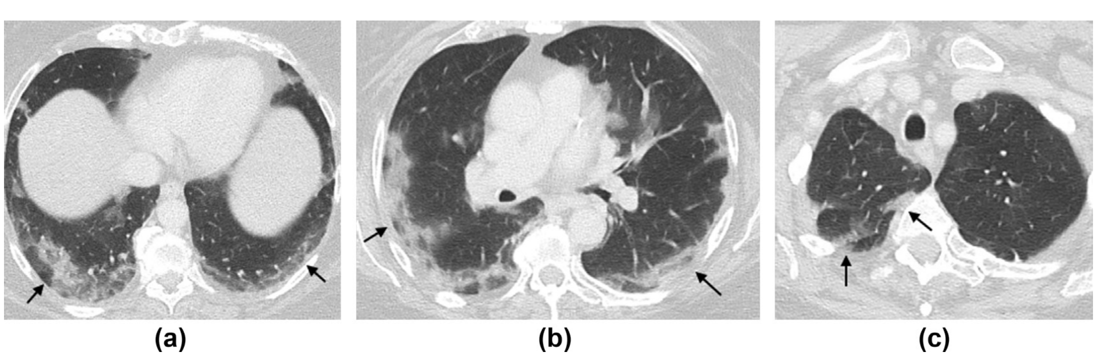

Figure 1 Patient with classic/probable COVID-19 CT features identified (black arrows) at (a) lung base, (b) limited chest (below carina), and (c) whole chest (above carina).

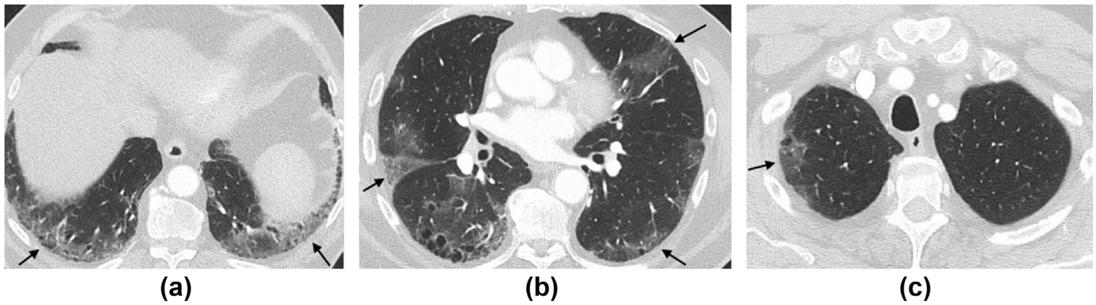

Figure 2 Patient with classic/probable COVID-19 CT features (black arrows) identified at (a) lung base, (b) limited chest (below carina), and (c) whole chest (above carina).

cases and below the carina in 90% of cases. Of note, in the two cases with indeterminate CT features defined as COVID-19 positive after clinical and RT-PCR correlation, the CT findings were visible at the lung bases.

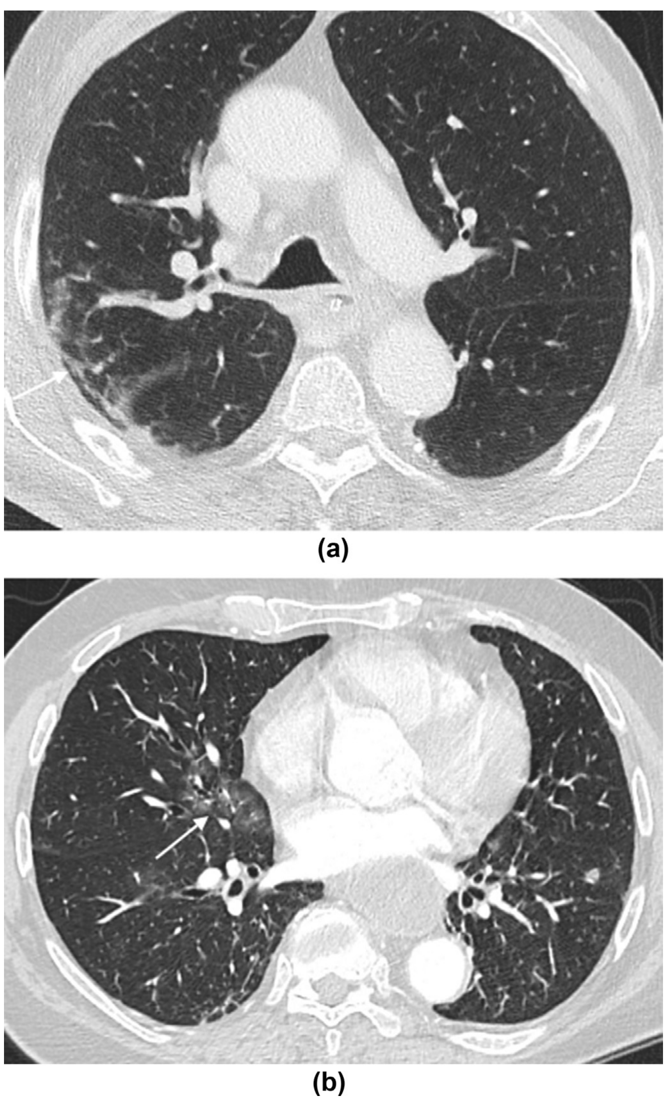

Figure 3 (a,b) Two different patients both showing indeterminate COVID-19 CT features based on isolated asymmetrical distribution. Neither of these patients had clinical features of COVID-19 and both were RT-PCR negative.

Clinical suspicion for COVID-19 at the time of referral for CT

In total, 7/27 patients (26%) with CT appearances graded as either indeterminate or classic/probable for COVID-19 were suspected clinically as having COVID-19 at the time of referral for CT (Table 3). In 20/27 (74%) patients in whom COVID-19 was not suspected clinically at the time of referral for CT, only a single case was identified as being COVID-19 positive after CT. This equates to a total unheralded COVID-19 lung disease diagnostic rate in the present cohort of patients of 1/172 (0.6%). In this single case, the abnormality on CT was present at the lung bases.

Radiation dose

The mean additional DLP associated with performing the thoracic CT was 266.7 (±218.9) mGycm (Table 5). This resulted in an estimated mean increased radiation dose of 3.7 (±3.1) mSv (Fig 4).

Discussion

During the transition into the next phase of the COVID-19 pandemic, it is vital that the longer-term suitability of imaging pathways established to support patient care during the initial surge phase of this global public health crisis is reviewed.[9–11] Although the numbers of cases in the UK continues to fall,[16] it is anticipated that SARS-CoV-2 will remain prevalent in society for many months until a suitable vaccine is available for widespread use.[6] In this context,

Table 1
Baseline patient characteristics.

Demographic	CT performed (N=172)
Age (years)	57.8±19.6
Sex	
Male	87 (50.6)
Female	85 (49.4)
Clinical	
COVID-19 RT-PCR performed	95 (55.2)
COVID-19 RT-PCR positive prior to CT	4 (2.3)

Values are mean ± SD or *n* (%).

CT, computed tomography; RT-PCR, reverse transcriptase-polymerase chain reaction.

Table 2
CT findings for COVID-19 (n=172).

	Total (%)	COVID-19 RT-PCR performed	COVID-19 RT-PCR positive	COVID-19 RT-PCR negative
All CT	172 (100)	95	7	88
CT features for COVID-19	27 (15.7)	21	7	14
Classic/probable CT features present	6 (3.5)	6	5	1
Indeterminate features present	21 (12.2)	15	2	13
No CT features for COVID-19	145 (84.3)	74	0	74

Values are n (%).
CT, computed tomography; RT-PCR, reverse transcriptase-polymerase chain reaction.

Table 4
Location of COVID-19 positive findings.

CT coverage	Positive CT features	Probable/Classic features	Indeterminate features
Full chest CT	27 (100)	6 (100)	21 (100)
Below carina	25 (93.6)	6 (100)	19 (90.0)
Lung bases	20 (74)	6 (100)	14 (66.7)

Values are n (%).
CT, computed tomography.

it is essential pragmatic precautionary measures are developed that safeguard the health of communities and healthcare workers, whilst at the same time ensuring that these practices are sustainable in order to enable radiology departments to restore elective activity to pre-pandemic levels.

The role of whole-chest CT to screen for COVID-19 lung disease in asymptomatic groups remains controversial. Although major UK and international imaging societies do not support the routine use of CT for screening for COVID-19 lung disease, some potential exceptions have been proposed for selected groups. This includes patients with acute abdominal pain and those undergoing certain types of elective surgery requiring postoperative ICU care.[9–11,18] The rationale for supporting the use of whole-chest CT is based on isolated reports of unheralded COVID-19 infection in patients presenting with acute abdominal pain as well as reported poorer postoperative outcomes in patients with COVID-19 disease[8,10]; however, there is little data in the literature to evaluate the diagnostic utility of imaging pathways incorporating whole-chest CT to address this issue, or that the introduction of these pathways significantly alters clinical outcomes.[8,20] Some authors have recommended that alternative approaches to whole-chest CT in these settings should be formally evaluated, including the role of review of limited lung CT images acquired for abdominal pain and other non-thoracic clinical indications prior to patient transfer from the CT machine.[20,21]

University Hospital Southampton is a large tertiary referral centre in the UK with 1,400 hospital beds, providing care for a local catchment area of 0.5 million people and a tertiary referral population of approximately 3 million people. The BSTI/BSGAR additional whole-chest CT for acute abdominal pain COVID-19 imaging pathway was introduced 28 March 2020 as part of the institution's evolving response to the initial surge phase of the COVID-19 pandemic.[10,11] Retrospective review of the institution's experience with this pathway was performed as part of an ongoing decision-making process for restoration of elective imaging levels within the department. Similar activity will undoubtedly be performed within other radiology departments in the UK. Where appropriate, it is vital that these experiences are disseminated widely to guide the ongoing efforts of the radiology community to develop practical and safe workflow solutions for healthcare delivery until effective widespread SARS-CoV-2 vaccines are available.

Table 3
Clinical suspicion for COVID-19 at the time of referral for CT in patients with abnormal CT.

COVID-19 pattern on CT	Total	Clinically suspected pre-CT	Clinically unsuspected pre-CT
Classic/positive COVID-19 CT	6	5 (83)	1[a](17)
Indeterminate	21	2 (10)	19[b] (90)
Abnormal CT	27	7 (26)	20 (74)

Values are n (%).
CT, computed tomography.
[a] CT abnormality identified at lung bases.
[b] None of these patients were subsequently shown to be COVID-19 positive after CT based on clinical/reverse transcriptase-polymerase chain reaction (RT-PCR) correlation.

Diagnostic utility and radiation burden

In the present cohort of acute abdominal pain patients, only six (3.4%) had classic/probable CT findings of COVID-19 and only a further two (1.1%) cases with indeterminate CT findings of COVID-19 were confirmed to be COVID-19 positive following correlation with clinical and RT-PCR findings. The total diagnostic yield for COVID-19 lung disease in the present study was eight (4.6%) and only one (0.6%) of these cases was clinically unsuspected for COVID-19 at the time of CT referral. Overall, this represents a very low diagnostic yield for unheralded COVID-19 lung disease. The additional whole-chest CT performed as part of this pathway resulted in the present patients receiving a mean additional radiation dose of 3.7 mSv (DLP 266.7).

Many authors have questioned the need for CT assessment in patients who are clinically stable and RT-PCR positive, as CT findings would not alter clinical diagnosis or management in these cases.[19,22] In patients who are RT-PCR negative, the role of CT is less well defined, but assessment of asymptomatic patients can result in significant false-negative rates of up to 46%.[12,22] Based on the authors' experience, additional whole-chest CT as part of a COVID-19 acute abdominal pain pathway has a very low overall diagnostic yield, and it is, therefore, difficult to continue to justify the increase in radiation dose that these patients are exposed to.

Table 5
Radiation dose (n=158[a]).

Coverage	DLP (mGy•cm)	Dose (mSv)[b]
Abdominal/pelvis CT	608.9 ± 458.5	8.5 ± 6.4
Whole-body CT (including chest)	875.6 ± 650.1	12.3 ± 9.1

Values are mean ± SD.
CT, computed tomography.
[a] Fourteen patients excluded as CT chest performed as a continuous helical scan with the abdomen and pelvis.
[b] CT chest k factor 0.014.

Distribution of CT findings

In total 27 (15.7%) of our cohort demonstrated abnormalities on CT, which were either classic/probable, or indeterminate for, COVID-19. Of these 27 cases, 74% were identifiable at the immediate lung bases and 90% within the lung below the carina. All eight patients (100%) with confirmed COVID-19 disease had abnormalities that could be identified at the lung bases alone. Specifically, the single case of unheralded COVID-19 in the patient cohort would have been diagnosed on review of the lung bases only, potentially negating the need for whole-chest CT in this group of patients.

Although the detailed distribution of lung abnormalities comparing lung bases to limited lower lobes below the carina has to the authors' knowledge not been reported, the prevalence of lower-lobe abnormalities identified on CT in patients with COVID-19 is reported to be as high as 93–98% in both Asian and European populations.[23,24] Unfortunately, the relatively small number of COVID-19 positive patients in our cohort makes it difficult on the basis of this data alone to make definitive recommendations on the use of a lung base review versus a limited chest review strategy; however, when combined with the known very high prevalence of lower-lobe disease, this would support the use of at least a limited lower-lobe imaging assessment for acute abdominal pain rather than necessitating a whole-chest CT approach, particularly for patient populations with a relatively low COVID-19 prevalence.[23,24] Further assessment of established COVID-19 CT imaging databases to define the distribution of lung parenchymal abnormalities in patients with confirmed COVID-19 lung disease using a lung base versus limited lungs (below carina) versus whole-chest scoring system is recommended to better define the relative roles of these CT strategies for acute abdominal pain patients.[25]

Study limitations

Several limitations of our study should be addressed. In our setting, clinical, demographic and outcome data were limited due to the retrospective study design and the timeframe allowed for analysis, in the context of an urgent need to provide evidence to guide decision-making around this imaging pathway at a time when greater levels of elective imaging care are required locally and across the UK. One limitation in particular, was that not all of our patients had RT-PCR testing if not clinically considered to be COVID-19 positive as was standard practice at that time. Although this means some of the indeterminate CT patients only had clinical correlation with CT findings to establish their COVID-19 clinical status, the fact that RT-PCR testing was not performed in these patients is likely to indicate that there was no significant clinical suspicion of COVID disease in this subgroup.

This study is further limited by retrospective analysis of data from only a single centre, which reflects the prevalence of SARS-CoV-2 in our population. This potentially means the present experience will differ from other centres with different COVID-19 disease burdens. In particular, those centres with a significantly higher prevalence of COVID-19 infection may experience a greater diagnostic yield than was seen in our cohort due to higher burden of disease in the population of patients attending their institutions' emergency departments. Although this was a particularly

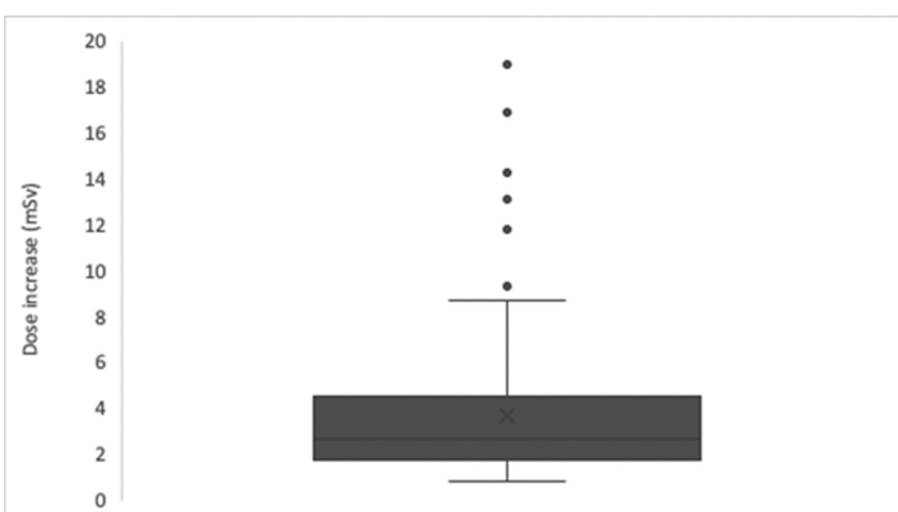

Figure 4 Box and whisker plot demonstrating increased CT radiation dose resulting from additional whole-chest CT.

important consideration during the initial surge phase of the pandemic, geographic differences in disease prevalence in the UK is anticipated to change as overall disease burdens decrease based on the experience of other countries.[16]

In conclusion, our single-centre experience suggests that the use of additional whole-chest CT in patients referred for CT assessment of acute abdominal pain has a very low diagnostic yield for identifying unheralded COVID-19 lung disease. In our institution, these findings also support review of the limited lung base images rather than necessitating a whole-chest CT for all patients with acute abdominal pain. This approach warrants further multicentre evaluation but may be applicable more widely.

Conflicts of interest

The authors declare no conflict of interest.

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