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

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# Chest CT screening for COVID-19 in elective and emergency surgical patients: experience from a UK tertiary centre

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AIM: To determine the incidence of possible COVID-19-related lung changes on preoperative screening computed tomography (CT) for COVID-19 and how their findings influenced decision-making. To also to determine whether the patients were managed as COVID-19 patients after their imaging findings, and the proportion who had SARS-CoV2 reverse transcriptionpolymerase chain reaction (RT-PCR) testing.

MATERIALS AND METHODS: A retrospective study was undertaken of consecutive patients having imaging prior to urgent elective surgery ($n$=156) or acute abdominal imaging ($n$=283). Lung findings were categorised according to the British Society of Thoracic Imaging (BSTI) guidelines. RT-PCR testing, management, and outcomes were determined from the electronic patient records.

RESULTS: 3% (13/439) of CT examinations demonstrated findings of classic/probable COVID-19 pneumonia, whilst 4% (19/439) had findings indeterminate for COVID-19. Of the total cohort, 1.6% (7/439) subsequently had confirmed RT-PCR-positive COVID-19. Importantly, all the patients with a normal chest or alternative diagnoses on CT who had PCR testing within the next 7 days, had a negative RT-PCR (92/407). There was a change in surgical outcome in 6% (10/156) of the elective surgical cohort with no change to surgical management was demonstrated in the acute abdominal emergency cohort requiring surgery (2/283).

CONCLUSION: There was a 7% (32/439) incidence of potential COVID-19-related lung changes in patients having preoperative CT. Although this altered surgical management in the elective surgical cohort, no change to surgical management was demonstrated in the acute abdominal emergency cohort requiring surgery.



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## Introduction

The worldwide spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and its associated pneumonia, coronavirus disease 2019 (COVID-19), is a major challenge to the delivery of surgical services.[1] The risk of nosocomial transmission should be balanced against the management of acute surgical conditions and urgent elective surgery.

In the UK, the National Health Service (NHS) established a moratorium on non-urgent elective surgery.[2] The four surgical Royal Colleges published guidance for the care of patients needing emergency surgery and urgent planned surgery, and emphasised that the identification of undetected SARS-CoV-2 infection in surgical patients was essential for the safe delivery of surgical services during the COVID-19 pandemic.[3] Preoperative computed tomography (CT) screening for COVID-19 was initially suggested and supported by the Royal College of Radiologists, with chest CT recommended in patients having abdominal CT for acute surgical conditions, and in patients who would require level II/III critical care following urgent elective surgery.[4]

The rationale for screening partly related to the finding that surgical outcomes were significantly worse in patients with undetected COVID-19. Lei and colleagues reported the outcomes of 34 patients with undetected infection undergoing elective surgery during the peak transmission of COVID-19 in Wuhan, China.[5] All patients developed clinical symptoms of COVID-19 pneumonia postoperatively. 40% were admitted to the intensive care unit (ICU) and 21% died. In comparison, the mortality of non-surgical COVID-19 pneumonia in Wuhan was estimated at 4.3–15% in a recent review article.[6] These data suggest that major surgery and mechanical ventilation may have exacerbated the risk of severe respiratory complications.

Diagnostic accuracy studies from Wuhan and Italy have reported CT sensitivity for COVID-19 as high as 97–98% in patients presenting to hospital with respiratory symptoms suspicious for COVID-19[7–9]; however, the prevalence of COVID-19 in emergency surgical patients in the community and elective surgical patients in self-isolation is likely to be significantly lower than that of those presenting to hospital. Taking this evidence into account, CT is likely to have a relatively low pick-up rate of COVID-19 in emergency and elective surgical patients, with its negative predictive value dependent on the community prevalence, which is currently relatively unknown.

The present study describes the results of preoperative CT screening for COVID-19 in emergency and elective surgical patients at a large tertiary centre in the UK, and reports the impact of preoperative CT on surgical decision-making and surgical outcomes during the COVID-19 pandemic.

## Materials and methods

A retrospective study was undertaken of CT chest imaging performed to screen for COVID-19 preoperatively, between 25 March and 27 April 2020 at a single tertiary centre in the UK. The project received institutional approval as a service improvement audit and informed consent was waived.

### *Patient population*

#### *Urgent elective surgery*

Preoperative chest CT screening was implemented on 26 March 2020. The radiology information system (CRIS) was used to identify consecutive patients undergoing chest CT within 24 h prior to urgent elective surgery during the study period (Fig 1).

#### *Emergency surgical conditions*

From 25 March 2020, patients presenting with abdominal emergencies underwent abdominal/pelvic CT, which also included the chest up to the level of the carina. The rationale for this was the low probability of isolated disease above this level.[10,11]

CT reports from patients presenting to the emergency departments with abdominal pain, acute surgical, acute medical, and gynaecological triage units were reviewed. Investigations for medical causes of abdominal pain were excluded (Fig 1). All CT studies were primarily reported or checked by a consultant radiologist within 24 h of imaging being performed.

### *Data collection*

CT reports were reviewed by authors (M.C. and M.T.), who were blinded to the RT-PCR result. Reports were categorised as normal or classic/probable COVID-19, indeterminate for COVID-19, or alternative diagnoses in accordance with the British Society of Thoracic Imaging (BSTI) guidelines.[12] As recommended by the BSTI, classic/probable COVID-19 features included lower lobe predominant, peripheral, multiple, bilateral foci of ground-glass opacification or bronchocentric, and peripheral consolidation (Fig 2). Indeterminate for COVID-19 was used for cases that had some of the above patterns, but which did not entirely fit into the classic/probable category or when an alternative diagnosis, such as interstitial lung disease, was potentially contributory (Fig 3).[12] Data were extracted on patient demographics, planned surgery, and RT-PCR results using the electronic patient records (EPR). In patients with both classic/probable or indeterminate CT features of COVID-19, or positive RT-PCR test results, further data were extracted on symptoms, surgical management, and surgical complications.

### *Imaging technique*

In the elective surgical cohort, all CT studies were performed as per the local low-dose unenhanced chest protocol (120 kVp tube voltage, 100–650 mAs automatic tube current modulation, 0.625 mm pitch contiguous sections). In the emergency surgical cohort, scanning was extended to include the lungs from below the carina. All images were

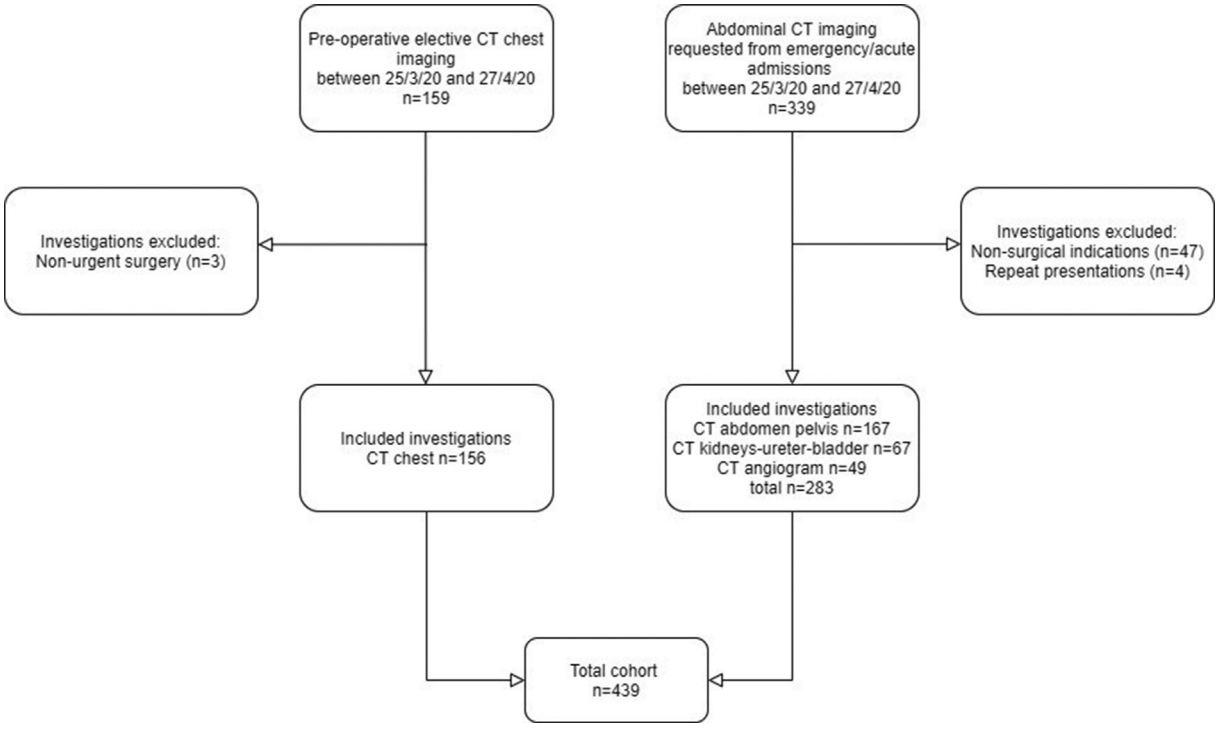


**Figure 1** Investigation flowchart.

obtained on one of the three CT machines (LightSpeed VCT; GE Healthcare) with patients in the supine position.

*RT-PCR*

During the study period, SARS-CoV-2 RT-PCR testing was not routinely used at our institution to screen asymptomatic surgical patients, and therefore, only a proportion of patients were tested. When a RT-PCR test was obtained, it was via a combined nose and throat swab, taken using a flocked swab and transported to the laboratory in viral transport medium. Guidance on taking a good-quality swab was provided through the hospital website. RNA extraction was carried out on the QiaSymphony platform and amplification of SARS-CoV-2 RNA was carried out on the Qiagen Rotorgene using the RdRp assay12.[13]

*Statistical analysis*

R and STATA software were used to extract data and perform statistical analysis. Descriptive statistics were used to summarise the data.


**Figure 2** CT findings classic/probable COVID-19 with lower lobe predominant, peripheral, multiple, bilateral foci of ground-glass opacification.

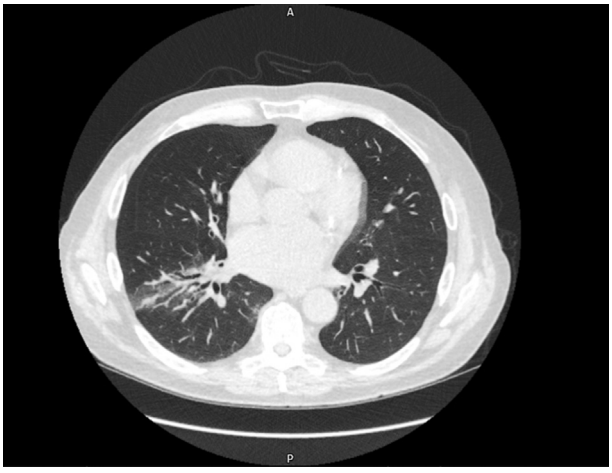


**Figure 3** CT findings indeterminate for COVID-19 with ground-glass opacification and atelectasis in the right lung base, which demonstrates some of the patterns of COVID-19 but does not entirely fit into the classic/probable category.

## Results

### *Patient and investigation characteristics*

#### *Urgent elective surgery*

Between 25 March 2020 and 27 April 2020, 156 preoperative chest CT studies were performed in 152 patients to screen for COVID-19 pneumonia in elective urgent surgical patients, with four patients undergoing repeat screening immediately prior to surgery. The median age was 64 (range 22–83) years. The surgical indications for preoperative chest CT are reported in Table 1.

#### *Acute abdominal emergencies*

Between 25 March 2020 and 27 April 2020, 283 acute abdominal CT studies (167 CT abdomen pelvis, 67 CT kidneys–ureter–bladder, 49 CT angiograms) were performed. The median age was 58 (range 20–98) years. The primary diagnoses made from acute abdominal imaging are reported in Table 2. Fifty percent of the requests were from the Emergency Department, 36% of the requests were from the Surgical Assessment Unit, and 14% were from the Acute Medical Assessment units.

### *COVID-19 lung findings*

#### *Urgent elective surgery*

CT abnormalities suggestive of COVID-19 were reported in 13 (8%) patients. 5 CT studies were reported as classic/probable COVID-19 and 8 were reported as indeterminate for COVID-19. The planned surgery, RT-PCR testing, symptoms, and surgical outcomes for these patients are reported in Table 3. 28 (18%) preoperative CT studies identified an alternative disease warranting further action, such as metastatic disease, bacterial infection, and nasogastric tube misplacement. 115 (74%) preoperative CT studies were reported as normal.

#### *Acute abdominal emergencies*

CT abnormalities suggestive of COVID-19 pneumonia were reported in 19 (7%) patients, of which 8 were reported as classic/probable COVID-19 and 11 as indeterminate for COVID-19. The CT diagnosis, RT-PCR testing, symptoms, and surgical outcomes for these patients are reported in Table 4.

**Table 1**
Surgical indications for preoperative chest computed tomography.

| Surgical indication | *n* |
|---|---|
| Bronchoscopy or other aerosol generating procedure | 11 |
| Major organ resection | 81 |
| Transplant | 25 |
| Cardiothoracic surgery | 25 |
| Other | 14 |
| Total | 156 |

**Table 2**
Surgical diagnoses in patients undergoing computed tomography for acute abdominal conditions.

| Diagnosis | *n* |
|---|---|
| Normal/no significant pathology | 102 |
| Appendicitis | 13 |
| Intestinal obstruction | 29 |
| Diverticulitis | 12 |
| Incarcerated/strangulated hernia | 2 |
| Gastrointestinal (GI) haemorrhage | 2 |
| Colitis | 13 |
| Intestinal perforation | 11 |
| Acute pancreatitis | 7 |
| Gallbladder and bile duct disease | 21 |
| Pelvic inflammatory disease | 3 |
| Urinary obstruction | 28 |
| Acute aortic pathology | 4 |
| Urinary tract calculus | 19 |
| Other | 17 |
| Total | 283 |

#### *Combined cohort*

In total, 3% (13/439) patients had CT findings of classic/probable COVID, 4% (19/439) had CT findings indeterminate for COVID-19, and 93% patients had normal lungs or other lung findings (Table 5). There was no statistically significant difference in the median age of those with COVID-19 related lung changes and those without.

### *RT-PCR testing and symptoms*

#### *Urgent elective surgery*

In the classic/probable group, 2/5 patients had a positive SARS-Cov-2 RT-PCR test and 3/5 had a negative RT-PCR test. In the indeterminate group, 7/8 patients had a negative RT-PCR test and 1/8 was not tested. One patient in each group was symptomatic.

Of the 143 patients with normal or alternative chest findings, 29 had RT-PCR testing within 7 days of their CT examination. All results were negative.

#### *Acute abdominal emergencies*

In the classic/probable group, 6/8 patients had a RT-PCR test, three of which were positive. 5/8 patients were symptomatic. In the indeterminate group, 7/11 patients had a RT-PCR test, two of which were positive. 2/11 were symptomatic.

24% (63/264) of patients with normal chest appearances proceeded to have RT-PCR within 7 days of their CT examination (median 2 days). All results were negative. 7/259 patients had had a negative RT-PCR prior to their imaging investigation.

#### *Combined cohort*

7/439 (1.6%) patients had positive RT-PCR, all of which had abnormalities on CT (five categorised as classic/probable COVID-19, two classified as indeterminate). 5/11 patients who had CT reported as classic/probable COVID-19 and had a RT-PCR test had a positive RT-PCR, whereas 2/14 who had CT reported as indeterminate for COVID-19 and a

**Table 3**
Planned surgery, reverse transcription-polymerase chain reaction (RT-PCR) testing, symptoms and surgical outcomes in patients with computed tomography (CT) abnormalities suggestive of COVID-19.

| Age (years) | Planned surgery | RT-PCR | COVID-19 symptoms | Managed as COVID-19 | Surgical outcome |
|---|---|---|---|---|---|
| CT features in keeping with classic/probable COVID-19 | | | | | |
| 59 | Transplant surgery | Negative | None | Yes | Suspended from transplant waiting list for 14 days, still awaiting transplant 64 days later |
| 63 | Major organ resection | Negative | None | Yes | Surgery postponed 14 days |
| 76 | Other | Positive | Cough | Yes | Surgery postponed 3 days |
| 82 | Other | Positive | None | Yes | Surgery postponed 14 days |
| 67 | Transplant surgery | Negative | None | Yes | Suspended from transplant waiting list for 14 days, still awaiting transplant 43 days later |
| CT features indeterminate for COVID-19 | | | | | |
| 53 | Major organ resection | Negative | None | Yes | Surgery proceeded same day, developed postoperative pneumonia (Clavien–Dindo grade II complication) |
| 73 | Major organ resection | Negative | None | Yes | Chest CT repeated after 15 days, then underwent surgery |
| 72 | Cardiothoracic surgery | Negative | None | Yes | Surgery cancelled, instead percutaneous intervention after 9 days |
| 66 | Major organ resection | Negative | None | Yes | Chest CT repeated after 21 days, then planning surgery |
| 77 | Other | Negative | None | Yes | Surgery postponed 7 days |
| 63 | Bronchoscopy or other AGP | Not done | None | No | Bronchoscopy proceeded same day, no complication |
| 62 | Cardiothoracic surgery | Negative | None | Yes | Surgery proceeded same day, developed postoperative pneumonia and pulmonary embolism (Clavien–Dindo grade II complication) |
| 38 | Transplant surgery | Negative | None | Yes | Suspended from transplant waiting list for 14 days, then underwent transplant 25 days later |

PCR test had a positive RT-PCR. 23% (92/407) of patients with normal or alternative findings on their chest CT had RT-PCR testing, and all results were negative (Table 5).

### *Surgery and outcomes*

#### *Urgent elective surgery*

Surgery was postponed in 9/156 cases, including all five in the classic/probable group. Cardiothoracic surgery was decided against in one patient and instead a percutaneous intervention was performed. Surgery proceeded as planned in three patients in the indeterminate group. Of these, one patient had a postoperative presumed COVID-19 pneumonia and one patient had postoperative presumed COVID-19 pneumonia and pulmonary emboli (both Clavien–Dindo grade II complications). Only one patient developed symptoms in the time period of their postponed operation. Looking specifically at the three renal transplant patients, only one subsequently received a transplant 25 days after the initial operative date, and the other two have not yet had transplant surgery at the time of writing (at 43 and 64 days after their initial operative date).

#### *Acute abdominal emergencies*

Surgery took place in two patients (see Table 4). One RT-PCR-positive and symptomatic patient with gallstone ileus had surgery for gallstone retrieval 2 days after abdominal imaging. This patient had postoperative fast atrial fibrillation requiring anti-dysrhythmic medication (Clavien–Dindo grade II). Another asymptomatic RT-PCR-negative patient had omental band resection to relieve intestinal obstruction and suffered no complications.

Three patients with classic/probable or indeterminate COVID-19 died. In one RT-PCR-positive patient, the death was attributed purely to COVID-19, whilst the other RT-PCR-positive patient died from gastrointestinal haemorrhage in combination with COVID-19. The third patient was RT-PCR-negative and death was attributed to decompensated heart failure rather than COVID-19. The remaining 17 patients were successfully discharged with a median duration of hospital stay of 2 days.

## Discussion

It is known that a significant proportion of people with SARS-CoV-2 infection may be asymptomatic, and some of these people may later become symptomatic (pre-symptomatic).[14] The asymptomatic proportion was estimated at 18% (95% CI: 16–20%) on the Diamond Princess cruise ship, and between 5–80% in studies in other cohorts.[15,16]

Studies describing asymptomatic patients were likely to reflect the surgical population more closely. Inui and colleagues showed that CT demonstrated abnormalities in 54% of asymptomatic RT-PCR-positive patients on the Diamond Princess cruise ship.[17] RT-PCR-positive asymptomatic patients with CT abnormalities were significantly older than those with normal CT (median age 38 versus 14 years)[18]; however, these studies only include patients who were SARS-CoV-2 RT-PCR positive and were unlikely to reflect the true prevalence of COVID-19 in the present population of emergency and elective surgical patients.[19]

**Table 4**
Imaging diagnosis, reverse transcription-polymerase chain reaction (RT-PCR) testing, symptoms and surgical outcomes in patients with computed tomography (CT) abnormalities suggestive of COVID-19.

| Age (years) | CT diagnosis | RT-PCR | COVID-19 symptoms | Managed as COVID-19 | Underwent surgery | Outcome | Admission length (days) |
|---|---|---|---|---|---|---|---|
| CT features in keeping with classic/probable COVID-19 | | | | | | | |
| 42 | Colitis | Negative | Respiratory | Yes | No | Ward-based care | 17 |
| 87 | Intestinal obstruction | Negative | None | No | Yes | Laparotomy No surgical complication | 15 |
| 72 | GI haemorrhage | Positive | Cardiac | Yes | No | Died of gastrointestinal haemorrhage and COVID-19 | 19 |
| 58 | Colitis | Positive | Fever, respiratory & GI | Yes | No | Died of COVID-19 | 5 |
| 80 | Normal/non-specific | Positive | Fatigue, respiratory & GI | Yes | No | Discharged home | 1 |
| 64 | Normal/non-specific | Not done | Fever & respiratory | Yes | No | Ward-based care, with brief ICU admission for high flow oxygen | 11 |
| 62 | Normal/non-specific | Not done | None | Yes | No | Ward-based care | 4 |
| 38 | Normal/non-specific | Not done | None | Yes | No | Discharged home | 0 |
| CT features indeterminate for COVID-19 | | | | | | | |
| 93 | Gallbladder and bile duct disease | Positive | Cough | Yes | Yes | Laparotomy Postoperative fast atrial fibrillation (Clavien–Dindo grade II complication) | 22 |
| 48 | Urinary obstruction | Negative | Fatigue | Yes | No | Discharged home | 4 |
| 31 | Ureteric calculi | Not done | None | No | No | Discharged home | 0 |
| 60 | Gallbladder and bile duct disease | Not done | None | No | No | Discharged home | 0 |
| 50 | Pelvic inflammatory disease | Positive | None | No | No | Discharged home | 2 |
| 56 | Urinary obstruction | Not done | None | Yes | No | Discharged home | 0 |
| 77 | Colitis | Not done | None | No | No | Ward-based care | 4 |
| 54 | Urinary obstruction | Negative | None | No | No | Discharged home | 2 |
| 50 | Other (rib fracture) | Negative | None | No | No | Ward-based care | 7 |
| 90 | Normal/non-specific | Negative | None | No | No | Died of cardiac failure and infective exacerbation of COPD | 10 |
| 74 | Normal/non-specific | Negative | None | No | | Discharged home | 1 |

GI, gastrointestinal; COPD, chronic obstructive pulmonary disease.

The present study has demonstrated an overall incidence of 7% (32/439) of classic/probable or indeterminate COVID-19-related lung changes in patients having preoperative chest CT imaging. Of the cohort, 1.6% (7/439) subsequently had a positive RT-PCR result for COVID-19. There was an alteration in surgical outcome in 6% (10/156) cases in the elective surgical cohort. Three patients in the elective surgical cohort and two patients in the emergency surgical cohort with COVID-19 pneumonia on CT underwent surgery. Of these, two had no surgical complication and three had surgical complications requiring pharmacological treatment (Clavien–Dindo grade II). All patients with normal or alternative chest CT findings who had PCR testing had a negative result. To the authors' knowledge, this is the first study to describe CT findings in this patient population and to correlate these findings with PCR testing and surgical outcomes.

**Table 5**
Summary of findings.

| | Urgent elective surgery ($n$=156) | Acute abdominal emergencies ($n$=283) | Combined cohort ($n$=439) |
|---|---|---|---|
| **Classic/probable COVID-19** | 5 | 8 | 13 |
| RT-PCR positive | 2 | 3 | 5 |
| RT-PCR performed | 5 | 5 | 10 |
| **Indeterminate for COVID-19** | 8 | 11 | 19 |
| RT-PCR positive | 0 | 2 | 2 |
| RT-PCR performed | 7 | 7 | 14 |
| **Normal or alternative diagnosis** | 143 | 264 | 407 |
| RT-PCR positive | 0 | 0 | 0 |
| RT-PCR performed | 29 | 63 | 92 |

RT-PCR, reverse transcription-polymerase chain reaction.

The present study has several limitations. Firstly, this was a retrospective study, and the data are reliant on documentation in clinical notes. Secondly, despite use of the BSTI classification, there remains inter-and intra- reader variability in reporting lung findings. Thirdly, the present study describes a very heterogeneous surgical population with a range of planned elective surgeries and a variety of

emergency surgical presentations and diagnoses. Nevertheless, the findings are likely to be generalisable to the presenting caseload in other hospitals and represent important data on which to base future preoperative screening for COVID-19 as normal diagnostic activities resume.

The utility of any preoperative chest CT needs to be balanced against the potential harm of a delayed operation. In the present study, the three renal transplant patients, who had CT features of COVID-19 but were PCR-negative, were suspended from the transplant waiting list for 14 days and have subsequently, experienced a significant operative delay. Considering the poor specificity of chest CT in the diagnosis of COVID-19, it is unknown whether their CT findings in fact related to their disease status; for example, potential fluid overload from renal failure, given that the described findings of COVID-19 overlap with many alternative clinical presentations.[20]

With more widespread availability of RT-PCR and its increased use in screening, it remains to be demonstrated in what circumstances preoperative chest imaging in elective surgical patients will be of value. Meanwhile, the relatively high incidence of other findings warranting further action, for example metastatic disease, needs to be considered; none of the screening scans were intentionally completion staging scans. For acute abdominal emergencies, studies are underway to determine whether the upper slices otherwise included on acute abdominal imaging are enough to detect COVID-19 pneumonia, without requiring additional imaging.[4] Although specific, RT-PCR testing has a reported sensitivity of only 60–70%.[7] As lockdown measures are lifted and population prevalence becomes more apparent, the results of composite CT and RT-PCR screening will need to be considered carefully against the risk and urgency of surgery to ensure the optimum balance of benefit versus prevention of harm for surgical patients. This decision warrants close discussion between the radiology and surgical teams working together.

## Conflict of interest

The authors declare no conflict of interest.

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