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COVID-19: using chest CT of major trauma patients to monitor and evaluate the second wave in London and the development of routine monitoring in practice

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AIM: To follow-up previous work evaluating incidental findings of COVID-19 signs on computed tomography (CT) images of major trauma patients to include the second wave prior to any major effects from vaccines.

MATERIALS AND METHODS: The study population included all patients admitted following major trauma between 1 January 2020 and 28 February 2021 with CT including the lungs (n=1776). Major trauma patients admitted pre-COVID-19 from alternate months from January 2019 to November 2019 comprised a control group (n=837). The assessing radiologists were blinded to the time period and used double reading in consensus to determine if the patient had signs of COVID-19. Lung appearances were classified as no evidence of COVID-19, minor signs, or major signs.

RESULTS: The method successfully tracked the second wave of the COVID-19 pandemic in London. The estimated population affected by the disease based on those with major signs was similar to estimates of the proportion of the population in London with antibodies (around 30% by end February 2021) and the total of major and minor signs produced a much higher figure of 68%, which may include all those with both antibody and just T-cell responses.

CONCLUSIONS: Incidental findings on CT from major trauma patients may provide a novel and sensitive way of tracking the virus. It is recommended that all major trauma units include a simple question on signs of COVID-19 to provide an early warning system for further waves.

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Introduction

This is the third in a series of papers to describe the experience of the population served by a large tertiary hospital in London during the COVID-19 pandemic by using chest computed tomography (CT) examinations of major trauma patients. The present study examines both the first and second waves of the pandemic between 1 January 2020 and 28 February 2021 and considers how the method can be best used in practice. The data and the methodology are described in earlier papers.[1,2] Briefly, the data examined CT images of major trauma patients during the pandemic and a control group from 2019 prior to the spread of SARS-CoV-2. Signs of COVID-19 were used to estimate the prevalence of the disease in the whole catchment area of the institution by assuming that major trauma patients represent a random sample of the local population.

CT images were classified for COVID-19 as showing major signs, minor signs, or negative. Major signs were defined as multifocal, bilateral, ground-glass opacities with or without consolidation in a peripheral, mixed (peripheral and central), or perilobular distribution not explained by contusions or other factors.[3] Minor signs were defined as non-peripheral, ground-glass opacities, or unilateral changes not explained by contusions or other factors. Based on all signs the estimated percentage of the population with the disease at the end of April 2020 was 45%.[1] Based on all signs of COVID-19 in the study group minus the control period we estimated the proportion of the population exposed to COVID-19 was >20% at the start of lockdown and 57% by the end. From the date of lockdown, the disease prevalence took 7 weeks to decline back to the control group baseline.[2]

Given the high level of COVID-19 in the population, the present study investigated the second wave of the pandemic in the same way, to explore disease prevalence in the second wave, the growth curve for the second compared with the first wave, and further examined the role of major and minor signs and how this is influenced by the first and second wave. Suggestions are provided of how this method can be incorporated into routine practice by any major trauma centre without requiring the control group and blind reading practices, so that it can function as an early warning of surges in COVID-19 and similar diseases.

Materials and methods

Ethical approval for the study was given by the National NHS Research Ethics Committee (REC) and the combined Health Research Authority (HRA) and Health and Care Research Wales (HCRW) (reference 20/YH/0202). The methods are the same as those reported in the first paper.[1] The data examined CT examinations of major trauma patients and used a control group from 2019 prior to the spread of SARS-CoV-2. Signs of COVID-19 were used to estimate the prevalence of the disease in the whole catchment area of the institution by assuming that major trauma patients represent a random sample of the local population. To eliminate bias, the radiologists were blinded to the time period and therefore unable to tell if the image was from the study or control periods.

CT examinations were classified for COVID-19 as showing major signs, minor signs, or negative. The prevalence in any month was the percentage of COVID-19 signs in the study group in that month minus the percentage in the whole control group, the numbers of patients and events in the control group being too few to divide into smaller time periods.

The disease prevalence in any month (minus the control group prevalence) was divided by 0.5 (which assumes a 2-week duration of COVID-19 signs in an individual with low or asymptomatic levels of disease) to obtain the incidence rate. The incidence rates are summed to obtain the cumulative incidence, which is an estimate of the proportion of the population who have had the disease.

All tests of significance and statistical analysis used STATA version 14 (Stata Corporation, TX, USA). The main statistical analysis was a test of two proportions, with $p<0.05$ considered as indicating significance.

Results

There were 1,776 patients in the study group and 837 in the control group. The mean age of the study group was 54.2 years (SD 23.6) and the control group 51.4 years (SD 23.2). The proportion of men in the study group was 66.2% and in the control group was 68.3%. Tables 1 and 2 show the number of patients and those with minor or major signs of COVID-19 over the months from January 2020 to February 2021 in the study group and in alternate months in 2019 in the control group. There were 65 (3.7%) from 1,776 patients with any signs in the study group and 12 (1.4%) from 837 patients in the control group ($p=0.002$). For major signs only, there were 25 (1.4%) in the study group and four (0.5%) in the control group ($p=0.03$). Signs of COVID-19 occurred in all age groups with 17 (3.1%) from 556 in those under 30

Table 1
Study group signs of COVID-19 by month.

Date	*N*	Minor signs	Major signs	Total signs (%)	Total signs[a]	Major signs[b]
Jan 2020	130	3	0	3 (2.3)	1.8	-1.0
Feb 2020	162	10	0	10 (6.2)	11.4	-1.9
Mar 2020	131	9	5	14 (10.7)	30.0	4.8
Apr 2020	100	8	5	13 (13.0)	53.2	13.8
May 2020	123	0	1	1 (0.8)	52.0	14.5
Jun 2020	119	1	0	1 (0.8)	50.8	13.5
Jul 2020	150	0	0	0 (0.0)	48.0	12.6
Aug 2020	139	1	1	2 (1.4)	48.0	12.1
Sep 2020	123	0	1	1 (0.8)	46.8	12.7
Oct 2020	124	1	1	2 (1.6)	47.2	13.4
Nov 2020	140	1	0	1 (0.7)	45.8	12.4
Dec 2020	131	2	3	5 (3.8)	50.6	16.1
Jan 2021	97	0	5	5 (5.2)	58.2	24.4
Feb 2021	107	4	3	7 (6.5)	68.4	30.1
Total	1776	40	25	65 (3.7)		

[a] [(Prevalence all signs in each month − 1.4)/0.5] summed over all months.
[b] [(Prevalence major signs In each month − 0.48)/0.5] summed over all months.

Table 2
Control group signs of COVID-19 by month.

Date	*N*	Minor signs (%)	Major signs (%)	Total signs (%)
Jan 2019	137	4 (2.92)	0 (0.00)	4 (2.9)
Mar 2019	115	1 (0.87)	1 (0.87)	2 (1.7)
May 2019	124	0 (0.00)	0 (0.00)	0 (0.0)
Jul 2019	149	1 (0.67)	0 (0.00)	1 (0.7)
Sep 2019	140	0 (0.00)	1 (0.71)	1(0.7)
Nov 2019	172	2 (1.16)	2 (1.16)	4 (2.3)
Total	837	8 (0.96)	4 (0.48)	12 (1.4)

years, 17 (1.7%) from 988 in those aged 30–59 years and 43 (4%) from 1,069 in those aged ≥60 years.

In Fig 1, the graph shows the 3-week moving average of any COVID-19 signs (major and minor) versus time as weeks from 1 January 2020. The control group prevalence is shown as a straight line at 1.4%. The study group shows peaks centred around the first and third lockdowns on 23 March and 6 January, respectively, but no peak around the second lockdown on 5 November.

In Fig 2, a similar graph shows the separate plots for the major signs and the minor signs. There is a notable change in the ratio of minor signs to major signs over time. If the first wave is defined as February to April 2020 and the second as December 2020 to February 2021, there is a reduction in the ratio of minor to major findings from the first wave to the second wave from 27:10 to 6:11. This was explored further with a rapid review of CT examinations in February 2020 and January 2021. Either this was a genuine decrease in minor signs or a change in the recognition of minor signs or chance. Table 1 and Fig 2 show that minor signs are critical to the interpretation of the data in the role of providing early warning. Minor signs are more common than major signs, and therefore, consistency of diagnosis is important. Minor signs in a clinical rather than research setting can be defined as indeterminate evidence of COVID-19 whereas major signs can be interpreted as evidence of COVID-19. In these studies, COVID-19 is not diagnosed, it is

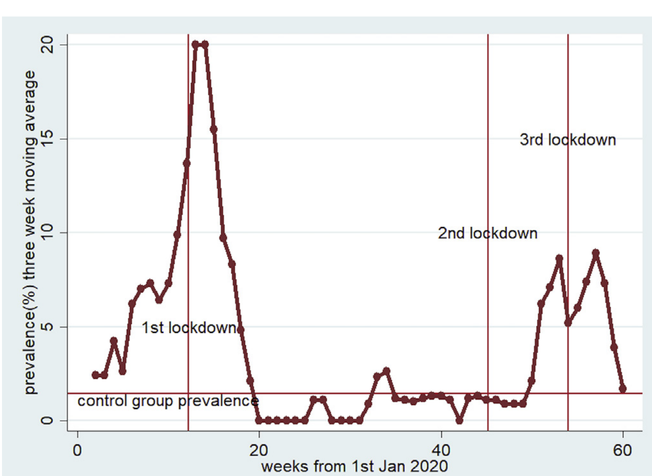

Figure 1 Graph of 3-week moving average of COVID-19 signs by weeks from January 2020 to end February 2021.

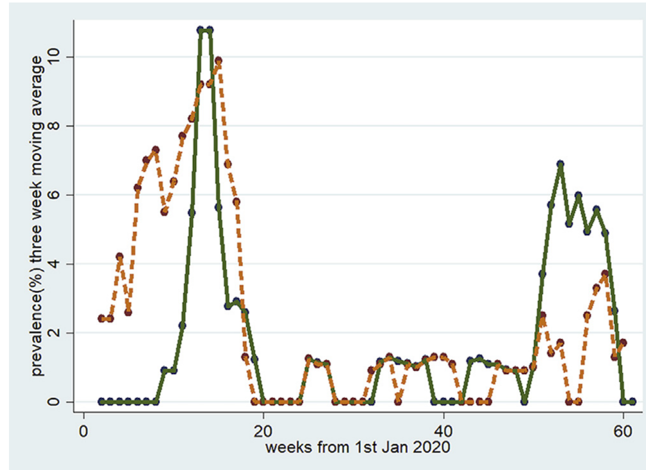

Figure 2 Graph of 3-week moving average of prevalence of major (green) and minor (yellow dashed) signs of COVID-19 by weeks from January 2020 to end February 2021.

the research definitions that are important. Minor signs are non-peripheral, ground-glass opacities or unilateral changes not explained by contusions or other factors.

The rapid review of the 10 minor signs in February 2020 to determine if there was any evidence of a change in criteria that may have inadvertently occurred between the first and second wave of CT readings showed concordance with the original readings. The total signs in February 2020 was 6.2% (10/162) and the total signs in the control group over all months was 1.4% (12/837), which is highly significant (p=0.0002). The method therefore provided a significant early warning of a high proportion of the population with COVID-19 by the end of February 2020 and this was dependent on identification of minor signs.

Fig 3 shows a random selection of selection of two pairs of images of control group and study group images. The study group images have been age and gender matched to the control group images. Fig 3a,b show examples of minor signs in the control and study groups; these are both older women >80 years. Further examination showed that five of the eight control group patients with minor signs were women >80 years. Women >80 years comprised only 10.1% of the control group and 11% of the whole study database. Fig 3c,d shows examples of major signs in the control and study groups; these are both men in their fifties.

Finally, Table 1 also shows the total cumulative incidence (risk of having had the disease) for all signs and just major signs. By the end of February 2021, it is estimated that, based on all signs, 68% of the population had had COVID-19 and using only major signs 30%. The figure of 30% is the same as the figure of 29.1% (95% confidence interval [CI] 27.5%–30.8%) for those testing positive to antibodies in February 2021.[4]

Discussion

COVID-19 infection will be a continuing threat to individuals and health services. New variants are continually

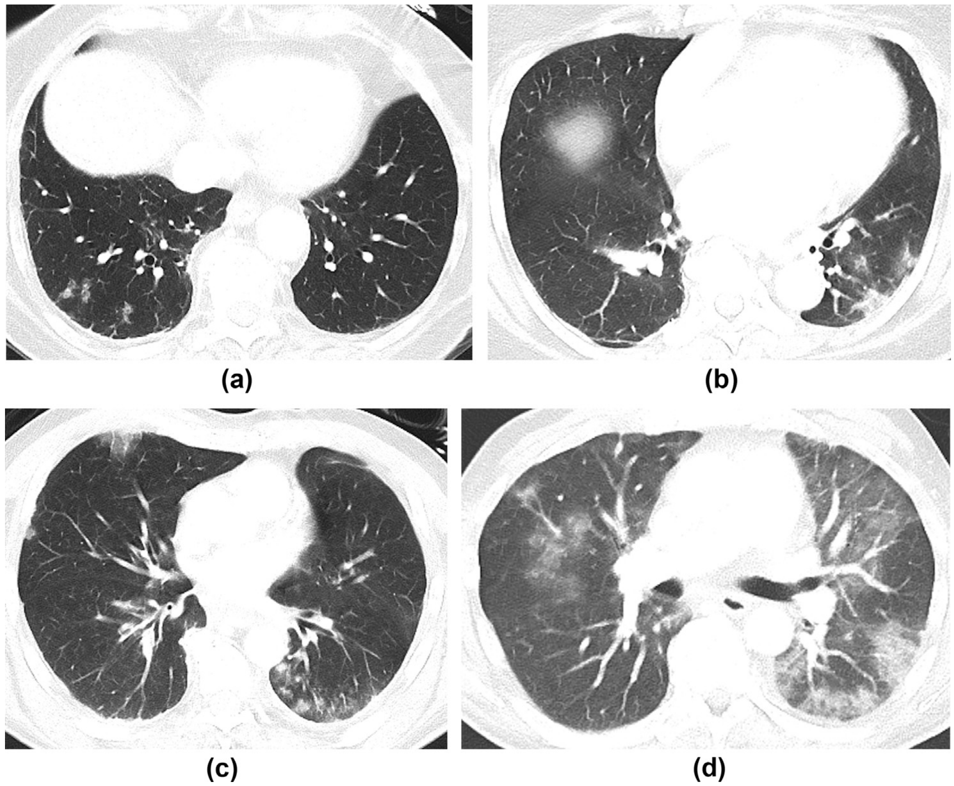

Figure 3 (a) Control group and (b) study group case examples classified as showing minor signs for COVID-19 in age and sex matched (women aged >80 years). (c) Control group and (d) study group case examples classified as showing major signs for COVID-19 in age and sex matched (men aged 50–59 years).

emerging, which have the potential to evade vaccines available at the time, and vaccination itself is not expected to produce lifelong immunity, although evidence is emerging that it may be durable for at least 6–12 months.[5] It is currently assumed that COVID-19 is likely to become a seasonal infection, with repeated vaccination required.[6]

It is now accepted that many people can harbour COVID-19, which is either completely asymptomatic, or so mild as to not be diagnosed. Whole town testing in Italy found that 42% of cases were asymptomatic at the time of a positive test and did not develop clinical disease[7]; however, the prevalence of asymptomatic disease in the UK population is unknown.[8] Lung changes consistent with COVID-19 infection can be picked up incidentally on CT examinations performed as part of a trauma scan, showing ground-glass changes that are not explained by aspiration or contusion. After correcting for changes occurring at a low level, pre-COVID-19 in 2019, these show a clear pattern of rise and fall in line with waves of the pandemic and lockdown. The current study shows that the technique successfully tracked the first and second waves, with low levels of detected disease in between. This illustrates the importance of radiologist awareness, and that routine prospective documentation of incidental changes in people scanned for trauma, a random event, can be used to track asymptomatic or unsuspected disease in the local population, and thereby act as an early warning of a new wave of infection.

Based on only major signs the percentage of the population with the disease by the end of April 2020 was originally estimated as 16%,[1] which was the same as the estimated antibody level of individuals exposed to the end of April of 17%. With the updated data and additional control group information, the new estimate at the end of April is 14%. With data followed to end of February 2021, the estimated percentage population with the disease was around 30%, which was similar to the figure of 29.1% for those testing positive to antibodies in February 2021.[4] There is therefore the suggestion from the present data that major signs may relate more closely to those in the general population with sufficient viral load to have an antibody response, but those with only minor signs more akin to those with just a T-cell response. Further research is required on the minor signs group and the difference seen in the prevalence of minor signs at the start of the first wave and the second wave. Applying this method at other trauma centres that have had a different experience of COVID-19, e.g., a smaller first wave and larger second wave, would provide valuable information to both confirm the viability of the method and provide further findings. The early warning signs in the first wave in February 2020 consist entirely of minor signs (10 from 162 patients in that month) and further work is required to examine these findings. This could suggest that COVID-19 signs, and therefore viral load may "build-up" in the population as more people are subject to multiple exposures as the disease expands into the population. Ultimately, data from other major trauma centres is required to increase numbers of events and to look at how different first and second wave intensities affect the findings. It is also possible that this methodology could be used to track the impact of the vaccine, which has been rolled out by age.

In practice, it is recognised that using blind reading and a control group may not be feasible for routine use of the method as an early warning system without the expenditure of a large amount of time and effort, often in a situation where rapid results are required (either at the early warning stage or during a pandemic) and staff are under pressure. It is recommended that a new variable be created on the system that can be assigned the values of negative, indeterminate COVID (minor) signs, and COVID (major) signs. This can be populated both prospectively and retrospectively if required. The control group levels are sufficiently low compared with the peak levels that no control group is necessary. If the estimation of COVID-19 signs from the CT examination is accomplished in "real-time" then there is no need to suspect a problem with bias. Data from a local cluster of major trauma centres, e.g., in London, could then be analysed regularly to look for further disease outbreaks. On a regular basis all that is required from any centre are three numbers[1]: number of major trauma patients,[2] number with minor signs, and[3] number with major signs.

We have developed a method to monitor and evaluate pandemics, such as the COVID-19 pandemic, which uses only routine information collected for other reasons. No additional radiation exposure or measurements are required. If confirmed, the present results suggest that CT examinations of major trauma patients are a highly sensitive way of measuring levels of COVID-19 in the population and that routine use of a simple additional question could provide a platform to evaluate future COVID-19 surges or other potential respiratory pandemics (once the radiological features of any new infection had been defined). Further work is required at other centres to examine the usefulness of the method in local areas, which have had a different temporal experience of the COVID-19 pandemic. Further evaluation of the minor (indeterminate) signs group and the optimum duration of COVID-19 signs on CT examinations is required to perfect the method.

Conflict of interest

The authors declare no conflict of interest.

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