


Original research

# COVID-19 hospital activity and in-hospital mortality during the first and second waves of the pandemic in England: an observational study

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## ABSTRACT

**Introduction** We aimed to examine the profile of, and outcomes for, all people hospitalised with COVID-19 across the first and second waves of the pandemic in England.

**Methods** This was an exploratory retrospective analysis of observational data from the Hospital Episode Statistics data set for England. All patients aged  $\geq 18$  years in England with a diagnosis of COVID-19 who had a hospital stay that was completed between 1 March 2020 and 31 March 2021 were included. In-hospital mortality was the primary outcome of interest. The second wave was identified as starting on 1 September 2020. Multilevel logistic regression modelling was used to investigate the relationship between mortality and demographic, comorbidity and temporal covariates.

**Results** Over the 13 months, 374 244 unique patients had a diagnosis of COVID-19 during a hospital stay, of whom 93 701 (25%) died in hospital. Adjusted mortality rates fell from 40%–50% in March 2020 to 11% in August 2020 before rising to 21% in January 2021 and declining steadily to March 2021. Improvements in mortality rates were less apparent in older and comorbid patients. Although mortality rates fell for all ethnic groups from the first to the second wave, declines were less pronounced for Bangladeshi, Indian, Pakistani, other Asian and black African ethnic groups.

**Conclusions** There was a substantial decline in adjusted mortality rates during the early part of the first wave which was largely maintained during the second wave. The underlying reasons for consistently higher mortality risk in some ethnic groups merits further study.

## INTRODUCTION

A second wave of the COVID-19 pandemic during autumn and winter 2020/2021 in the UK placed unprecedented pressure on the National Health Service (NHS). Reported rates of hospitalisation increased substantially during this period, and at their peak were almost double the peak of the first wave.<sup>1</sup> Early reports from a small number of NHS hospital trusts in England have suggested that during the early part of the second wave in late 2020 the risk of mortality increased substantially from that seen in the summer and early autumn period when patient numbers were low.<sup>2</sup>

The Getting It Right First Time (GIRFT) programme is funded by the Department of Health and Social Care in England to investigate variation

## Key messages

### What is the key question?

► In-hospital mortality rates are a key marker for the performance of health services in managing patients with COVID-19. However, little is known about how hospitals within the National Health Service in England coped with the surge in cases during winter 2020/2021. The aim of this study was to investigate mortality rates over time and in specific patient groups during the first and second waves of the pandemic in English hospitals.

### What is the bottom line?

► There was a substantial decline in adjusted in-hospital mortality rates during the early part of the first wave which was largely maintained during the second wave. However, an increase in mortality during the early part and peak of the second wave was apparent. Although mortality declined from the first to the second wave in all patient groups, the decline was less apparent in older patients with greater comorbidity burden and some ethnic groups.

### Why read on?

► We provide a complete record of all COVID-19-related hospital activity in England over a 13-month period. Understanding how outcomes have changes over time and which patient groups have responded less well to advances in patient management is important in preparing for future case surges.

in practice and patient outcomes across the NHS. GIRFT has a particular interest in assessing the variability of outcomes for COVID-19 during the pandemic to identify lessons to be learnt in terms of patient care that can be used to inform the response to future case surges.<sup>3</sup> Previous work by our team has noted a substantial fall in mortality for people hospitalised with COVID-19 during the early part of the first wave and consistently low in-hospital mortality rates, of around 11%–12%, during summer 2020.<sup>4,5</sup>

The aim of the current study was to detail the demographic profile and outcomes for patients in hospitals with COVID-19 in England during the



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first 13 months of the pandemic. A specific aim was to compare outcomes, and the patient factors affecting those outcomes, for the first and second waves.

## METHODS

### Ethics

Consent from individuals involved in this study was not required for this analysis of the Hospital Episodes Statistics (HES) administrative data set. The analysis and presentation of data follows current NHS Digital guidance for the use of HES data for research purposes. Reported data are anonymised to the level required by ISB1523 Anonymisation Standard for Publishing Health and Social Care Data.<sup>6</sup>

### Study design and data collection

This was a retrospective, exploratory analysis of HES data. HES data are collected by NHS Digital for all NHS-funded patients admitted to hospitals in England. Data are entered by trained coders in each hospital trust and data collection and reporting is mandatory. Hospital trusts run all NHS hospitals in England. A hospital trust provides secondary and/or tertiary care for all people living in a geographically defined catchment area. Catchment population can vary widely due to factors including the inconsistent nature of traditional administrative boundaries and trust mergers. Most trusts will run between one and four large secondary/tertiary care hospitals.

### Timing, case ascertainment, inclusion and exclusion criteria

We reviewed HES data for all completed episodes of hospital care in England with a discharge date from 1 March 2020 to 31 March 2021 that involved a diagnosis of COVID-19. HES data are collated and generally defined at the point of discharge. We only considered completed episodes of care, where the patient had been discharged and their outcome was known (either discharged alive or having died during their stay). Patients aged <18 years were excluded. Cases of COVID-19 were identified using the International Statistical Classification of Disease and Related Health Problems 10<sup>th</sup> edition (ICD-10) codes U07.1 (presence of COVID-19 has been confirmed by laboratory testing) and U07.2 (clinical or epidemiological diagnosis of COVID-19 where laboratory confirmation is inconclusive or not available).

Where a patient had multiple admissions during the study period, only the chronologically last admission was retained. This ensured that all admissions were independent of one another at a patient level and avoided biasing the data by including cases where the outcome was predefined (alive at discharge) by virtue of a subsequent admission. The data extraction process is summarised in figure 1.

### Outcomes

The primary outcome was in-hospital mortality as recorded by the Office for National Statistics. An in-hospital death was recorded if the date of death was the same as or  $\pm 1$  day of the hospital discharge date recorded in HES.

### Covariates

Age: Categorised as 18–39 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years and  $\geq 80$  years for exploratory analysis and treated as continuous in the final multivariable model. The categorisation was felt to be clinically meaningful while avoiding over stratification.

Sex: Male or female.

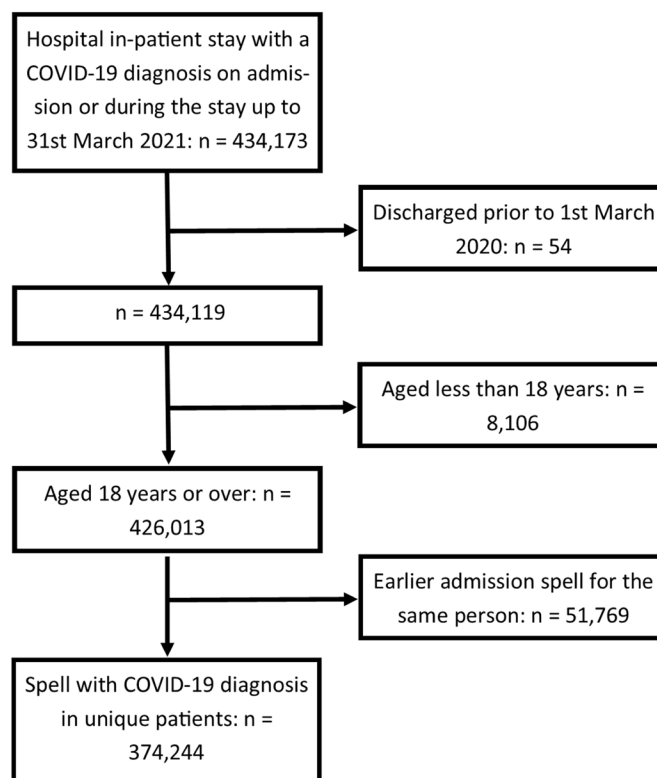


Figure 1 Study flow diagram showing data extraction process.

Ethnicity: Coded as white, Bangladeshi, Indian, Pakistani, other Asian, black Africa, black Caribbean, other black, mixed, other, not stated/missing. The other Asian group was comprised of all people who identified as ethnically Asian but who did not identify specifically as of Bangladeshi, Indian or Pakistani ethnicity. Likewise, the other black group was comprised of all people who identified as ethnically black but who did not identify specifically as of African or Caribbean ethnicity.

Deprivation: Recorded using the Index of Multiple Deprivation (IMD) for the Lower Super Output Area (LSOA) of the patients' home address, with scores categorised into quintiles based on national averages. The IMD categorises all households in England into percentiles of relative deprivation based on their LSOA of residence. It includes items measuring income, employment, health and disability, education and skills training, crime, barriers to housing and services and living environment.

Comorbidities: These were the 14 comorbidities used to construct the Charlson Comorbidity Index (peripheral vascular disease, congestive heart failure, acute myocardial infarction, cerebrovascular disease, dementia, chronic pulmonary disease, connective tissue disease/rheumatic disease, peptic ulcer, liver disease (mild and moderate/severe), diabetes (with and without chronic complications), paraplegia/hemiplegia, renal disease, cancer (primary and metastatic), HIV/AIDS).<sup>7</sup> The ICD-10 codes used to define chronic pulmonary disease are: I27.8, I27.9 (both pulmonary heart disease), J40.X to J47.X (bronchitis, emphysema, other chronic obstructive pulmonary disease, asthma, bronchiectasis) J60.X to J67.X (pneumoconiosis, airway disease/hypersensitivity pneumonitis due to organic dust), J68.4 (chronic respiratory conditions due to chemicals, gases, fumes and vapours), J70.1 (pulmonary disease due to radiation), J70.3 (chronic drug-induced interstitial lung disorders). The comorbidity was deemed present if it was recorded in HES as a secondary diagnosis in the index admission or as a primary or

secondary diagnosis in any admission during the previous year, in accordance with the recommendations of Quan *et al.*<sup>8</sup>

**Obesity:** Recorded as present if the ICD-10 code E66 was used as a diagnostic code during the admission.

**Discharge date:** Categorical into day, week or wave of discharge depending on the analysis undertaken. The first wave was defined as discharges between 1 March 2020 and 31 August 2020 and the second wave as discharges between 1 September 2020 and 31 March 2021. Weekly and wave data were used for descriptive statistics. The first 2 weeks of data were combined due to small numbers and the last 2 weeks combined due to the final week only having 4 days. Daily data were used for the final multivariable model.

**Admission date:** Categorical as day, week or month of admission. This was counted from 1 February 2020 to 28 February 2021. The earlier starting point reflected admission activity and captured patients who were admitted in early 2020 and acquired COVID-19 nosocomially. We also excluded admissions data from March 2021 due to a bias in the data from patients who were still in hospital beyond 31 March 2021 and so not counted in HES. As for discharge week, the first 2 weeks and last 2 weeks were combined.

### Data management and statistical analyses

Data were extracted onto a secure encrypted server controlled by NHS England and NHS Improvement. Analysis within this secure environment took place using standard statistical software: Microsoft Excel (Microsoft Corp), Stata (StataCorp) and Alteryx (Alteryx). Age data were non-normally distributed and summarised using the median and IQR. All other data are described by frequency and percentage.

As for our previous work, in-hospital mortality was modelled using hierarchical multilevel logistic regression models developed using the 'melogit' command in Stata.<sup>5</sup> Two-level intercept only models were constructed, allowing adjustment for clustering of patients within hospital trusts, with hospital trust as the random effect. The covariates listed above were included as fixed effects in the models. To compare in-hospital mortality data for the first and second wave, models were constructed for each period separately with all variables treated as categorical to aid comparison and interpretation.

For the model of in-hospital mortality for the entire study period, age, discharge date and IMD score were treated as continuous variables and modelled using restricted cubic splines where non-linearity was evident. Non-linearity was identified where only the first linear spline contributed to the model fit. Age was modelled using three knots at the 10th, 50th and 90th percentile. Discharge date was modelled using six knots at the 5th, 23rd, 41st, 59th, 77th and 95th percentile. The optimal number of knot and knot position was identified using the recommendations of Harrell<sup>3,9</sup> and with reference to Akaike Information Criterion. IMD score was modelled as a linear variable. All other variables were modelled as categorical terms. The model outputs for age and discharge date were plotted using the 'adjustrcspline' command in Stata. In sensitivity analysis discharge date was replaced by admission date for some analysis. For multilevel regression modelling, the same six knot positions were used as for discharge date.

Only for sex (0.01%), deprivation (2.2%) and ethnicity (6.4%) were there missing data (see [table 1](#)). For ethnicity, a number of patients did not state their ethnicity, although an answer was recorded for all patients. In these cases, HES was searched for a different hospital admission of the same patient where ethnicity

had been recorded and this value was used. Where more than one ethnicity was recorded for different admissions the most recent record was used. For descriptive analysis numbers are presented for all available data and the number of missing values stated. No attempt was made to impute missing values during our main modelling, meaning that model outputs are based only on complete records. However, a sensitivity analysis was run using multiple imputation of missing values for ethnicity deprivation and sex. The method of imputation is described in the footnote to online supplemental table S1. The models were summarised in terms of ORs and 95% CIs. The model outputs should be interpreted, within the context of exploratory analysis, as mutually adjusted associations rather than as causal relationships.<sup>10</sup>

### RESULTS

There were 426 013 (n=293 309 (68.8%) second wave) hospital stays in patients aged 18 years and over during the study period. Exclusion of 51 769 (n=37 456 (72.4%) second wave) earlier admissions gave a data set of 374 244 unique patients who had a diagnosis of COVID-19 either on admission or during their stay. The data extraction process is summarised in [figure 1](#). In total, 339 987 (90.8%) patients had COVID-19 confirmed by test. There was a trend towards more COVID-19 cases being confirmed by test over the study period (79.3% first wave and 95.8% second wave).

There were 93 701 (25.0%) in-hospital deaths and 75 035 (80.1%) of these deaths had COVID-19 as the primary cause listed on the death certificate; 74 786 (99.7%) of these were test confirmed COVID-19. The median age of those who survived to discharge was 66 years (IQR 51–80) and was 81 years (IQR 72–87) for patients that died in hospital.

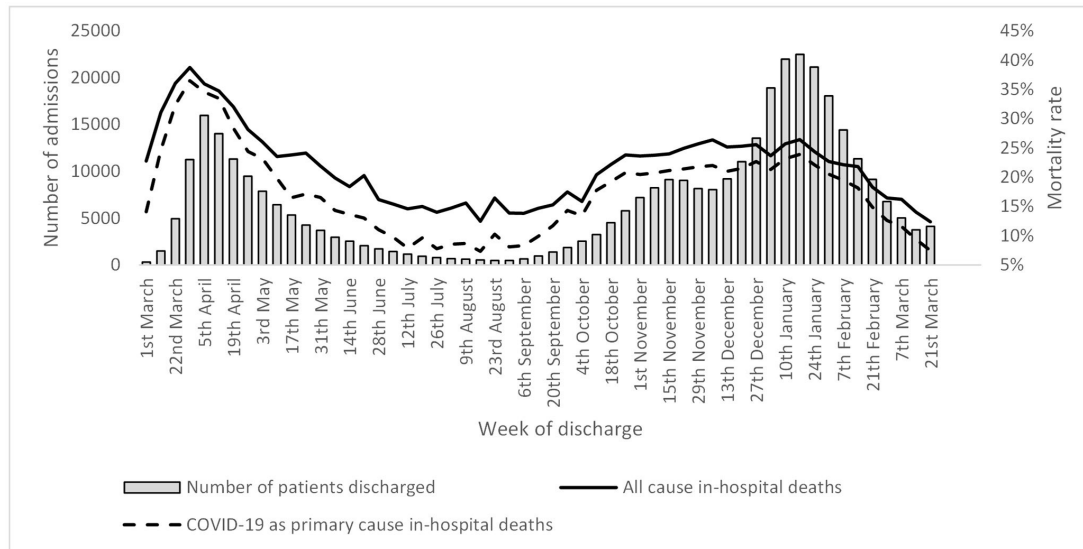
The crude number of discharges and in-hospital deaths per week are summarised in [figure 2](#). The rapid decline in the death rate during the early phase of the first wave is evident, with a more modest increase in the death rate during the peak of the second wave, followed by a fall. The trend for all-cause deaths and COVID-19 as the primary cause of deaths was very similar. The same data plotted by week of admission, rather than discharge, are shown in online supplemental material figure S1. The data by admission date show a similar trend. The temporal trend in the age band of patients is presented in [figure 3](#) and shows the relatively younger age of patients discharged during March 2020 and July–September 2020 and the steady decrease in the number of patients aged 80 years and over discharged from January 2021 to March 2021. The median age of patients peaked at 76 years in late May 2020, declined to 60 years in early September 2020 and stabilised at 69–73 years from November 2020 to January 2021, before declining to 65 years by late March 2021.

The profile of patients discharged during the first and second waves is summarised in [table 1](#). All demographic and socioeconomic groups saw a decline in crude in-hospital mortality rates from the first to the second wave, and this was most noticeable for younger age groups and people of black ethnicity. Declines were more modest for people aged 80 years and over and for most comorbidities investigated. Chronic pulmonary disease was the most common comorbidity in both waves: first wave: 26.2% of all patients and second wave 25.6% of all patients. Crude mortality rates fell only slightly, from 32.5% in the first wave to 28.9% in the second wave for patients with chronic pulmonary disease. For people with congestive heart failure, peptic ulcer, metastatic carcinoma and HIV/AIDS mortality rates were very similar across the two waves.

**Table 1** Patient demographic, socioeconomic and clinical profile and number of deaths during the first and second waves

Variable	March 2020–August 2020		September 2020–March 2021	
	Discharges (n=112 391)	Deaths (n=32 998, 29.4%)	Discharges (n=261 853)	Deaths (n=60 703, 23.2%)
<b>Age band (years)</b>				
18–39	8886	237 (2.7)	27 320	402 (1.5)
40–49	8566	584 (6.8)	22 407	1034 (4.6)
50–59	14 553	1980 (13.6)	36 883	3297 (8.9)
60–69	16 964	4099 (24.2)	41 469	7800 (18.8)
70–79	23 883	8485 (35.5)	53 289	15 803 (29.7)
≥80	39 539	17 613 (44.5)	80 485	32 367 (40.2)
<b>Sex (missing=46)</b>				
Female	50 711	13 084 (25.8)	124 896	25 373 (20.3)
Male	61 663	19 914 (32.3)	136 928	35 324 (25.8)
<b>Deprivation quintile (missing 8072)</b>				
1 (most deprived)	28 379	7983 (28.1)	69 000	14 601 (21.2)
2	24 550	7156 (29.1)	57 061	12 865 (22.5)
3	20 970	6420 (30.6)	48 670	11 824 (24.3)
4	19 026	5878 (30.9)	43 703	10 876 (24.9)
5 (least deprived)	16 995	5131 (30.2)	37 818	9524 (25.2)
<b>Ethnicity (missing=24 072)</b>				
White	84 798	26 569 (31.3)	197 644	50 149 (25.4)
Bangladeshi	738	196 (26.6)	2940	569 (19.4)
Indian	3373	935 (27.7)	7841	1650 (21.0)
Pakistani	2782	628 (22.6)	8734	1469 (16.8)
Other Asian	2994	620 (20.7)	6613	1023 (15.5)
Black African	2680	466 (17.4)	4376	507 (11.6)
Black Caribbean	2310	779 (33.7)	3886	772 (19.9)
Other black	1132	258 (22.8)	2069	271 (13.1)
Mixed	1007	215 (21.4)	2366	295 (12.5)
Other	3842	791 (20.6)	8047	1074 (13.3)
<b>Charlson Comorbidity Index items*</b>				
Peripheral vascular disease	5986	2512 (42.0)	13 287	5172 (38.9)
Congestive heart failure	16 600	7768 (46.8)	33 987	15 487 (45.6)
Acute myocardial infarction	10 286	4221 (41.0)	23 316	8858 (38.0)
Cerebrovascular disease	10 943	4306 (39.3)	23 913	8500 (35.5)
Dementia	17 409	7865 (45.2)	29 588	11 940 (40.4)
Chronic pulmonary disease	29 414	9572 (32.5)	67 078	19 410 (28.9)
Connective tissue disease/rheumatic disease	3361	1157 (34.4)	8449	2583 (30.6)
Peptic ulcer	785	275 (35.0)	2011	686 (34.1)
Mild liver disease	3706	876 (23.6)	10 074	2120 (21.0)
Moderate or severe liver disease	1261	669 (53.1)	2778	1310 (47.2)
Diabetes without chronic complications	27 489	9580 (34.9)	61 763	17 331 (28.1)
Diabetes with chronic complications	3392	1271 (37.5)	7668	2431 (31.7)
Paraplegia and hemiplegia	2831	1039 (36.7)	5477	1775 (32.4)
Renal disease	20 734	9133 (44.0)	46 196	18 909 (40.9)
Primary cancer	6507	2844 (43.7)	13 026	5166 (39.7)
Metastatic carcinoma	3494	1439 (41.2)	7956	3354 (42.2)
HIV/AIDS	193	24 (12.4)	265	37 (14.0)
Obesity	10 113	2590 (25.6)	30 786	5999 (19.5)

\*For the Charlson Comorbidity Index items: Only those with the disease are listed. There were no missing data. Individual patients can appear in multiple disease categories.



**Figure 2** Number of discharges and mortality rate per week of discharge.

Based on multilevel, multivariable modelling, ORs for the association between the covariates and in-hospital mortality risk for the first and second waves are shown in [table 2](#). During the second wave the relationship between greater age and greater risk of death appeared to be stronger than during the first wave, with the relative odds of death in those aged 80 years and over (compared with those aged 18–39 years) much greater during the second wave. For sex, deprivation and the Indian, Pakistani and black African ethnic groups the relative odds of death were similar in both waves. For the black Caribbean, other black and mixed ethnic groups the relative odds of death were noticeably lower and for the Bangladeshi ethnic group noticeably higher during the second wave than during the first (relative to the white ethnic group).

The odds of death were high for people with moderate or severe liver disease in both waves, reflecting the high crude mortality rate and the relatively young age of these patients: across both waves the median age for patients with moderate or severe liver disease was 60 years (IQR 51–70) in those that survived to discharge and 65 years (IQR 55–75) in those that died in hospital. For the comorbidities congestive heart failure, chronic pulmonary disease and metastatic carcinoma the relative odds of death were substantially higher in the second wave.

In sensitivity analysis, multivariable, multilevel logistic regression models were constructed for each wave with missing values

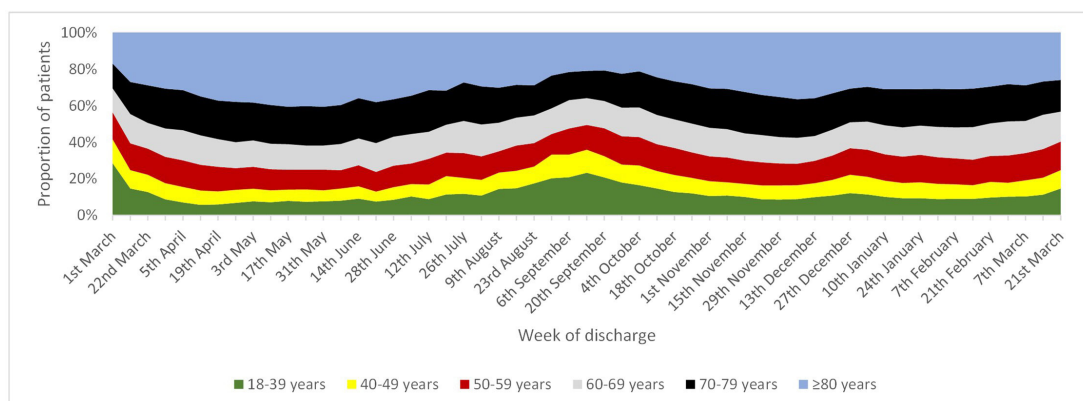
for sex, deprivation and ethnicity imputed, the model outputs are shown in online supplemental table S1 and are very similar to those for the main analysis presented in [table 2](#).

A multivariable, multilevel logistic regression model was constructed for the entire study period with age, discharge date and IMD score treated as continuous variables. The adjusted mortality rate over time is shown in [figure 4](#). The adjusted mortality rates fell from 40%–50% in March 2020 to 11% in August 2020 before rising to 21% in January 2021 and falling back by March 2021. The other model outputs are shown in online supplemental table S2 and figure S2 and confirm the strong relationship between age and mortality and the broad pattern of associations reported in [table 2](#).

Multivariable, multilevel modelling was also performed using admission date as the time variable. The adjusted relationship between predicted probability of mortality and admission date is shown in online supplemental figure S3, giving a very similar profile to that found when using discharge date as the time variable, although with an early peak in mortality risk during winter 2020/2021.

## DISCUSSION

We report on trends in the profile of, and outcomes for, all COVID-19 hospital patients in England across the first 13



**Figure 3** Patient age band per week of discharge.

**Table 2** Multilevel multivariable logistic regression models of factors associated with in-hospital mortality for each period

Variable	March–May (OR, 95% CI)	June–September (OR, 95% CI)
<b>Age band (years)</b>		
18–39	1 (reference)	1 (reference)
40–49	2.24 (1.90 to 2.64)	2.83 (2.49 to 3.21)
50–59	4.70 (4.06 to 5.45)	5.35 (4.78 to 6.00)
60–69	8.66 (7.50 to 10.00)	11.38 (10.19 to 12.72)
70–79	14.48 (12.56 to 16.71)	18.93 (16.96 to 21.13)
≥80	21.16 (18.35 to 24.39)	29.86 (26.76 to 33.33)
<b>Sex</b>		
Female	1 (reference)	1 (reference)
Male	1.47 (1.43 to 1.52)	1.45 (1.42 to 1.48)
<b>Deprivation quintile</b>		
5 (least deprived)	1 (reference)	1 (reference)
4	1.02 (0.97 to 1.07)	1.00 (0.97 to 1.04)
3	1.06 (1.01 to 1.11)	1.04 (1.00 to 1.08)
2	1.04 (0.99 to 1.09)	1.03 (1.00 to 1.07)
1 (most deprived)	1.05 (1.00 to 1.11)	1.05 (1.01 to 1.09)
<b>Ethnicity</b>		
White	1 (reference)	1 (reference)
Bangladeshi	1.45 (1.20 to 1.77)	1.65 (1.48 to 1.85)
Indian	1.26 (1.15 to 1.38)	1.31 (1.23 to 1.40)
Pakistani	1.22 (1.10 to 1.36)	1.24 (1.16 to 1.33)
Other Asian	1.15 (1.04 to 1.27)	1.24 (1.15 to 1.34)
Black African	1.06 (0.94 to 1.19)	1.11 (1.00 to 1.24)
Black Caribbean	1.19 (1.08 to 1.32)	0.91 (0.83 to 0.99)
Other Black	1.26 (1.07 to 1.48)	1.00 (0.87 to 1.16)
Mixed	1.31 (1.11 to 1.55)	1.02 (0.88 to 1.17)
Other	1.04 (0.95 to 1.14)	0.97 (0.90 to 1.05)
<b>Charlson Comorbidity Index items*</b>		
Peripheral vascular disease	1.18 (1.11 to 1.25)	1.28 (1.23 to 1.33)
Congestive heart failure	1.54 (1.48 to 1.60)	1.81 (1.77 to 1.86)
Acute myocardial infarction	1.07 (1.02 to 1.12)	1.19 (1.16 to 1.23)
Cerebrovascular disease	1.05 (1.00 to 1.10)	1.11 (1.08 to 1.15)
Dementia	1.39 (1.34 to 1.45)	1.43 (1.39 to 1.47)
Chronic pulmonary disease	1.09 (1.05 to 1.12)	1.31 (1.28 to 1.34)
Connective tissue disease/rheumatic disease	1.19 (1.10 to 1.29)	1.20 (1.14 to 1.26)
Peptic ulcer	0.99 (0.84 to 1.16)	1.14 (1.03 to 1.27)
Mild liver disease	0.96 (0.88 to 1.05)	1.11 (1.05 to 1.17)
Moderate or severe liver disease	4.75 (4.16 to 5.41)	5.15 (4.71 to 5.64)
Diabetes without chronic complications	1.12 (1.08 to 1.16)	1.07 (1.04 to 1.09)

Continued

**Table 2** Continued

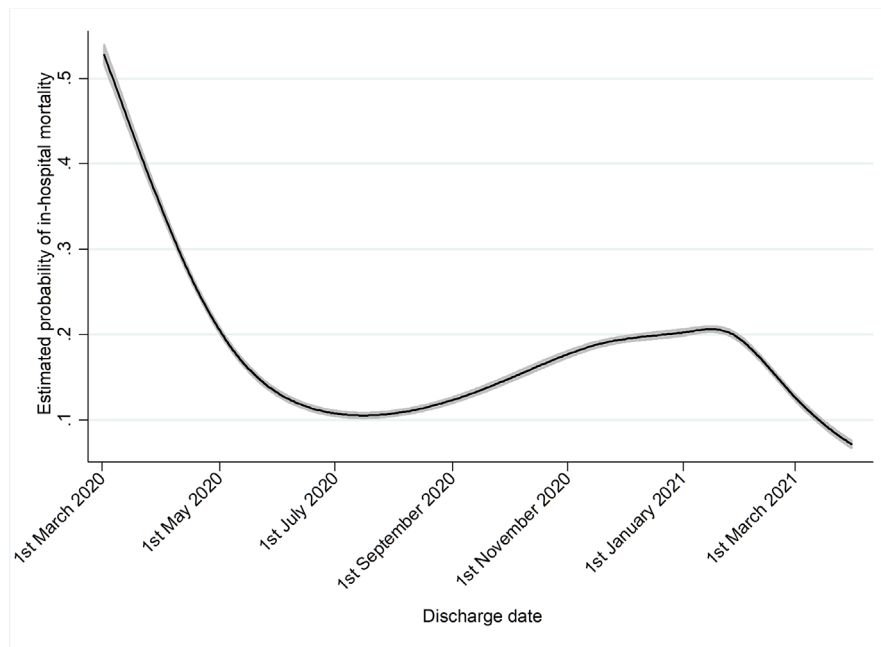
Variable	March–May (OR, 95% CI)	June–September (OR, 95% CI)
Diabetes with chronic complications	1.19 (1.10 to 1.29)	1.11 (1.05 to 1.17)
Paraplegia and hemiplegia	1.10 (1.05 to 1.15)	1.16 (1.12 to 1.20)
Renal disease	1.15 (1.13 to 1.17)	1.22 (1.20 to 1.23)
Primary cancer	1.51 (1.43 to 1.60)	1.57 (1.51 to 1.64)
Metastatic carcinoma	1.97 (1.83 to 2.13)	2.54 (2.41 to 2.67)
Obesity	1.32 (1.25 to 1.40)	1.43 (1.38 to 1.48)

Models are multilevel, multivariable models that included each of the variables listed as fixed effects and for NHS hospital trust as a random effect. The March–August model is based on data for 103 563 patients and the September–March model on data for 239 674 patients with no missing data. A stable OR for the comorbidity HIV/AIDS could not be calculated due to small numbers. Figures in bold denote 95% CI not crossing the value 1, indicating statistical significance.

\*For Charlson Comorbidity Index items, the reference category is patients without the specified comorbidity. For Charlson Comorbidity Index items relating to liver disease, diabetes and cancer, three mutually exclusive categories were used.

months of the pandemic in England. This covers the peaks in activity during the first and second waves. As reported previously, in-hospital mortality rates fell substantially during the early part of the first wave (March–May 2020) and remained low during summer and early autumn 2020.<sup>4,5</sup> The current study reveals that mortality rates rose steadily during late 2020, but stayed well below their first wave peak, and then declined during February–March 2021. This broadly supports earlier evidence from Public Health England of increasing mortality rates during late 2020, although the adjusted peak in mortality reported in our study is lower.<sup>2</sup> This reduction in mortality rates between the two peaks in hospital COVID-19 activity, despite much higher peak patient numbers, may reflect advances in secondary care management of the disease, including rapidly expanding critical care capacity, and improvements in organisation of hospital networks in provision of resources to manage surges of acutely unwell patients.<sup>11–14</sup> It may also reflect wider healthcare organisation including improved management in primary care and a change in messaging, with greater encouragement for people to present to healthcare services early.<sup>15</sup>

Crude in-hospital mortality rates were lower in the second wave than in the first for all demographic and socioeconomic groups. For all comorbidity groups the fall in crude in-hospital mortality rates in the second wave were more modest or showed little change. Relative to the reference categories, the associations between sex and deprivation and in-hospital mortality were stable from the first to the second wave. However, there was evidence that the associations between increasing age (relative to the 18–39 age group) and most comorbidities (relative to those without the comorbidity) was stronger in the second wave, suggesting that these patient groups may be relatively less responsive to the various treatment options that emerged during the pandemic than younger patients and those with fewer comorbidities. The more limited decline in mortality rates is most apparent for those with metastatic carcinoma and congestive heart failure, perhaps reflecting impaired overall physiological reserve to stressors. The high odds of in-hospital death for those with moderate or severe liver disease is striking in both waves, with a high in-hospital mortality rate and relatively young patient population combining to give a high adjusted risk of death. Many of the comorbidities associated with COVID-19



**Figure 4** Predicted probability of in-hospital mortality by discharge date with 95% CIs shown as grey shading.

related in-hospital mortality are also associated with non-COVID-19 mortality, suggesting that COVID-19 mostly magnifies pre-existing risks faced by patients with these diseases.<sup>16</sup>

Chronic pulmonary disease was the most common comorbidity, seen in around a quarter of all patients. These patients had only a modest fall in crude in-hospital mortality rates from the first to the second wave, and a higher relative odds of death in the second wave compared with the first wave. Further dedicated studies of the pattern of mortality and assessments of treatment efficacy in patients with COVID-19 with pulmonary disease would add to the current evidence base and may help improve outcomes.<sup>17</sup>

The increase in the mortality rate during the early phase of the second wave is interesting and may suggest increasing strain on services as community cases numbers rose and hospital admissions rapidly increased to levels higher than those seen at the peak of the first wave. It may also reflect changing admission criteria as patient numbers increased, with only those deemed in urgent need of hospital care admitted. This would likely result in a more severely ill patient population and higher mortality rates. The increasing median age of patients during the early phase of the second wave suggests that this may be the case. The modest, but consistent decline in patient age profiles from January 2021 onwards may reflect the vaccination programme in England, which prioritised older age groups during this period.

For black and mixed ethnic groups, our previous work found evidence that relatively high adjusted in-hospital mortality rates in March–May 2020 had declined to levels seen in white ethnicity patients by summer/autumn 2020.<sup>4</sup> These changes appear to have been maintained over the second wave. In contrast, adjusted in-hospital mortality rates in Asian (Bangladeshi, Pakistani, Indian and other Asian) ethnicity patients remained at higher levels than seen in white patients throughout the study period. These findings are similar to those reported by researchers using the OpenSAFELY data platform which looked at a community-based sample of over 17 million adults in England up to 31 December 2020.<sup>18</sup> The authors noted an increased (relative to white ethnicity groups) risk of hospitalisation, and death in people of South Asians and

black ethnicity in the first wave and an attenuation of these risks in the second wave for black, but not South Asian ethnicity groups. They also report that in the second wave, risk of hospital admission was no different between white and black Caribbean groups and the risk of death was no different between white and all black ethnicity groups. Some of the excess risks reported for non-white ethnic groups by the OpenSAFELY study may be due to the fact that both the first and second waves had high case numbers in London, where the population is more ethnically diverse compared with most of England. However, the authors also note that London general practitioners were under-represented in their data set. The Real-time Assessment of Community Transmission (REACT) study has reported limited variability in the infection to mortality ratio between ethnic groups in the UK and concluded that higher mortality rates in some ethnic groups were due to higher infection rates and not due to the care received.<sup>19</sup> Although our findings might appear to contradict this conclusion for South Asian ethnicity groups, the conclusion would hold if people of South Asians ethnicity with SARS-Cov-2 infection had a greater tendency than other ethnic groups to only present to healthcare services if severely ill. There is some evidence from early in the pandemic that black and Asian ethnicity people were more likely to be admitted to hospital later in the disease course, although whether this was still the case during the second wave is uncertain.<sup>20</sup> A study dedicated to understanding the reasons for the consistent excess burden of mortality in Asian ethnic groups is merited.

Our study has a number of strengths and some limitations. Our data set covers all people admitted to hospital in England and thus collider bias should be minimal when considering hospital populations.<sup>21</sup> However, our findings should not be extrapolated beyond the hospital setting other than to provide insight by contrasting the findings in each setting. Community-based studies have a very different denominator population, where the majority of the cohort, even when infected with SARS-Cov-2, do not require hospitalisation. As such mortality rates and associations for community-based studies will vary considerably from those reported here. In our data set, when comparing the first and

second waves, differences in case-mix between the two periods means that collider bias is inevitable.

This was an exploratory analysis and the modelled effects reported should be interpreted as associations rather than causal.<sup>10</sup> A number of unmeasured variables related to clinical presentation and treatment received are likely to have confounded our findings.

As with most administrative data sets, data on clinical presentation are lacking and this will be an important determinant of outcomes. We also did not have access to data on the use of various treatment options over time, particularly use of drug treatments. Information from clinical trials on the efficacy of drug treatments (eg, dexamethasone, tocilizumab) changed practice over time. Dexamethasone was widely used from June 2020 and tocilizumab from February 2021.<sup>12–22</sup> Although such drugs have undoubtedly improved patient outcomes, we are unable to comment on their specific effects on outcomes in this study. We included data for test-confirmed and clinically diagnosed COVID-19 to ensure as complete coverage of hospital activity as possible. However, we recognise that some clinically diagnosed cases, may not have had COVID-19. Likewise, we included all deaths for any cause, including those that will be unrelated to COVID-19 infection. Our sensitivity analyses, including in previous publications, suggest that this is unlikely to have introduced a significant bias with regard to the general trends reported.<sup>5</sup>

In summary, we present a complete record of COVID-19 hospital activity in England over the first 13 months of the pandemic covering the peaks of the first and second waves. During the second wave, mortality rates remained well below the first wave peak despite much larger patient numbers. Noticeably lower mortality rates in black ethnicity patients later in the pandemic are also encouraging. However, mortality rates in Asian ethnicity patients remain above those found in other ethnic groups and appear harder to address. With high levels of vaccination in England, and while vaccines remain effective in preventing severe disease, the number and profile of patients admitted to hospital with COVID-19 is likely to change dramatically. This should help avoid hospitals becoming overwhelmed and help maintain the improvements in patient outcomes seen during 2020 and early 2021.

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licence/data sharing agreement from NHS Digital, for which conditions of use (and further use) apply. Individuals and organisations wishing to access Hospital Episodes Statistics data can make a request directly to NHS Digital.

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