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ORIGINAL ARTICLE

Patient response, treatments, and mortality for acute myocardial infarction during the COVID-19 pandemic

Jianhua Wu [1,2], Mamas Mamas[3], Muhammad Rashid [3], Clive Weston[4], Julian Hains[5], Tom Luescher[6], Mark A. de Belder[5], John E. Deanfield[5,7], and Chris P. Gale [1,8,9]*

[1]Leeds Institute for Data Analytics, University of Leeds, Worsley Building, Level 11, Clarendon Way, University of Leeds, Leeds LS2 9JT, UK; [2]Division of Clinical and Translational Research, School of Dentistry, University of Leeds, Leeds, UK; [3]Keele Cardiovascular Research Group, Institute for Prognosis Research, University of Keele, Keele, UK; [4]Glangwili General Hospital, Carmarthen, Wales, UK; [5]National Institute for Cardiovascular Outcomes Research, Barts Health NHS Trust, London, UK; [6]Imperial College, National Heart and Lung Institute, London, UK; [7]Institute of Cardiovascular Sciences, University College, London, UK; [8]Leeds Teaching Hospitals NHS Trust, Leeds, UK; and [9]Leeds Institute for Cardiovascular and Metabolic Medicine, University of Leeds, Leeds, UK

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Aims COVID-19 might have affected the care and outcomes of hospitalized acute myocardial infarction (AMI). We aimed to determine whether the COVID-19 pandemic changed patient response, hospital treatment, and mortality from AMI.

Methods and results Admission was classified as non-ST-elevation myocardial infarction (NSTEMI) or STEMI at 99 hospitals in England through live feeding from the Myocardial Ischaemia National Audit Project between 1 January 2019 and 22 May 2020. Time series plots were estimated using a 7-day simple moving average, adjusted for seasonality. From 23 March 2020 (UK lockdown), median daily hospitalizations decreased more for NSTEMI [69 to 35; incidence risk ratios (IRR) 0.51, 95% confidence interval (CI) 0.47–0.54] than STEMI (35 to 25; IRR 0.74, 95% CI 0.69–0.80) to a nadir on 19 April 2020. During lockdown, patients were younger (mean age 68.7 vs. 66.9 years), less frequently diabetic (24.6% vs. 28.1%), or had cerebrovascular disease (7.0% vs. 8.6%). ST-elevation myocardial infarction more frequently received primary percutaneous coronary intervention (81.8% vs. 78.8%), thrombolysis was negligible (0.5% vs. 0.3%), median admission-to-coronary angiography duration for NSTEMI decreased (26.2 vs. 64.0 h), median duration of hospitalization decreased (4 to 2 days), secondary prevention pharmacotherapy prescription remained unchanged (each > 94.7%). Mortality at 30 days increased for NSTEMI [from 5.4% to 7.5%; odds ratio (OR) 1.41, 95% CI 1.08–1.80], but decreased for STEMI (from 10.2% to 7.7%; OR 0.73, 95% CI 0.54–0.97).

Conclusion During COVID-19, there was a substantial decline in admissions with AMI. Those who presented to hospital were younger, less comorbid and, for NSTEMI, had higher 30-day mortality.

Keywords Acute myocardial infarction • COVID-19 • MINAP • Mortality • Treatments • Admissions

Introduction

To reduce the spread of COVID-19, many countries have imposed social containment mandates (so-called 'lockdown'), which have resulted in a dramatic decline in local population movement, including emergency attendances at hospital.[1,2] A number of studies have described a decline in patients with acute myocardial infarction (AMI) presenting to hospital during this period, and some have suggested that people with symptoms of AMI may be delaying, or not, seeking help from the emergency medical services.[3–8] Equally, in preparation for, and in response to, the large numbers of patients admitted with probable COVID-19, hospitals have undertaken major

* Corresponding author. Tel: +44 (0)113 343 8916, Email: c.p.gale@leeds.ac.uk

reorganization of their emergency care facilities, including cardiac catheterization laboratories. The Chinese Society of Cardiology (CSC) expert consensus statement recommended medical management for the majority of patients presenting with non-ST-elevation myocardial infarction (NSTEMI), and thrombolysis in those presenting with STEMI during the COVID-19 pandemic.[9] In contrast, in North America and Canada, it has been proposed that thrombolysis may be used as an alternative to primary percutaneous coronary intervention (PCI) for patients with STEMI where restriction in regular services exist, and in the UK that primary PCI should remain the preferred reperfusion strategy.[10–12]

To date, evidence concerning the presentation, care, and outcomes from AMI during the COVID-19 pandemic is limited. Information has been derived from single centres or small groups of hospitals or, in studies involving routine health system data, have limited information about prognostic characteristics of patients including details of the baseline risk, comorbidities, call-for-help times, investigations and guideline-indicated treatments, and clinical outcomes, particularly from a national perspective.[13,14] An understanding of how COVID-19 lockdown may have influenced the health seeking behaviour of patients with AMI as well as the delivery of care by specialist services is important if widespread unintended consequences of the pandemic are to be minimized and preparations made for a potential second wave. To that end, the Chief Scientific Advisor to the Government of the United Kingdom commissioned the National Institute for Cardiovascular Outcomes Research to produce a report to support the response of the Department of Health to the COVID-19 pandemic in the UK. This investigation details the first national insights around the patient and healthcare response to AMI during and in the recovery phase of the COVID-9 pandemic. It will also provide updated time series summary data (When published this word will have a hyperlink to cardiovascularcovid.leeds.ac.uk) to monitor the progress of AMI patient characteristics, care, and outcomes during the current COVID-19 pandemic in England.

Methods

Data and patients

The Myocardial Ischaemia National Audit Project (MINAP) is a comprehensive clinical database of patients hospitalized with AMI, mandated by the UK Department of Health for all hospitals in England.[15–17] Data are collected prospectively at each hospital, electronically encrypted, and transferred online to a central database at the National Institute for Cardiovascular Outcomes Research (NICOR). During COVID-19 pandemic, MINAP data were obtained through weekly live feeding into NHS Digital server.

The analytical cohort was derived from patients with AMI admitted to one of 180 acute NHS hospitals in England between 1 January 2017 and 22 May 2020. Patients were eligible for the study if they were aged 18–100 years and admitted to an NHS hospital in England with a final diagnosis of STEMI or NSTEMI. The final diagnosis was determined by local clinicians according to presenting history, clinical examination, and the results of inpatient investigations in keeping with the consensus document of the Joint European Society of Cardiology and American College of Cardiology.[18] Recurrent events of AMI for patients who had an AMI within 30 days of their previous admission were excluded, as these were considered potential complications/adverse outcomes of the index event.

Time of symptom onset was defined as the time within 10 min of when symptoms began, and if there was a prodrome of intermittent pain, the time of onset of those symptoms that led the patient to call for help. For the derivation of symptom to call-for-help duration, only patients who presented to hospital by ambulance were included. Where admission followed an out of hospital cardiac arrest, with no better information available, the time of the arrest was used for the onset of symptoms. The time of hospital admission was defined as the time of arrival of the ambulance at the hospital, or the accident and emergency department registration time for patients who self-presented to the department.

Statistical analyses

Baseline characteristics were described using numbers and percentages [with 95% confidence interval (CI) of the percentages] for categorical data and means and standard deviations or medians and interquartile ranges for normal and non-normally distributed continuous variables. For NSTEMI, the probability of inpatient all-cause mortality was calculated using the GRACE risk score,[19] and categorized into low (1–108), intermediate (109–140), and high risk (141–372). Time trends of patient and treatment characteristics were primarily summarized by comparing data from the start of the study (1 January 2019–22 March 2020) with two other periods: a decline phase from 23 March (UK 'lockdown') to the nadir in admissions (on 19 April 2020), and a recovery phase (from 20 April 2020 to 22 May 2020) using χ^2 squared and *t*-tests as appropriate to the distributions of the data. Visual comparison were also made across other dates including first suspect case (31 December 2019), China lockdown (23 January 2020), World Health Organization declaration of a public health emergency (30 January 2020), and Italy lockdown (2 March 2020). Counts of daily cases were represented as numbers and unadjusted incidence risk ratios (IRR) with accompanying 95% CIs.

For time series plots, a 7-day simple moving average (indicating the mean number of daily admissions for that day and the preceding 6 days), adjusted for seasonality, was estimated. To provide an estimate of the impact of the COVID-19 pandemic on admissions and the provision of services, an interrupted times series using a generalized linear model for a Poisson distribution, was fitted and adjusted for seasonality with a harmonic term. A scaling adjustment was made after checking for overdispersion, and autocorrelation examined through partial autocorrelation function.

Patient data were deterministically linked to Civil Registration Deaths Data received up to 21 June 2020 (final follow-up). Seven-day and 30-day unadjusted all-cause mortality were reported with accompanying 95% CIs.

Given the NHS reorganization aimed at managing COVID-19,[20] there may have been a reduction in clinical coding and data submission to NICOR, which could mimic a reduction in AMI admissions during the period of study. This was mitigated and investigated through a number of steps. Regular notifications were actioned by the British Cardiovascular Society and British Cardiovascular Intervention Society to its members, and from NICOR to each hospitals' MINAP audit clerk emphasizing the importance of inputting and submitting contemporary data to NICOR. A survey of each acute NHS hospitals' MINAP data coding as well as tracking of submission status was undertaken, and from this, 99 'rapid-reporting' hospitals who provided weekly uploads of MINAP data were identified and used as primary analysis.

All tests were two-sided, and statistical significance was considered as $P < 0.05$. Statistical analyses were performed in R version 3.6.3.

Ethical approval

This work was endorsed by the Chief Scientific Advisor to the Government of the UK to provide health data intelligence to the

Scientific Advisory Group for Emergencies (SAGE)—responsible for ensuring timely and coordinated scientific advice is made available to decision-makers, to inform NHS care. The Secretary of State for Health and Social Care has issued NHS Digital with a Notice under Regulation 3(4) of the NHS(Control of Patient Information Regulations) 2002 (COPI) to require NHS Digital to share confidential patient information with organizations entitled to process this under COPI for COVID-19 purposes. NICOR which includes the MINAP registry (Ref: NIGB: ECC 1-06 (d)/2011) has support under section 251 of the NHS Act 2006 to use patient information for medical research without informed consent. For this rapid NHS evaluation, health data linkage was enabled under COVID-19 public health NHS England Directions 2020, conferred by Section 254 of the Health and Social Care Act 2012. The study complies with the Declaration of Helsinki.

Results

The analytical cohort was drawn from 117 327 patients hospitalized with AMI in England during the study period (Supplementary material online, *Figure S1*). Following exclusions, there were 50 689 patients admitted with AMI to 99 hospitals in England by 22 May 2020. Data included 17 246 STEMI and 33 443 NSTEMI.

Patients with acute myocardial infarction

From 23 March 2020, there was a 42.3% decrease to a nadir on 19th April in the number of hospitalizations with AMI, representing a decline in the median daily number of admission from 104 to 60 (IRR 0.59, 95% CI 0.56–0.61). From the nadir to 22 May 2020, the median number of admissions increased to 72 (1.19, 95% CI 1.12–1.26), and qualitatively plateaued after an initial recovery (*Figure 1*).

Patients hospitalized with AMI during the decline phase were younger (66.87 vs. 68.69 years), more frequently male (69.6% vs. 67.9%, *Table 1*) and less frequently had diabetes (24.5% vs. 28.1%), and cerebrovascular disease (7.1% vs. 8.6%, *Figure 2*). They had a lower median creatinine concentrations, less frequently self-presented to hospital without making use of the Emergency Ambulance Service (11.4% vs. 20.6%) and less frequently had pulmonary oedema (2.5% vs. 4.4%, *Table 2* and *Figure 3*). The median duration in symptom onset to call-for-help and median duration in call-for-help to hospital arrival times for those arriving by ambulance remained stable (*Table 2*). The proportion of patients followed-up by a cardiologist, receiving inpatient echocardiography and, referred for cardiac rehabilitation remained very high, as did the prescription of secondary prevention pharmacotherapies at the time of discharge from hospital (*Figure 3*). The median length of hospital stay decreased from 4 to 2 days (*Table 2*), and all-cause mortality at 30 days remained stable (*Figure 4*).

During the recovery phase (20 April to 22 May 2020), the patient characteristics of admission with AMI were similar to those of patients in the decline phase (*Table 1* and *Figure 2*). However, there was a partial return to pre-lockdown rates for self-presentations with AMI to hospitals (16.7% vs. 20.6%) and those with pulmonary oedema (3.7% vs. 4.4%, *Table 2*). Whilst the median duration in symptom onset to call-for-help was no different from previous phases, the median duration in call-for-help to hospital arrival times for those arriving by ambulance was shorter by 4 min (*Table 2*). The proportion of patients seen by a cardiologist, receiving inpatient echocardiography, referred for cardiac rehabilitation, and use of secondary prevention therapies each remained very high (*Table 2* and *Figure 3*). The median length of hospital stay increased to 3 days (*Figure 3*), and all-cause mortality at 30 days remained stable (*Figure 4*).

Patients with ST-elevation myocardial infarction

There was a 28.6% decrease to a nadir on 19th April in the number of hospitalizations with STEMI representing a decline in the median daily number of admission from 35 to 25 (IRR 0.74, 95% CI 0.69–0.80) and remain stable in recovery phase.

The profiles care and outcomes of patients hospitalized with STEMI were not different from STEMI admitted before lockdown (Supplementary material online, *Table S1* and *Figure 3*). There was, however, a 50% reduction in people self-presenting to hospital in the decline phase (8.2% vs. 4.0%), which increased following the nadir in admissions (5.8%). During the recovery phase, the median duration in call-for-help to hospital arrival times decreased by 3 min compared with pre-lockdown, and there was an increase in the median in-hospital time to reperfusion by 4 min. The use of primary PCI was very high throughout the study period and a small number of STEMI received thrombolysis (0.3%). Over the three time periods, the median length of hospital stay changed from 3 to 2 to 3 days, and crude all-cause mortality at 30 days decreased from 10.2% pre-lockdown to 7.7% in the decline phase and increased to 8.3% in the recovery phase (Supplementary material online, *Table S1* and *Figure 4*).

Patients with non-ST-elevation myocardial infarction

There was a 49.3% decrease to a nadir on 19th April in the number of hospitalizations with NSTEMI representing a decline in the median daily number of admission from 69 to 35 (IRR 0.51, 95% CI 0.47–0.54). From the nadir to 31 May 2020, the median number of admission increased to 46 (1.32, 95% CI 1.22–1.42) (*Figure 1*).

Following lockdown, patients hospitalized with NSTEMI were younger (68.5 vs. 70.2 years) and less frequently had diabetes mellitus (26.7% vs. 31.5%), and pulmonary oedema (2.2% vs. 4.7%, Supplementary material online, *Table S2*). In the decline phase, there was a 3% reduction in the proportion of NSTEMI who received an invasive coronary strategy, and less inter-hospital transfers for such an approach. However, for those who received an invasive strategy, the median time to invasive coronary angiography was reduced from 64 to 26 to 38 h over the three sequential phases (Supplementary material online, *Table S2*). Delays to receipt of an invasive coronary strategy for NSTEMI were less likely to be due to catheter laboratory issues and more likely due to patient comorbidities. During the recovery phase, the median call to hospital admission duration decreased by 5 min. Following lockdown, the proportion seen by a cardiologist, the prescription of secondary prevention medications and referral for cardiac rehabilitation were maintained at high levels, but the use of inpatient echocardiography was lower in the decline phase. Over the three time periods, the median length of hospital stay changed from 5 to 2 to 3 days. All-cause mortality at 30 days increased from 5.4% pre-lockdown to 7.5% in the decline phase and decreased to 5.0% in the recovery phase (*Figure 4*).

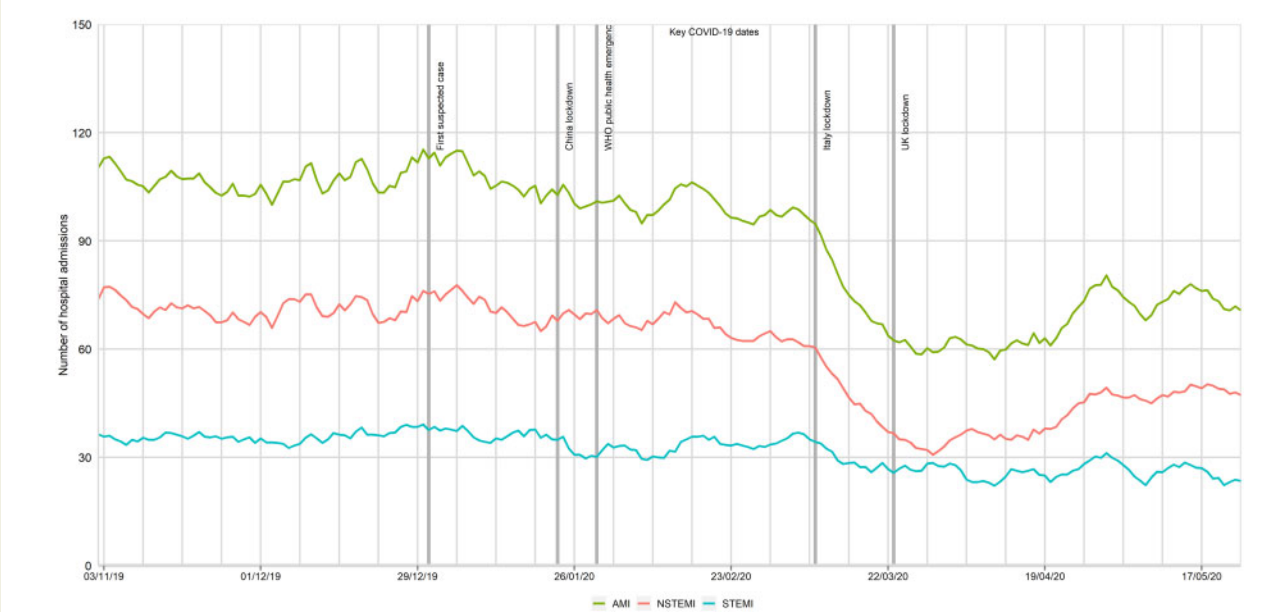

Figure 1 Times series of daily hospitalizations of acute myocardial infarction between 1 January 2019 and 22 May 2020, by ST-elevation myocardial infarction and non-ST-elevation myocardial infarction. Data from 99 National Health Service hospitals in England. Lines represent a 7-day simple moving average (indicating the mean number of daily admissions for that day and the preceding 6 days), adjusted for seasonality. The dates of the COVID lockdown including first suspect case (31 December 2019), China lockdown (23 January 2020), World Health Organization declaration of a public health emergency (30 January 2020), and UK lockdown (23 March 2020) are shown with a bold vertical line. Updates of all figures are available at cardiovascularcovid.leeds.ac.uk. AMI, acute myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

Table 1 Baseline characteristics for patients hospitalized with acute myocardial infarction in England before and following the UK COVID-19 lockdown

	AMI before UK lockdown $n = 46555$	AMI between 23 March 2020 and 19 April 2020 $n = 1708$	AMI after 20 April 2020 $n = 2426$	*P*-trend
Age (years), mean (SD)	68.69 (13.55)	66.87 (13.46)	67.60 (13.33)	<0.001
Male	31580 (67.9%, 67.4–68.3)	1186 (69.6%, 67.3–71.8)	1703 (70.3%, 68.4–72.1)	0.017
Current smoker	10863 (25.2%, 24.8–25.6)	424 (27.7%, 25.5–30.1)	583 (26.3%, 24.5–28.2)	0.051
Past medical history				
CABG surgery	3030 (7.3%, 7.1–7.6)	98 (6.7%, 5.5–8.1)	161 (7.6%, 6.5–8.8)	0.587
Cerebrovascular disease	3584 (8.6%, 8.3–8.9)	104 (7.0%, 5.8–8.5)	168 (7.8%, 6.8–9.1)	0.056
Chronic renal failure	3241 (7.7%, 7.5–8.0)	117 (7.9%, 6.6–9.4)	152 (7.0%, 6.0–8.2)	0.484
Congestive heart failure	3174 (7.6%, 7.3–7.8)	101 (6.8%, 5.6–8.2)	146 (6.8%, 5.8–8.0)	0.244
COPD or asthma	7358 (17.6%, 17.2–18.0)	258 (17.5%, 15.6–19.5)	371 (17.3%, 15.7–19.0)	0.931
Diabetes mellitus	12597 (28.1%, 27.7–28.5)	396 (24.6%, 22.5–26.8)	611 (26.5%, 24.7–28.3)	0.002
Hyperlipidaemia	12935 (30.9%, 30.5–31.3)	453 (30.5%, 28.2–33.0)	702 (32.7%, 30.7–34.7)	0.216
Hypertension	22813 (53.6%, 53.1–54.1)	797 (52.8%, 50.2–55.3)	1172 (53.8%, 51.7–55.9)	0.805
Peripheral vascular disease	1838 (4.4%, 4.2–4.6)	62 (4.2%, 3.3–5.4)	93 (4.4%, 3.6–5.3)	0.922
Previous MI	10187 (24.1%, 23.7–24.5)	350 (23.4%, 21.3–25.7)	482 (22.4%, 20.6–24.2)	0.169
Previous PCI	6679 (16.2%, 15.8–16.5)	237 (16.2%, 14.3–18.2)	340 (16.1%, 14.5–17.7)	0.993

Data from 99 National Health Service acute hospitals in England. Before UK lockdown: 1 January 2019 to 22 March 2020; all cells represent numbers of cases (%, 95% CI) unless otherwise stated.
AMI, acute myocardial infarction; CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; IQR, interquartile range; PCI, percutaneous coronary intervention; SD, standard deviation.

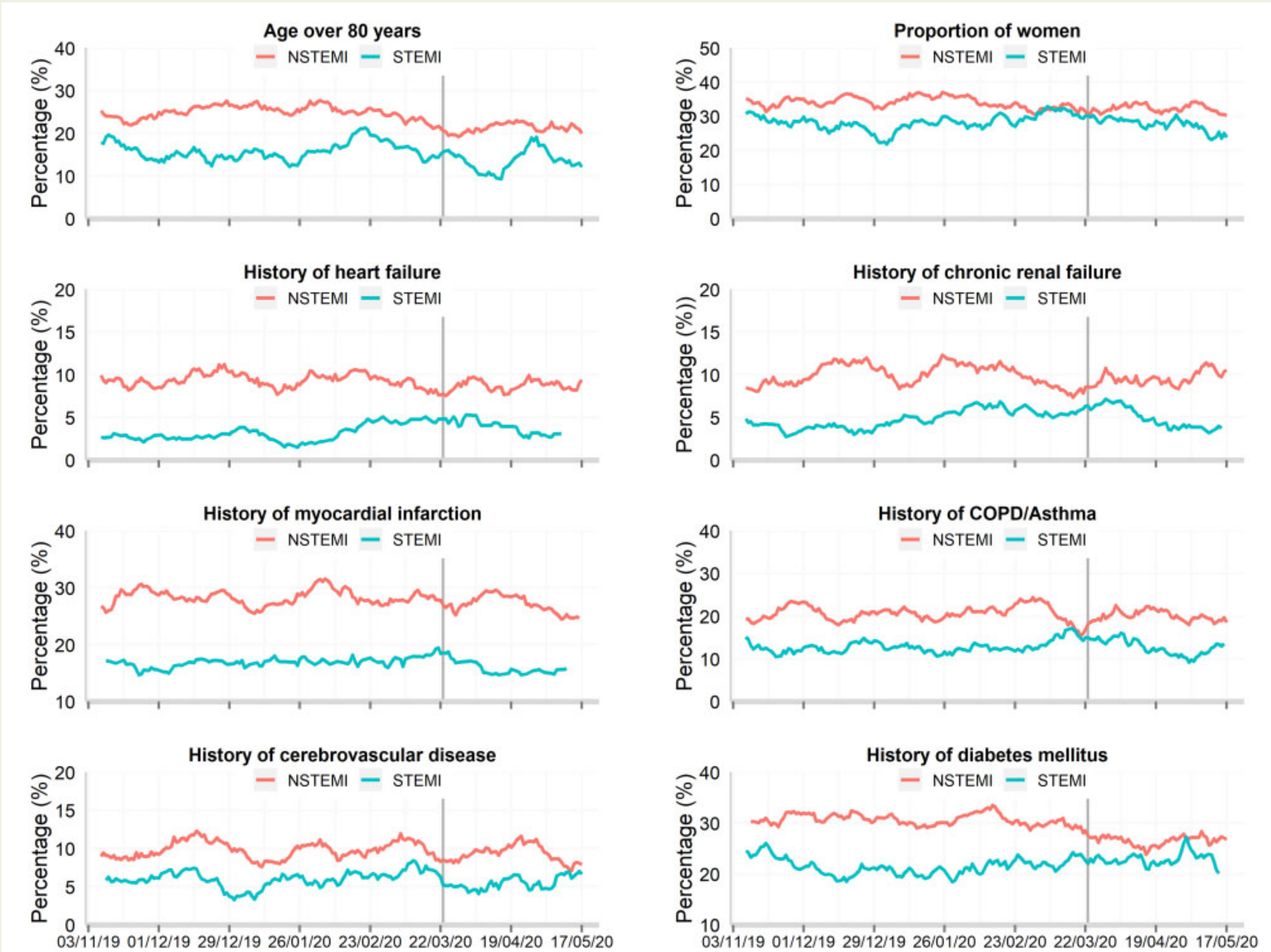

Figure 2 Time series plot of daily hospitalizations with acute myocardial infarction between 1 January 2019 and 22 May 2020 for baseline patient characteristics, by ST-elevation myocardial infarction and non-ST-elevation myocardial infarction. Data from 99 National Health Service hospitals in England. Lines represent a 7-day simple moving average (indicating the mean number of daily admissions for that day and the preceding 6 days), adjusted for seasonality. The date of the COVID lockdown (23 March 2020) is shown with a bold vertical line. Updates of all figures are available at cardiovascularcovid.leeds.ac.uk. NSTEMI, non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

Discussion

The onset of social containment—a state of lockdown—to reduce the spread of COVID-19 infection has been associated with almost 50% decline in hospitalizations with AMI and a significantly higher early mortality for NSTEMI until the nadir of admissions, despite high levels of in-hospital care. Although there was an initial recovery in numbers of admission, this plateaued and until the end of the study, period remained at two-thirds of the pre-lockdown rate. Given the numbers of AMI not attending hospital (and delays to presentation among those admitted), there is likely to be an increase in AMI-related mortality in the community and increased heart failure admissions in the near future. Whilst the decline in admissions support findings from other data sources,[3–8,14] this investigation identifies the nadir and, of concern, a cessation in the recovery trajectory of admissions. It is, therefore, important that there is ongoing public messaging about seeking urgent medical assistance for AMI.

There was a greater decline in admissions with NSTEMI. It is probable that patients with NSTEMI did not seek medical help because they felt that their symptoms, which are less likely to be chest pain or chest discomfort,[21] did not warrant the risk of potential exposure to the COVID-19 infection in hospital. Although we elected to stratify the analyses by date of the UK lockdown, it is apparent that the decline in admissions started earlier in 2020, and international media coverage of death, overwhelmed hospitals, country-specific lockdowns as well as a declaration by the World Health Organization of a public health emergency led many patients with AMI not to go to hospital for fear of catching the COVID-19 infection, being isolated on a ward without visitors, and through wanting to protect hospitals. In addition, the association between increasing age or pre-existing health conditions with poorer outcomes following COVID-19 infection was well publicized at the start of the pandemic and many patients with NSTEMI would have looked upon

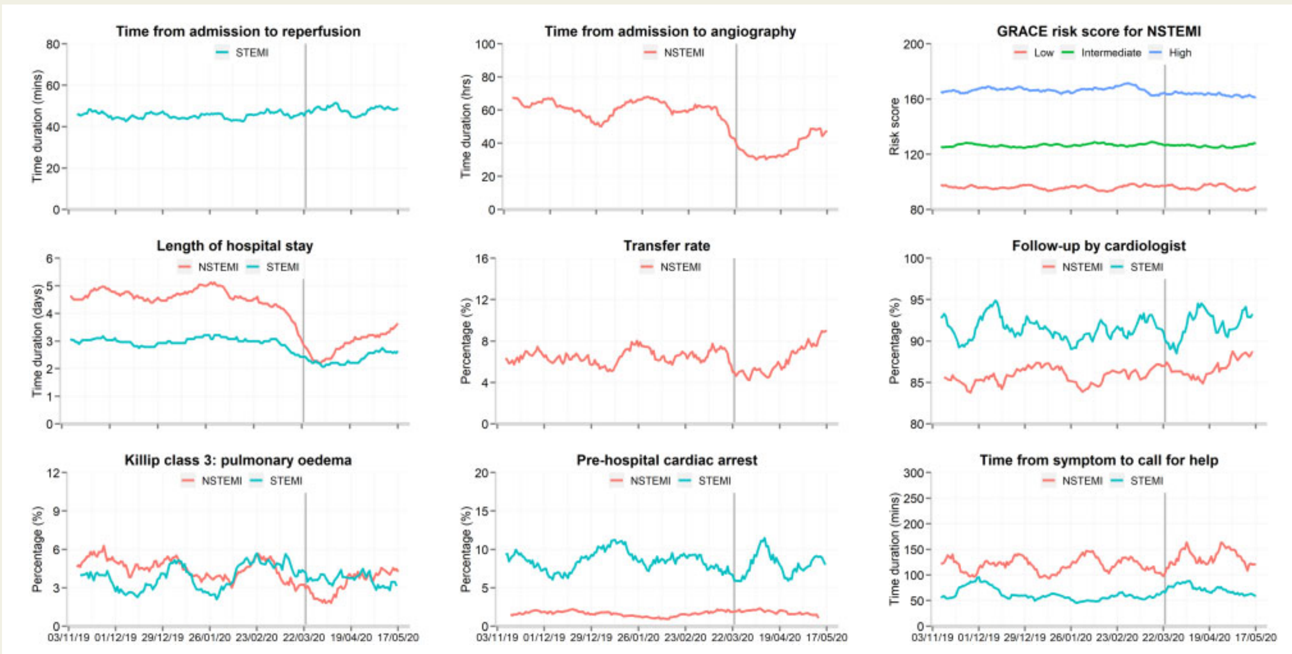

Figure 3 Time series plot of daily hospitalizations with acute myocardial infarction between 1 January 2019 and 22 May 2020 for patient response and hospital care, by ST-elevation myocardial infarction and non-ST-elevation myocardial infarction. Data from 99 National Health Service hospitals in England. Lines represent a 7-day simple moving average (indicating the mean number of daily admissions for that day and the preceding 6 days), adjusted for seasonality. The date of the COVID lockdown (23 March 2020) is shown with a bold vertical line. Symptom to call-for help data are only for patients who presented to hospital by ambulance. Transfer rate refers to the proportion of patients hospitalized with non-ST-elevation myocardial infarction where were transferred between hospitals for an invasive coronary strategy. Updates of all figures are available at cardiovascularcovid.leeds.ac.uk. NSTEMI: non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

themselves as being at significant risk by virtue of their age and comorbidity.

Early mortality increased for NSTEMI, but not STEMI. In the UK, the management of STEMI is institutionally operationalized,[22] as was evidenced by maintenance of very high levels of care. The safeguarding of the UK nationwide primary PCI service is in contrast to other international recommendations drawn from preliminary information about over-burdened services due to the additional workload arising from COVID-19 patients and hospital measures imposed to reduce the spread of the infection.[8] For NSTEMI, mortality rates increased in the decline phase, when fewer patients were attending hospital. It is possible that other factors were at play, including a higher comorbidity burden, more myocardial ischaemia and potentially the influence of the COVID-19 infection. Moreover, there was a decline in NSTEMI with pulmonary oedema, which suggests that cases with large areas of myocardial ischaemia may have died in the community. Although, in-hospital care standards were maintained at a high level, we observed a slightly lower use of an invasive coronary strategy and lower inter-hospital transfer rates for this strategy during the decline phase, suggesting that perhaps more patients were managed medically, who otherwise would have received an invasive management.

In contrast to other countries, where recommendations about the management of patients with AMI were modified, the UK upheld its processes of care for AMI. This was evidenced in all three phases of the period of this study, where the use of evidence-based care was very high, and increased slightly for antiplatelet pharmacotherapies. What is more, the COVID-19 pandemic has enabled a natural experiment of the NHS AMI services in England—indicating that for NSTEMI the duration of time to receive an invasive coronary strategy may be dramatically reduced when the ratio of staff and facilities to patients is increased.

Interrogation of these live data from a national registry of AMI offers the opportunity to prepare for future major health crises. First, it is apparent that, prior to Government directives about social distancing, the public appeared to react to the international crisis as it unfolded through the media. Second, whilst social isolation was recommended for higher risk patients, such patients are also at higher risk of AMI. It is important that the public be reminded during the recovery phase that they should attend hospital in the event of a medical emergency—a message delivered by both Government and health representatives early during the UK lockdown. Third, although this investigation was unable to quantify all of the adverse consequences associated with the decline and change in presentation of AMI, there is good evidence from the literature of higher rates of death, stroke, and heart failure when patients with AMI do not receive treatment or present late.[23] Finally, a latent excess of AMI-related mortality and morbidity should be expected and health services prepared in advance.[23]

Although the strengths of this linked registry are apparent, we acknowledge the study limitations. MINAP does not collect data for all cases of AMI in England[24] and for some hospitals, there is a lag in data uploading. This may have over-estimated the decline in rates of

Table 2 Clinical presentation, treatments, and outcomes of patients hospitalized with acute myocardial infarction in England before and following the UK COVID-19 lockdown

	AMI before lockdown $n = 46555$	AMI between 23 March 2020 and 19 April 2020 $n = 1708$	AMI after 20 April 2020 $n = 2426$	P-trend
Clinical presentation				
Self-presented to hospital	9608 (20.6%, 20.3–21.0)	195 (11.4%, 10.0–13.0)	406 (16.7%, 15.3–18.3)	<0.001
Systolic blood pressure (mmHg), mean (SD)	139.48 (28.05)	141.07 (28.13)	141.81 (28.61)	<0.001
Heart rate (b.p.m.), median (IQR)	77.00 (66.00–90.00)	78.00 (67.00–91.00)	79.00 (67.00–91.00)	<0.001
Creatinine (µmol/L), median (IQR)	84.00 (71.00–104.00)	83.00 (69.00–101.00)	84.00 (70.00–102.00)	0.005
Pre-hospital cardiac arrest	1731 (3.8%, 3.7–4.0)	67 (4.1%, 3.2–5.2)	73 (3.1%, 2.5–3.9)	0.173
If pre-hospital cardiac arrest: no ROSC or return but died in-hospital	532 (30.7%, 28.6–33.0)	15 (22.4%, 13.5–34.5)	24 (32.9%, 22.6–45.0)	0.314
Electrocardiographic ST-segment elevation	15380 (33.3%, 32.8–33.7)	706 (41.8%, 39.4–44.1)	841 (35.2%, 33.3–37.1)	<0.001
Pulmonary oedema	1879 (4.4%, 4.2–4.6)	39 (2.5%, 1.8–3.4)	82 (3.7%, 3.0–4.6)	<0.001
Cardiogenic shock	674 (1.6%, 1.5–1.7)	24 (1.5%, 1.0–2.3)	34 (1.5%, 1.1–2.2)	0.987
Patient and healthcare response times				
Symptom to call duration (min), median (IQR)	79.00 (24.00–303.00)	76.50 (27.00–299.75)	90.00 (30.00–316.00)	0.115
Call to hospital admission duration (min), median (IQR)	79.00 (60.00–104.00)	80.00 (63.00–103.75)	76.00 (59.00–95.00)	<0.001
Medications at time of discharge				
ACEi/ARB	30284 (94.5%, 94.2–94.7)	1160 (95.1%, 93.7–96.2)	1686 (94.8%, 93.6–95.7)	0.557
Beta-blocker	32248 (96.2%, 96.0–96.4)	1232 (96.9%, 95.8–97.8)	1731 (96.9%, 96.0–97.7)	0.121
Aspirin	34516 (97.9%, 97.8–98.1)	1314 (98.4%, 97.6–99.0)	1852 (98.4%, 97.7–98.9)	0.193
Statin	34858 (97.6%, 97.4–97.7)	1322 (97.9%, 97.0–98.6)	1875 (97.6%, 96.8–98.2)	0.730
Clopidogrel/prasugrel/ticagrelor	34280 (97.5%, 97.4–97.7)	1321 (99.2%, 98.6–99.6)	1857 (99.0%, 98.4–99.4)	<0.001
In-hospital outcomes				
Referral for cardiac rehabilitation	32303 (89.3%, 88.9–89.6)	1220 (89.7%, 87.9–91.2)	1684 (89.6%, 88.1–90.9)	0.798
In-patient echocardiography	31406 (77.3%, 76.9–77.7)	1118 (76.6%, 74.3–78.7)	1637 (78.5%, 76.6–80.2)	0.361
Planned follow-up with a cardiologist	30816 (85.4%, 85.0–85.8)	1119 (87.1%, 85.1–88.8)	1604 (87.6%, 85.9–89.0)	0.011
Length of hospital stay, median (IQR)	4.00 (2.00–7.00)	2.00 (2.00–4.00)	3.00 (2.00–5.00)	<0.001
Seven-day mortality	2035 (4.4%, 4.2–4.6)	81 (4.7%, 3.8–5.9)	100 (4.1%, 3.4–5.0)	0.630
Thirty-day mortality	3268 (7.0%, 6.8–7.3)	129 (7.6%, 6.4–8.9)	149 (6.1%, 5.2–7.2)	0.167

Data from 99 National Health Service acute hospitals in England. Before UK lockdown: 1 January 2019 to 22 March 2020; all cells represent numbers of cases (%, 95% CI) unless otherwise stated.
ACEi/ARB: angiotensin converting enzyme inhibitor/angiotensin receptor blocker; AMI, acute myocardial infarction; ROSC, return of spontaneous circulation.

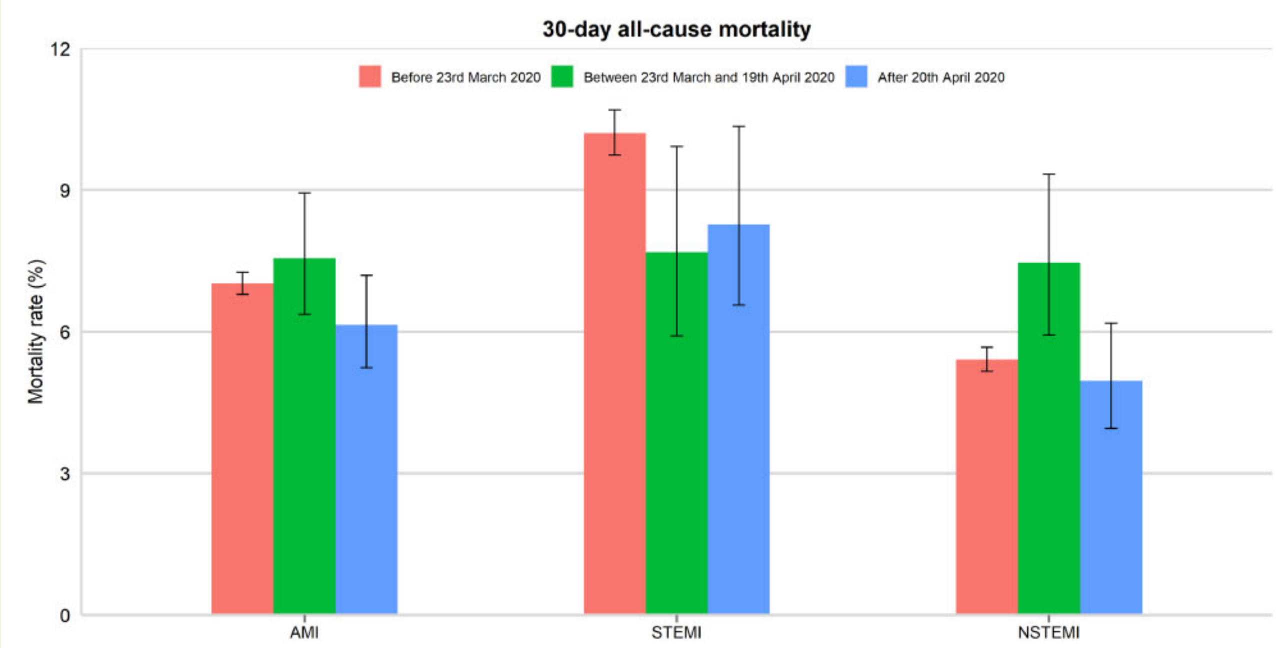

Figure 4 Unadjusted all-cause mortality rates at 30 days following admission with ST-elevation myocardial infarction and non-ST-elevation myocardial infarction, by pre-lockdown, decline, and recovery phases. Mortality rates were presented with 95% confidence interval. Updates of all figures are available at cardiovascularcovid.leeds.ac.uk. AMI, acute myocardial infarction; NSTEMI, non-ST elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

admissions. Nonetheless, we surveyed all acute hospitals in England and encouraged rapid reporting. Linkage to the national death registry enabled accurate censorship dates, but given the short-follow-up time it is possible that the full impact of the COVID-19 pandemic on the prognosis of patients admitted with AMI is not apparent.

Conclusion

Nationwide data from England linked to death registration, show that following the UK lockdown due to the COVID-19 pandemic there was a halving of admissions with AMI to a nadir at about one month suggesting many patients delayed seeking help from the emergency services. Despite evidence for enduring high levels of specialist hospital care and there was an increase in early deaths for NSTEMI. Given that AMI is common, and that delayed or no treatment for AMI is associated with major cardiovascular and cerebrovascular events, Governments, and health systems across the globe should prepare for an excess of AMI-related mortality and morbidity in the near future.

Supplementary material

Supplementary material is available at *European Heart Journal – Quality of Care and Clinical Outcomes* online.

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Conflict of interest: none declared.

Data availability

The authors do not have authorization to share the data, but the data can be accessed through NHS Digital upon approval.

References

1. Jia JS, Lu X, Yuan Y, Xu G, Jia J, Christakis NA. Population flow drives spatio-temporal distribution of COVID-19 in China. *Nature* 2020;**582**:389–394.

2. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/883660/EDSSSBulletin2020wk18.pdf (12 August 2020).
3. Mafham MM, Spata E, Goldacre R, Gair D, Curnow P, Bray M *et al.* COVID-19 pandemic and admission rates for and management of acute coronary syndromes in England. *Lancet* 2020. doi: 10.1016/S0140-6736(20)31356-8.
4. Metzler B, Siostrzonek P, Binder RK, Bauer A, Reinstadler SJ. Decline of acute coronary syndrome admissions in Austria since the outbreak of COVID-19: the pandemic response causes cardiac collateral damage. *Eur Heart J* 2020;**41**: 1852–1853.
5. De Filippo O, D'Ascenzo F, Angelini F, Bocchino PP, Conrotto F, Saglietto A *et al.* Reduced rate of hospital admissions for ACS during COVID-19 outbreak in Northern Italy. *N Engl J Med* 2020;**383**:88–89.
6. Garcia S, Albaghdadi MS, Meraj PM, Schmidt C, Garberich R, Jaffer FA *et al.* Reduction in ST-segment elevation cardiac catheterization laboratory activations in the United States during COVID-19 pandemic. *J Am Coll Cardiol* 2020;**75.** doi: 10.1016/j.jacc.2020.04.011.
7. Mahmud E, Dauerman HL, Welt FG, Messenger JC, Rao SV, Grines C *et al.* Management of Acute Myocardial Infarction During the COVID-19 Pandemic. *Catheter Cardiovasc Interv* 2020.
8. Tam CF, Cheung KS, Lam S, Wong A, Yung A, Sze M *et al.* Impact of Coronavirus Disease 2019 (COVID-19) outbreak on ST-segment-elevation myocardial infarction care in Hong Kong, China. *Circ Cardiovasc Qual Outcomes* 2020; **13**:e006631.
9. Han Y, Zeng H, Jiang H, Yang Y, Yuan Z, Cheng X *et al.* CSC expert consensus on principles of clinical management of patients with severe emergent cardiovascular diseases during the COVID-19 epidemic. *Circulation* 2020;**141**:e810–e816.
10. Wood DA, Sathananthan J, Gin K, Mansour S, Ly HQ, Quraishi AU, Lavoie A *et al.* Precautions and procedures for coronary and structural cardiac interventions during the COVID-19 pandemic: guidance from Canadian Association of Interventional Cardiology. *Can J Cardiol* 2020. doi: 10.1016/j.cjca.2020.03.027.
11. The American Heart Association's Mission: Lifeline and Get With The Guidelines Coronary Artery Disease Advisory Work Group and the Council on Clinical Cardiology's Committees on Acute Cardiac Care and General Cardiology and Interventional Cardiovascular Care. Temporary emergency guidance to STEMI systems of care during the COVID-19 pandemic: AHA's Mission: Lifeline. *Circulation* 2020;**142**:199–202.
12. Daniels MJ, Cohen MG, Bavry AA, Kumbhani DJ. Reperfusion of STEMI in the COVID-19 era—business as usual? *Circulation* 2020;**141**:1948–1950.
13. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)31356-8/fulltext (12 August 2020).
14. https://www.nejm.org/doi/full/10.1056/NEJMc2009166 (12 August 2020).
15. Wilkinson C, Weston C, Timmis A, Quinn T, Keys A, Gale CP. The Myocardial Ischaemia National Audit Project (MINAP). *Eur Heart J Qual Care Clin Outcomes* 2020;**6**:19–22.
16. Rashid M, Kontopantelis E, Kinnaird T, Curzen N, Gale CP, Mohamed MO *et al.* Association between hospital cardiac catheter laboratory status, use of an invasive strategy, and outcomes after NSTEMI. *Can J Cardiol* 2020;**36**:868–877.
17. Rashid M, Curzen N, Kinnaird T, Lawson CA, Myint PK, Kontopantelis E *et al.* Baseline risk, timing of invasive strategy and guideline compliance in NSTEMI: nationwide analysis from MINAP. *Int J Cardiol* 2020;**301**:7–13.
18. Antman E, Bassand J-P, Klein W, Ohman M, Sendon JLL, Rydén L *et al.* Myocardial infarction redefined—a consensus document of the Joint European Society of Cardiology/American College of Cardiology committee for the redefinition of myocardial infarction: the Joint European Society of Cardiology/ American College of Cardiology Committee. *JACC* 2000;**36**:959–969.
19. Granger CB, Goldberg RJ, Dabbous O, Pieper KS, Eagle KA, Cannon CP *et al.*; Global Registry of Acute Coronary Events Investigators. Predictors of hospital mortality in the global registry of acute coronary events. *Arch Intern Med* 2003; **163**:2345–2353.
20. https://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/03/specialty-guide-cardiolgy-coronavirus-v1-20-march.pdf (12 August 2020).
21. Canto JG, Rogers WJ, Goldberg RJ, Peterson ED, Wenger NK, Vaccarino V, Kiefe CI *et al.* Association of age and sex with myocardial infarction symptom presentation and in-hospital mortality. *JAMA* 2012;**307**:813–822.
22. Hall M, Laut K, Dondo TB, Alabas OA, Brogan RA, Gutacker N *et al.*; National Institute for Cardiovascular Outcomes Research. Patient and hospital determinants of primary percutaneous coronary intervention in England, 2003-2013. *Heart* 2016;**102**:313–319.,
23. Shiomi H, Nakagawa Y, Morimoto T, Furukawa Y, Nakano A, Shirai S *et al.*; CREDO-Kyoto AMI investigators. Association of onset to balloon and door to balloon time with long term clinical outcome in patients with ST elevation acute myocardial infarction having primary percutaneous coronary intervention: observational study. *BMJ* 2012;**344**:e3257.
24. Herrett E, Shah AD, Boggon R, Denaxas S, Smeeth L, van Staa T *et al.* Completeness and diagnostic validity of recording acute myocardial infarction events in primary care, hospital care, disease registry, and national mortality records: cohort study. *BMJ* 2013;**346**:f2350.