Substantial decline in hospital admissions for heart failure accompanied by increased community mortality during COVID-19 pandemic.

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Abstract

Objective: We hypothesised that a decline in admissions with heart failure during COVID-19 pandemic would lead to a reciprocal rise in mortality for patients with heart failure in the community.

Methods: We used national heart failure audit data to identify 36,974 adults who had a hospital admission with a primary diagnosis of heart failure between February and May in either 2018, 2019 or 2020.

Results: Hospital admissions for heart failure in 2018/19 averaged 160/day but were much lower in 2020, reaching a nadir of 64/day on 27th March-2020 (incidence rate ratio:0.40, 95% CI:0.38-0.42). The proportion discharged on guideline-recommended pharmacotherapies was similar in 2018/19 compared to the same period in 2020. Between 1st February-2020 and 31st May-2020, there was a 29% decrease in hospital deaths related to heart failure (IRR:0.71,95% CI:0.67-0.75; estimated decline of 448 deaths), a 31% increase in heart failure deaths at home (IRR:1.31,95% CI:1.24-1.39; estimated excess 539) and a 28% increase in heart failure deaths in care homes and hospices (IRR:1.28,95% CI:1.18-1.40; estimated excess 189). All-cause, in-patient death was similar in the COVID-19 and pre-COVID-19 periods (OR:1.02,95% CI: 0.94–1.10). After hospital discharge, 30-day mortality was higher in 2020 compared to 2018/19 (OR:1.57, 95% CI:1.38–1.78).

Conclusion: Compared with the rolling daily average in 2018/19, there was a substantial decline in admissions for heart failure but an increase in deaths from heart failure in the community. Despite similar rates of prescription of guideline-recommended therapy, mortality 30-days from discharge was higher during the COVID-19 pandemic period.

Key questions

What is already known about this subject?

A decline in admission for many cardiovascular diseases was observed during first wave of COVID-19 pandemic

What does this study add?

The reduction in heart failure (HF) admissions during the COVID-19 pandemic was accompanied by an increase in heart failure deaths in the community and 30-days after discharge.

How might this impact on clinical practice

Novel models of care at home and in the community should be explored for patients with HF during the COVID-19 pandemic, with public health messages towards this group of patients aimed at seeking medical assistance in the event of illness.

Introduction

Health care systems across the globe were restructured during the COVID-19 pandemic in anticipation of a large influx of emergency admissions. This reconfiguration resulted in closure of elective and out-patient services, reductions in speciality beds and the relocation of cardiology staff to other high-dependency areas of the hospital.[1, 2] Such measures may have affected both the provision of healthcare to patients with heart failure as well as their outcomes.

During the early and peak phases of the first wave of the COVID-19 pandemic, hospitals in the United Kingdom (UK) described a decline in admissions for many cardiovascular conditions, including HF.[3, 4] These reports are limited because they are either based on the activity of a small number of centres, lack granularity about treatments and processes of care, or do not report outcomes following hospital discharge.[5]

We hypothesised that a decline in admissions with heart failure would lead to a reciprocal rise in mortality for patients with heart failure in the community. England has a suite of clinical and administrative datasets that routinely collect detailed health information and outcomes for the population. We used such multi-sourced and linked electronic heath records from the National Heart Failure Audit (NHFA), Hospital Episode Statistics (HES) and the Civil Registration of Death Data of the Office for National Statistics (ONS) to quantify the extent and impact of changes in admissions for heart failure and understand whether in-hospital management of patients and their post discharge outcomes has been affected as a result of the COVID-19 pandemic.

Methods

The current study was based on English data from three national databases: NHFA, HES and the Civil Registration of Deaths, ONS (Supplement Figures 1-2). The first confirmed case of coronavirus in England was on 29th January 2020; thus, we took 1st February 2020 as the start date of the COVID-19 period.

The National Heart Failure Audit

The NHFA was established in 2007 for hospitals in England & Wales to monitor & improve the quality of care of patients admitted to hospital with a diagnosis of heart failure, capturing information on their clinical presentation, characteristics, investigations, specialist input, management and outcomes in the real world [6, 7]. Further details about NHFA is presented in Supplement method section. For the purpose of this analysis, we included data relating to an admission with a diagnosis of heart failure from 1st January 2018 to 31st May 2020 from England. We dichotomised study participants on the basis of their date of index hospitalization: COVID-19 period (1st February – 31st May 2020) and Pre-COVID-19 period (1st February - 31st May 2018 and 1st February – 31st May 2019). Furthermore, we excluded hospitals that did not submit data consistently each month during this period. We only included the first admission for heart failure during the whole study period (a patient could potentially be hospitalised more than once). Records with missing data for sex and National Health Service (NHS) identification number were excluded.

Hospital Episode Statistics

HES collects data for all hospital admissions, outpatient appointments and accident and emergency attendances for all NHS hospitals in England. HES data was extracted for the same study period as NHFA data. Index admissions for heart failure were identified using

International Classification of Diseases (ICD)-10 recorded in the primary position. HES data are more complete, since they included patients from hospitals not include in the above NHFA dataset, and were used to calculate the daily rate of admissions for heart failure.

Civil Registration of Death

The Civil Registration of Deaths, ONS dataset comprises mortality information for all deaths in England. Deaths certification and registration is a legal requirement in the UK and a doctor who has seen the deceased during the last 14 days of life must complete a medical certificate of causes of death (MCCD) within 5 days unless a post-mortem examination or inquest is organised. During the COVID-19 pandemic, emergency guidance enabled any doctor in the UK (not just the attending) to complete the medical certificate of cause of death, the duration of time over which the deceased was not seen before referral to the coroner was extended from 14 to 28 days and causes of death could be 'to the best of their knowledge and belief' without diagnostic proof, if appropriate and to avoid delay. ICD-10 codes, corresponding to the principal and contributory causes of death on the MCCD, were used to identify deaths from heart failure. Individual patient data from the NHFA were linked using each patient's unique NHS identification number to the ONS dataset to track mortality for 30 days from hospital discharge; this also allowed mortality within 30-days of admission to be calculated. We also collected ONS data for all adult deaths in England. We reported daily deaths for heart failure recorded in the primary position and in any position.

Rationale for using Multiple databases

Each dataset utilized in this study has its own strengths and limitations and only a combination of datasets or linkage analysis can give a comprehensive overview of the impact of COVID-19 on HF services, and serve to validate our findings using more than one dataset. In summary,

the NHFA dataset is the national HF dataset that was used to describe clinical characteristics, pharmacotherapy and mortality during index admission and its linkage with ONS dataset provided further information about mortality during 30-day after admission and cause of death. The NHFA captures approximately 70% of total HF admissions captured in HES, which is an administrative dataset of all hospital admissions in the UK that we used to describe the overall rate of hospitalizations for heart failure. However, HES as an administrative dataset, lacks granular details around processes of care, and treatments of HF. Therefore we used a combination of these two databases, to better define clinical pathways, treatments, admission rates and outcomes.

Outcomes

The main outcomes of interest were in-hospital all-cause mortality, 30-day all-cause mortality (measuring from the date of hospital admission), and the daily incidence of heart failure-related deaths by place of death up until the 14th July 2020.

Statistical methods

Daily admissions and deaths from heart failure were depicted using a 7-day simple moving average (the mean number of daily deaths for that day and the preceding 6 days) from 1st February to 31st May of each year. Poisson regression was used to estimate the incidence rate ratio (IRR) of daily deaths related to heart failure during the pre-COVID-19 and COVID-19 periods, adjusted for time trends by including a cubic spline function of time. We calculated the excess deaths by subtracting the observed total deaths from March 2020 to the average total deaths in 2018 and 2019 in the same period.

Continuous data were presented as medians with interquartile ranges (IQR), and categorical variables were presented as counts and proportions. We tested differences between the groups

using the Chi-squared test for non-parametric data, Student's T test for normally distributed continuous variables and Wilcoxon rank sum test where continuous data were not normally distributed.

For the NHFA, we used multiple imputation with chained equations to impute data for all variables with missing information. Multivariable logistic regression models were fit to estimate the risk of death for the COVID-19 and pre-COVID-19 periods. In a sensitivity analysis, we repeated the multivariable logistic regression analysis for 30-day mortality amongst patients discharged alive during each period (Supplement method section for more details).

Analyses were performed using the Stata/MP 16.1 statistical software (College Station, TX) and R version 4.0.0. All statistical analyses were two-tailed, and an alpha of 5% used throughout.

Ethics

All datasets used in our study collect information routinely used for audit research purposes without requiring informed patient consent fall under section 251 of the NHS Act 2006 and therefore institutional board review was not required for this study.[8, 9] The UK Secretary of State for Health and Social Care has released a time limited Notice, under Regulation 3(4) of the NHS (Control of Patient Information Regulations) 2002, to analyse confidential patient information. This study is a part of work stream authorised by the Scientific Advisory Group for Emergencies (SAGE), the body accountable for ensuring that appropriate and coordinated scientific advice is made available to UK government decision makers. SAGE helps UK cross-government decisions in the Cabinet Office Briefing Room and by NHS England, which supervises commissioning decisions in the NHS, and NHS Improvement, which is responsible for overseeing quality of care in NHS hospitals

Results

Admissions with heart failure

There were 36,974 index events available from the NHFA, of which 27,183 (74%) occurred in pre-COVID-19 years and 9,791 (26%) during the COVID-19 period (Supplementary Figure 1 & 2). In the HES record, the total number of index admissions for heart failure was 38,470 and 14,150 for the same three time-periods.

There was a decline in daily admissions for heart failure (NHFA: from 112 to 60 per day: IRR: 0.53, 95% CI: 0.52-0.55) (HES: from 157 to 92 per day; IRR: 0.60, 95% CI: 0.59-0.62) from the middle of March 2020 compared with daily admissions in the same period in 2018/2019. Thereafter, there was a persistently low rate of admissions as compared with similar months during the pre-COVID-19 period (Figure 1). These trends were similar across age groups, sex, and heart failure categories (Supplement Figures 3 & 4). There were similar distributions of ages, sex and heart failure categories in patient cohorts admitted during the COVID-19 and pre-COVID-19 periods (Table 1). The prevalence of a prior history of hypertension, diabetes mellitus, valvular heart disease (VHD), asthma, chronic obstructive pulmonary disease (COPD) and cerebrovascular accident (CVA) were similar. Patients admitted during the COVID-19 period had higher plasma concentrations of brain natriuretic peptide (BNP) or N-terminal Brain Natriuretic Peptide (NT-Pro BNP) and a similar prevalence of AF and HFrEF relative to those admitted during the pre-COVID-19 era (Table 1). Prescription of pharmacotherapy were broadly similar between the two cohorts (Table 1). The median length of hospital stay was 7 days (IQR 3-13) during the COVID-19 period and 8 days (IQR 4-15) during the pre-COVID-19 period.

Deaths

Location and number of deaths (HF as a cause of death at primary position).

The numbers of deaths reported by ONS with heart failure as the primary cause were 6,900, 6,739 and 7,187, between February and May in 2018, 2019 and 2020 respectively. We observed an increase in deaths due to heart failure from middle of March to late April 2020 in the COVID-19 period compared with the pre-COVID period (Figure 2). There was a 29% decline in deaths related to heart failure in hospital (IRR: 0.71, 95% CI: 0.67 - 0.75, equivalent to a decrease of 448 deaths), a 31% increase in deaths at home (IRR: 1.31, 95% CI: 1.24-1.39, equivalent to an increase of 539 deaths) and a 28% increase in deaths in care homes and hospices (IRR: 1.28, 95% CI: 1.18-1.40, equivalent to an increase of 189 deaths). In total, we estimate an excess of 280 deaths from heart failure during the COVID-19 study period.

Mortality in patients admitted with heart failure captured by the NHFA

Inpatient deaths. All-cause, in-patient mortality was similar in the COVID-19 and pre-COVID-19 periods (10% in both groups, OR:1.02, 95% CI: 0.94 – 1.10) (Table 2)**.**

30-day deaths. Mortality within 30-days from admission was higher in the COVID-19 versus pre-COVID-19 period (15% vs. 13%, OR: 1.15, 95% CI: 1.07 – 1.23) (Table 2). A lower proportion of patients in the COVID-19 versus pre-COVID-19 period had heart failure as a principal cause of death on the death certificate (48.3% vs 53.3%) and a greater proportion, as expected, had COVID-19 as a principal cause of death (9.6% vs 0) (Table 3 and Supplement figure 5).

Increasing age, longer QRS duration, worse NYHA class and increasing peripheral oedema were independently associated with increased risk of death in hospital in both study periods, whereas prior history of DM was independently associated with increased risk of death in COVID-19 period only. (Table 4).

Sensitivity analysis. Death at 30-days from admission was higher for patients who discharged alive from hospital during the COVID-19 versus pre-COVID-19 period (OR: 1.57, 95% CI: 1.38- 1.78)) (Supplement Table 1) and multivariable analysis revealed similar predictors of 30-day mortality (Supplement Table 2). Details about missing data in all variables by study cohort are presented in Supplement table 3.

Figure 3 is our central illustration figure and visual take home graphics.

Discussion

In this analysis of national multi-sourced electronic health records, we examined the impact of the COVID-19 pandemic on heart failure hospitalizations and deaths in England. We observed a steady decline in heart failure hospitalizations from the middle of March 2020, with reductions ranging from 40% (HES) to 47% (NHFA); this was followed by persistently low rates of hospitalisation during the COVID-19 period relative to the same months in the pre-COVID-19 period. Despite the restructuring of hospital services and diversion of resources to COVID-19 care, adjusted in-hospital mortality related to heart failure and provision of guideline-directed heart failure medications and investigations were similar in the COVID-19 and pre-COVID-19 periods in NHFA. Finally, the reduction in heart failure admissions during the COVID-19 pandemic was accompanied by an increase in heart failure deaths in the community, with 280 excess deaths with heart failure as a principal cause over the 4-month pandemic period.

The NHFA is the largest heart failure registry in the world. It was established to monitor and report hospital clinical activity against a set of key performance indicators. The large sample size provides sufficient statistical power to capture differences in clinical outcomes between the patient groups studied. This is the first national analysis to assess the direct and indirect impact of the COVID-19 pandemic on hospitalization rates and mortality for patients

with heart failure in the hospital and community. We found a dramatic decline in heart failure hospitalizations during the COVID-19 pandemic. This reduction probably reflects successful attempts at hospital avoidance by patients to minimise the risk of hospital-acquired COVID-19 and, perhaps, increased support in the community. Patients with heart failure may have remained at home due to fears of exposure to COVID-19, breaking their shielding or social quarantine, leading to an increase in heart failure deaths in the community. Furthermore, some NHS trusts introduced new rapid access cardiology clinics and use of acute care services at home to reduced hospitalizations during COVID-19 pandemic but its impact on overall NHS service is relatively unknown. [10-12]. In addition, hospital services were reconfigured to create additional beds for COVID-19 patients by repurposing cardiology wards, cancelling out-patient clinics (or replacing them with remote clinics) and postponing elective procedural activities.

Our work suggests that the quality of care for patients hospitalized for heart failure was not compromised despite the structural and organizational changes during the COVID-19 pandemic. The rates of investigations, including echocardiography, were similar in the COVID-19 and pre-COVID-19 periods. Plasma concentrations of BNP/NT-proBNP were somewhat higher in the COVID-19 period, suggesting a higher threshold for admission and sicker patients. Simultaneously, it appears that these "sicker" patients received on average less aggressive diuresis (less median weight loss during hospitalization) during the hospitalization and had shorter length of stay. Interestingly we observed an increased odds of 30-day mortality during the COVID period that may be explained by our observation that sicker patients were less aggressively diuresed and had shorter lengths of stay. patients may have been discharged prematurely to create more hospital beds or with arrangements to receive palliation for some end stage heart failure patients in community. Gaps in post-discharge care due to closure of ambulatory care centres during the COVID-19 pandemic may have contributed to suboptimal

care and increased risk of death following hospitalization. These are the possible main factors for observing higher natriuretic peptides values, shorter stay in the hospital and lesser weight loss during COVID-19 period compared to Pre-COVID-19 period. Meanwhile, deaths attributed to heart failure in the community and care homes also increased during the COVID-19 pandemic.

A recent analysis of patients hospitalized with heart failure in Denmark did not report an increase in in-patient deaths during the COVID-19 period relative to a similar period in 2019 (142 vs 132 per 1000 person-year; age and sex adjusted death rate ratio, 1.05 (95% CI, 0.93 – 1.18, P 0.45).[5] In contrast, a study of 1,372 patients in two hospitals in London found that patients hospitalized for heart failure during the COVID-19 pandemic had worse outcomes (in-hospital deaths) than those hospitalized during a similar period in 2019 (Hazard ratio; 2.23, 95% CI 1.34 – 3.72, P = 0.002).[3] Small sample size, lack of robust multivariable analyses and non-availability of outcome data after discharge were the main limitations of these studies which may yield different results compared to current study.

Similar to any observational study there are limitations. While we had information about the proportion of patients with HFrEF, we could not differentiate between patients who had heart failure with mid-range ejection fraction (HFmrEF) and HF with preserved ejection fraction (HFpEF). Some general aspects of health such as frailty, mood, social network and cognitive functions were not recorded. More detailed assessments of cardiac function, especially with echocardiography or other imaging modalities were not available. During the earlier phase of the COVID-19 pandemic, widespread COVID-19 testing was not available in England for everyone and was limited to targeted and high-risk patients. It's not possible to ascertain from current study how many HF patients actually had COVID-19 infection during hospital admission. It's also possible that some patients were admitted due to COVID-19 infection and developed an acute exacerbation of HF that was not captured in the NHFA as the

primary diagnosis for discharge or death was not HF. Other patients might have been admitted in hospital due to exacerbation of HF and became infected with COVID-19 during the hospital stay and ultimately died in the hospital or community. Finally, during the COVID-19 pandemic, emergency guidance enabled any doctor in the UK to complete the medical certificate of cause of death and causes of death could be 'to the best of their knowledge and belief'. This may have resulted in misclassification or bias towards certain causes of death. However if anything, this would tend to under-estimate HF deaths in the community that may have been labelled as COVID-19 deaths. Moreover, the accuracy of a diagnosis of heart failure on death certificates is uncertain. One study published in 2017 reported that there was no prior record of heart failure in the primary or secondary care record for 55% of ONS records reporting heart failure as a cause of death.[13] However, this limitation applied equally on both study cohorts.

Conclusion

This analysis of approximately 37,000 acute heart failure admissions is the first national study to compare incidence, processes of care, treatments, and clinical outcomes during and after hospitalisation during the COVID-19 pandemic. We report a 47% reduction in heart failure hospitalizations during the COVID-19 pandemic, accompanied by an increase in heart failure deaths at home and in care homes and hospices. We estimate 280 excess heart failure deaths during this period, and 2165 deaths excess deaths in patients with heart failure. Despite restructuring of hospital services during the COVID-19 pandemic, standard of care appears to have been maintained for those patients hospitalised with heart failure with similar adjusted in-hospital mortality rates, but higher 30-day mortality rates compared to the Pre-COVID-19 period. The reduction in heart failure hospitalization with concomitant increase in heart failure deaths in the community has important implications around public health messaging during the

peak COVID-19 pandemic; “stay at home, protect the NHS” should need to be elaborated further to the public that “stay at home” does not mean to avoid attending hospitals or seeking healthcare advice in the event of illness as it may influence clinical outcome”.[14]

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Data sharing

The data underlying this article were provided by NHS digital by permission. Data will be shared on request to the corresponding author with permission of NHS digital**.**

Discolours: None

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Author contributions: AS & MAM were responsible for the study design and concept. AS performed the data cleaning and analysis. AS and MAM wrote the first draft of the manuscript, and all authors contributed to the writing of the paper.

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Tables

Table 1: Baseline characteristics of patients admitted for heart failure during the Pre-COVID-19 and COVID-19 periods (data derived from NHFA database)

Variables	Pre-COVID-19 period	COVID-19 period	p-value
Number of patients	27,183	9,791	
Age, (IQR)	80 (71 – 87)	80 (71 – 87)	0.47
Women (%)	11,925 (44%)	4,267 (44%)	0.62
Race			
White	12,985 (76%)	4,769 (79%)	<0.001
BAME	4,046 (24%)	1,265 (21%)	<0.001
Location of in-patient care			
Cardiology	11,281 (42%)	3,871 (40%)	0.001
General Medicine	9,091 (33%)	3,344 (34%)	
Geriatric Medicine	4,097 (15%)	1,477 (15%)	
Other	2,671 (10%)	1,071 (11%)	
NYHA Class at the time of hospitalization			
Class 1	1,550 (6%)	654 (7%)	<0.001
Class 2	4,007 (15%)	1,359 (14%)	
Class 3	11,957 (46%)	4,495 (48%)	
Class 4	8,525 (33%)	2,877 (31%)	
Peripheral oedema			
No oedema	5,535 (22%)	2,137 (23%)	<0.001
Mild oedema	6,185 (24%)	1,947 (21%)	
Moderate oedema	8,638 (34%)	3,150 (34%)	
Severe oedema	5,341 (21%)	1,951 (21%)	
Pre-existing co-morbid conditions			
CAD	10,917 (41%)	3,655 (39%)	<0.001
Valve disease	7,670 (29%)	2,667 (28%)	0.09
Hypertension	14,991 (56%)	5,443 (56%)	0.35
Diabetes mellitus	9,312 (35%)	3,263 (34%)	0.13
Asthma	2,447 (9%)	917 (10%)	0.25
COPD	2,812 (18%)	1,678 (18%)	0.23
Prior device therapy			
CRT-D/CRT-P	1,256 (5%)	386 (4%)	0.09
ICD	728 (3%)	267 (3%)	
PPM	2,490 (9%)	890 (9%)	
In-hospital clinical investigations			
Heart rate at admission (beat/minute) (IQR)	83 (70 – 100)	84 (71 – 101)	0.002
Systolic BP at admission (IQR)	130 (111 – 149)	130 (112 – 151)	0.001

Hemoglobin at discharge (grams/dl) (IQR)	12 (10 -13)	12 (10 -13)	0.89
Creatinine at discharge (mg /dl) (IQR)	108 (83 – 148)	106 (82– 147)	0.01
Serum Na at discharge (mmol/L) (IQR)	138 (135 – 141)	138 (135 – 141)	0.77
Plasma BNP during hospitalization (ng/L) (IQR)	570 (82 – 1515)	761 (263 – 1927)	<0.001
Plasma NT-proBNP (ng/L) (IQR)	4,526 (1,897 – 10,417)	5,046 (2,198 – 11,372)	<0.001
QRS interval (milliseconds)	106 (91 – 138)	106 (91 – 136)	0.67
AF on ECG (%)	11,827 (47%)	4,305 (47%)	0.27
HFrEF (%)	14,371 (53%)	5,101 (52%)	0.20
Valve disease (%)	8,999 (33%)	3,208 (33%)	0.55
Echocardiogram performed during hospitalization	23,935 (88%)	8,513 (87%)	0.005
Length of stay, pharmacotherapy at discharge and discharge planning			
Length of hospital stay (IQR)	8 (4 – 15)	7 (3 – 13)	<0.001
ACEi/ARB (%)	12,738 (72%)	4,527 (74%)	0.001
Beta blockers (%)	17,219 (85%)	6,234 (87%)	0.001
Loop diuretics (%)	21,747 (94%)	7,784 (94%)	0.65
Thiazide diuretics (%)	911 (6%)	281 (5%)	0.39
MRA (%)	8,348 (50%)	2,945 (53%)	0.001
Digoxin (%)	3,633 (21%)	1,269 (22%)	0.19
Median weight loss during hospitalization (Kg) (IQR)	-2.1 (-.5.7 to 0)	-1.80 (-5.4 to 0)	0.001
Heart failure nurse follow up (%)	13,923 (58%)	4,969 (57%)	0.46
Cardiology follow up (%)	10,749 (45%)	3,615 (42%)	<0.001

NHFA; National Heart Failure Audit, IQR; Interquartile range, HF; Heart failure, BAME; Black, Asian & Minority ethnic, NYHA; New York Heart Association, CAD; Coronary artery disease, COPD; Chronic obstructive pulmonary disease, CVA; Cerebrovascular accident,

CRT; Cardiac resynchronization therapy, ICD; implanted cardiac defibrillator, PPM, Permanent pacemaker, BP; blood pressure, Na; Sodium, BNP; Brain Natriuretic Peptide, NT-pro BNP; N-terminal pro type Brain Natriuretic Peptide, HFrEF; heart failure with reduced ejection fraction, HFpEF; heart failure with preserved ejection fraction, AF; atrial fibrillation, ECG; electrocardiogram, ACEi; angiotensin converting enzyme inhibitor, ARB; angiotensin receptor blockers, MRA; mineralocorticoid receptor antagonist, Kg; Kilogram

Table 2: Crude data & adjusted odds of in-patient and 30-day mortality from admission during the COVID-19 versus Pre-COVID-19 period (data derived from Civil Registration of Death and NHFA databases)

Outcome	Total	Pre-COVID-19 period	COVID-19 period	P-Value
No of patients	36,974	27,183	9,791	
All-cause in-patient mortality (%)	3,752	2,752 (10%)	1,000 (10%)	0.80
All cause 30-day mortality from date of admission (%)	5,033	3,594 (13%)	1,439 (15%)	<0.001
Multivariable Logistic regression analysis on non-imputed data (complete case analysis)				
Outcome	OR*	Lower bound 95% CI	Upper bound 95% CI	P-value
Inpatient mortality (n = 21,036)	1.02±	0.91	1.13	0.73
30-day mortality from date of admission (n = 21,036)	1.17Ω	1.07	1.29	0.001
Multivariable Logistic regression analysis on imputed data				
Outcome	OR*	Lower bound 95% CI	Upper bound 95% CI	P-value
Inpatient mortality (n = 36,956)	1.02#	0.94	1.1	0.66
30-day mortality from date of admission (n = 36,956)	1.15+	1.07	1.23	<0.001

30-day outcomes were measured from date of hospital admission

Area under ROC curve: 0.52, SE: 0.005, 95% CI 0.52 – 0.53

+ Area under ROC curve: 0.79, SE: 0.003, 95% CI 0.78 – 0.80

OR; odds ratio, NHFA; National Heart Failure Audit, ROC; receiver operator characteristics, SE; standard error, CI; confidence interval

* Adjusted for age, gender, prior medical conditions (Coronary artery disease, Valvular heart disease, Diabetes mellitus, hypertension, asthma, Chronic obstructive pulmonary disease), prior smoking history, place of care. atrial fibrillation on ECG, heart rate at hospitalization, blood pressure at hospitalization, QRS duration, New York Heart association class shortness of breath, severity of peripheral oedema, prior device implantation, HFrEF (LVEF <40%)

Table 3: Comparison of in-patient and 30-day from admission cause of death during Pre-COVID-19 and COVID-19 period (data derived from Civil Registration of Death and NHFA databases)

Primary Cause of death	In-patient (Pre-COVID-19 period)	In-patient (COVID-19 period)	P-value	30–day (Pre-COVID-19 period)	30–day from Admission (COVID-19 period)	P-value
Cardiac causes						
Heart Failure	1,518 (56.0%)	519 (53.3%)	0.12	1,883 (53.3%)	682 (48.3%)	0.002
ACS	59 (2.2%)	24 (2.5%)	0.62	103 (2.9%)	39 (2.8%)	0.78
Other cardiac causes	184 (6.8%)	44 (4.5%)	0.01	262 (7.4%)	72 (5.1%)	0.003
Respiratory causes						
Acute respiratory infection	406 (15.1%)	135 (13.9%)	0.37	526 (14.9%)	206 (14.6%)	0.80
Respiratory failure	65 (2.4%)	13 (1.3%)	0.04	77 (2.2%)	21 (1.5%)	0.12
COVID-19	0	82 (8.3%)	-	0	136 (9.6%)	-
Sepsis	55 (2.0%)	19 (1.9%)	0.87	79 (2.2%)	23 (1.6%)	0.18
Other non-cardiac causes	405 (15.0%)	139 (14.2%)	0.57	603 (17.1%)	234 (16.6%)	0.69

NHFA; National Heart Failure Audit, ACS; acute coronary syndrome, CAD; coronary artery disease,

Table 4: Factors independently associated with in-hospital mortality during the Pre-COVID-19 and COVID-19 periods (data derived from Civil Registration of Death and NHFA databases)

Variables	Pre-COVID-19 period			COVID-19 period		
N=	27,172			9,784		
Model performance	Area under ROC curve: 0.68, SE: 0.004, 95% CI: 0.67 – 0.69			Area under ROC curve: 0.68, SE: 0.004, 95% CI: 0.67 – 0.69		
	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value
Age	**1.04**	**1.03 – 1.05**	**<0.001**	**1.03**	**1.02 – 1.04**	**<0.001**
Female sex	0.92	0.83 – 1.03	0.17	0.96	0.82 – 1.10	0.54
Admission heart rate+ (beat /minute)	**1.03**	**1.02 – 1.04**	**0.02**	1.01	0.99 – 1.02	0.09
Admission BP (mmhg)ϒ	**0.93**	**0.92 – 0.94**	**<0.001**	**0.92**	**0.90-0.93**	**<0.001**
QRS durationβ	**1.06**	**1.04 - 1.07**	**<0.001**	**1.04**	**1.01- 1.06**	**0.01**
CAD	0.98	0.90 – 1.07	0.69	0.99	0.86– 1.40	0.86
Valve disease	**1.13**	**1.03 – 1.22**	**0.01**	1.03	0.88 – 1.22	0.73
hypertension	**0.88**	**0.81 – 0.95**	**0.002**	**0.76**	**0.66 – 0.87**	**<0.001**
DM	1.01	0.92 – 1.10	0.84	**1.18**	**1.02 – 1.37**	**0.02**
asthma	**0.73**	**0.64 – 0.86**	**<0.001**	1.01	0.82 – 1.27	0.96
COPD	**1.26**	**1.22 – 1.65**	**0.003**	0.98	0.82 – 1.18	0.88
Atrial fibrillation	1.02	0.93 – 1.12	0.63	0.90	0.77 – 1.05	0.20
NYHA III/IV*	**1.17**	**1.05 – 1.31**	**0.006**	**1.27**	**1.05 – 1.52**	**0.01**
peripheral oedema#	**1.22**	**1.11 – 1.33**	**0.005**	**1.28**	**1.10 – 1.49**	**0.001**
Care in cardiology ward	**0.72**	**0.65 – 0.78**	**<0.001**	**0.70**	**0.61 – 0.81**	**<0.001**
IECD	**0.85**	**0.75 – 0.97**	**0.01**	0.91	0.74– 1.11	0.35
HFrEF	1.01	0.92 – 1.1	0.97	0.96	0.83 – 1.11	0.57

ROC; receiver operator characteristics, SE; standard error, CI; confidence interval , HF; heart failure, NYHA; New York Heart Association, CAD; coronary artery disease, COPD; chronic obstructive pulmonary disease, , HFrEF; heart Failure with reduced ejection fraction, ECG; electrocardiogram

+ (per 1 unit change in model)

∗ NYHA class I/II are reference

None or mild peripheral oedema are reference

ϒ per 10 degree rise in blood pressure

β per 10 millisecond change

IECD = implantable electrical cardiac device

receptor antagonist (MRA)) to the variables used in the above model.

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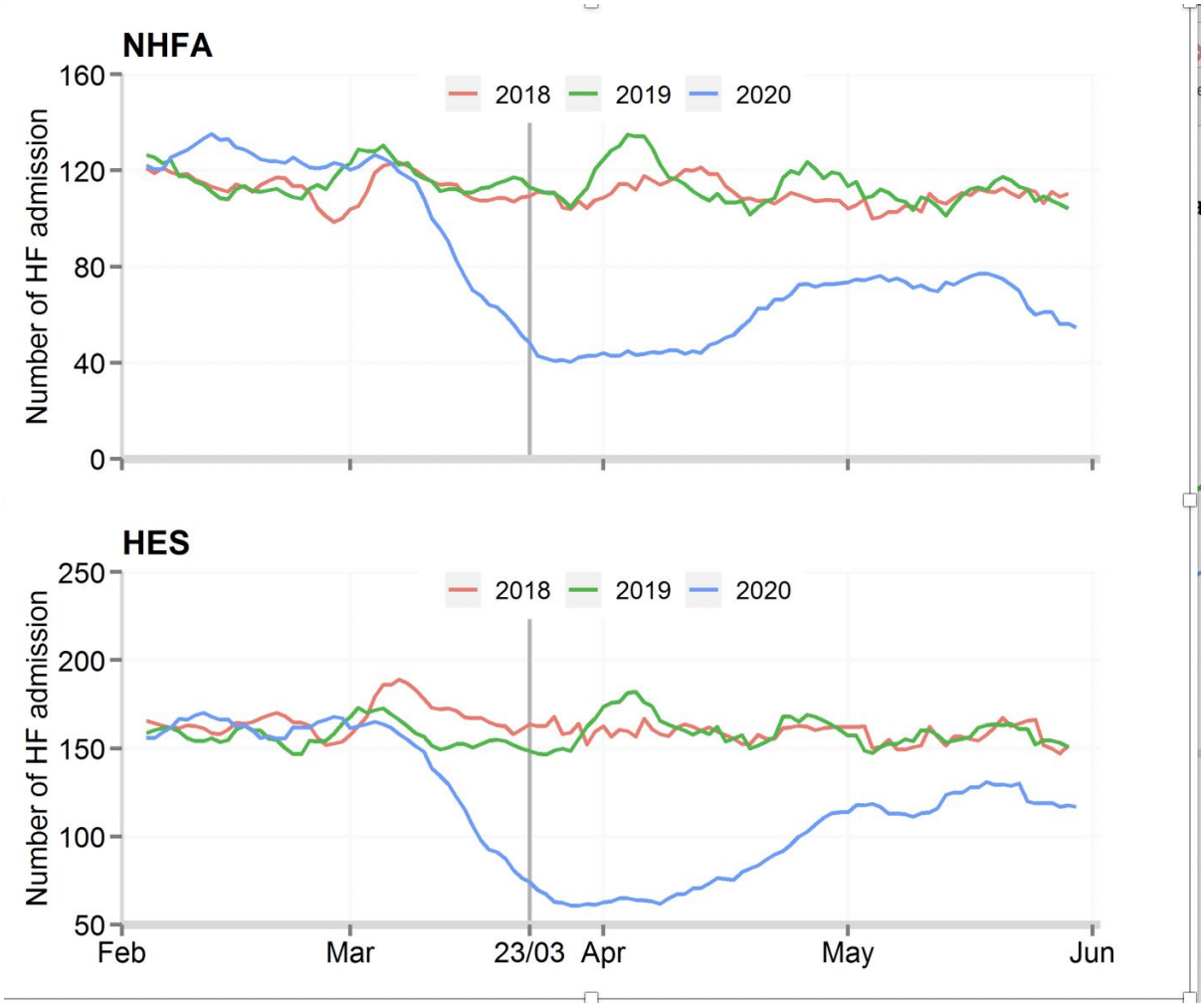
Figures

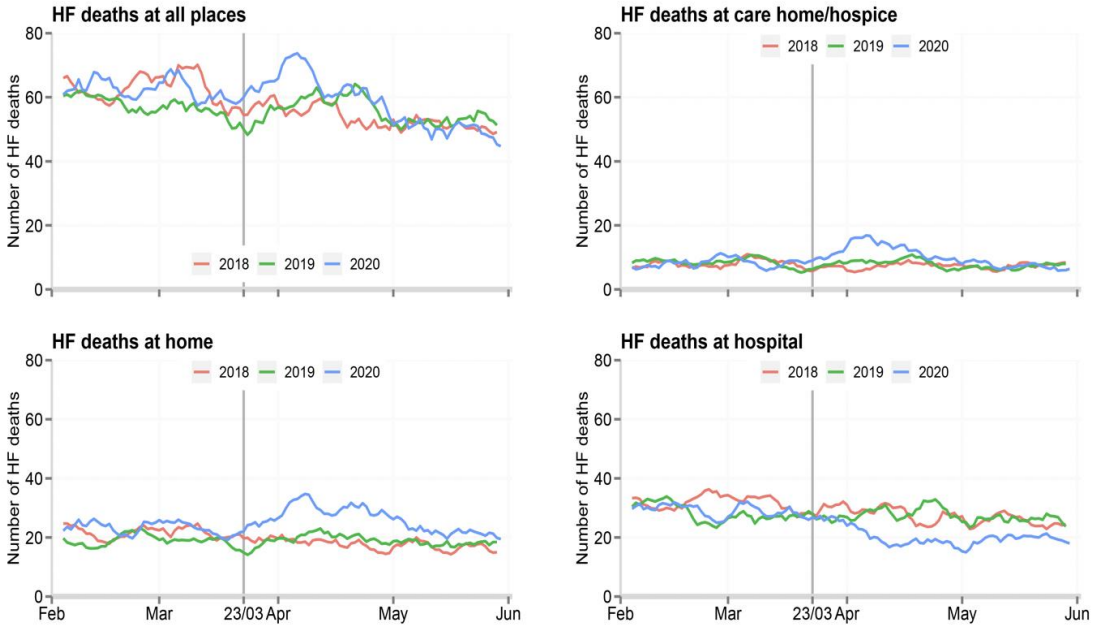
Figure 1: Daily number of heart failure hospitalizations between 1st February and 31st May 2018, 2019 and 2020



Legend: Each curve represents a 7-day rolling average of daily heart failure hospitalizations. A decline in daily admissions for heart failure (NHFA: from 112 to 60 per day: IRR: 0.53, 95% CI: 0.52-0.55); HES: from 157 to 92 per day; IRR: 0.60, 95% CI: 0.59-0.62) from the middle of March 2020. There was a persistently low rate of admissions as compared with similar months during the Pre-COVID-19 period

NHFA; National Heart Failure Audit, HES; Hospital Episode Statistic
Pre-COVID-19 period: February- May 2018 & February-May 2019
COVID-19 period: February-May 2020

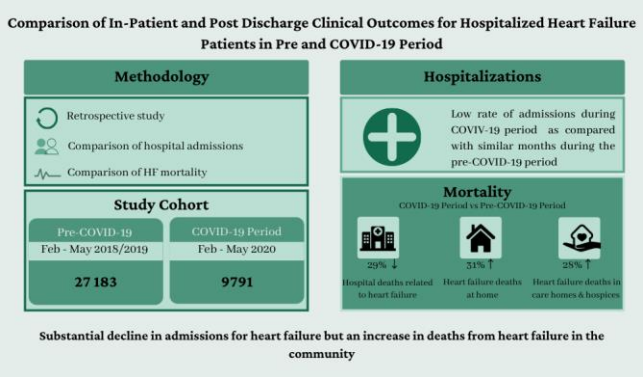
Figure 2: Comparison of daily deaths in hospital, home and care home/hospice during study period with heart failure certified as the primary cause



Legend: Each curve represents a 7-day rolling average of daily deaths. There was an increase in deaths due to heart failure from middle of March to late April 2020 in the Covid-19 period compared to pre-COVID-19 period. A 29% decline in deaths related to heart failure in hospital (IRR: 0.71, 95% CI: 0.67 - 0.75, equivalent to a decrease of 448 deaths), a 31% increase of deaths at home (IRR: 1.31, 95% CI: 1.24-1.39, equivalent to an increase of 539 deaths) and a 28% increase in deaths in care homes and hospices (IRR: 1.28, 95% CI: 1.18-1.40, equivalent to an increase of 189 deaths)

HF; heart failure, IRR; Incidence rate ratio
Pre-COVI-19 period: February- May 2018 & February-May 2019
COVID-19 period: February-May 2020

Figure 3: Visual take home graphics



Legend: Graphical summary

HF; Heart failure