Contemporary epidemiology of hospitalised heart failure with reduced versus preserved ejection fraction in England: a retrospective, cohort study of whole-population electronic health records

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Summary

Background Heart failure is common, complex, and often associated with coexisting chronic medical conditions and a high mortality. We aimed to assess the epidemiology of people admitted to hospital with heart failure with reduced ejection fraction (HFrEF) and heart failure with preserved ejection fraction (HFpEF), including the period covering the COVID-19 pandemic, which was previously not well characterised.

Methods In this retrospective, cohort study, we used whole-population electronic health records with 57 million individuals in England to identify patients hospitalised with heart failure as the primary diagnosis in any consultant episode of an in-patient admission to a National Health Service (NHS) hospital. We excluded individuals with less than 1 year of medical history records in primary or secondary care; admissions to NHS hospitals for which less than 10% of heart failure cases were linkable to the National Heart Failure Audit (NHFA); individuals younger than 18 years at the time of the heart failure hospitalisation; and patients who died in hospital during the index heart failure admission. For patients with new onset heart failure, we assessed incidence rates of 30-day and 1-year all-cause and cause-specific (cardiovascular, non-cardiovascular, and heart failure-related) emergency rehospitalisation and mortality after discharge, and dispensed guideline-recommended medical therapy (GRMT). Follow-up occurred from the index admission to the earliest occurrence of the event of interest, death, or end of data coverage. We estimated adjusted hazard ratios (HRs) to compare HFrEF with HFpEF. We computed population-attributable fractions to quantify the percentage of outcomes attributable to coexisting chronic medical conditions.

Findings Among 233 320 patients identified who survived the index heart failure admission across 335 NHS hospitals between Jan 1, 2019, and Dec 31, 2022, 101 320 (43·4%) had HFrEF, 71 910 (30·8%) had HFpEF, and 60 090 (25·8%) had an unknown classification. In patients with new onset heart failure, there were reductions in all-cause 30-day (−5·2% [95% CI −7·7 to −2·6] in 2019–22) and 1-year rehospitalisation rates (−3·9% [−6·6 to −1·2]). Declining 30-day rehospitalisation rates affected patients with HFpEF (−4·8% [−9·2 to −0·2]) and HFrEF (−6·2% [−10·5 to −1·6]), although 1-year rates were not statistically significant for patients with HFpEF (−2·2% [−6·6 to 2·3] *vs* −5·7% [−10·6 to −0·5] for HFrEF). There were no temporal trends in incidence rates of 30-day or 1-year mortality after discharge. The rates of all-cause (HR 1·20 [1·18–1·22]) and cause-specific rehospitalisation were uniformly higher in those with HFpEF than those with HFrEF. Patients with HFpEF also had higher rates of 1-year all-cause mortality after discharge (HR 1·07 [1·05–1·09]), driven by excess risk of non-cardiovascular death (HR 1·25 [1·21–1·29]). Rates of rehospitalisation and mortality were highest in patients with coexisting chronic kidney disease, chronic obstructive pulmonary disease, dementia, and liver disease. Chronic kidney disease contributed to 6·5% (5·6–7·4) of rehospitalisations within 1 year for HFrEF and 5·0% (4·1–5·9) of rehospitalisations for HFpEF, double that of any other coexisting condition. There was swift implementation of newer GRMT, but markedly lower dispensing of these medications in patients with coexisting chronic kidney disease.

Interpretation Rates of rehospitalisation in patients with heart failure in England have decreased during 2019–22. Further population health improvements could be reached through enhanced implementation of GRMT, particularly in patients with coexisting chronic kidney disease, who, despite being at high risk, remain undertreated.

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Research in context

Evidence before this study

We searched PubMed for large-scale observational studies published between Jan 1, 2019, and June 15, 2024, that investigated post-discharge outcomes in individuals with heart failure before, during, and after the COVID-19 pandemic. We used the term "heart failure" in combination with "surviv*", "mortality", "hospital*", "outcome*", "morbid*", "epidemiology", or "trend*", and with "retrospective", "cohort", "regist*", or "database". No large population-based studies have comprehensively assessed how COVID-19 has affected outcomes in individuals with heart failure with reduced ejection fraction (HFrEF) and preserved ejection fraction (HFpEF). Research during earlier time periods have indicated moderate reductions in post-discharge mortality in Europe and increasing rates of mortality from heart failure in the USA, particularly among younger individuals (aged <45 years), but the effect of COVID-19 remains uncertain. The implementation of guideline-recommended medical therapy (GRMT) and the effect of coexisting chronic medical conditions on heart failure outcomes over this period also remain underexplored.

Added value of this study

To our knowledge, this whole-population study of 233 320 patients with heart failure across England and 19 linked electronic health record datasets from the National Health Service Secure Data Environment (including 57 million individuals) represents the largest and most comprehensive evaluation of the epidemiology of hospitalised heart failure to date, including the COVID-19 pandemic. Our study shows reductions in 30-day and 1-year rehospitalisation (which differs from the overall unchanged mortality rates between 2019 and 2022) in patients with heart failure, suggesting that

heart failure outcomes improved in England during the COVID-19 pandemic. Post-discharge outcomes varied by type of heart failure as patients with HFpEF had higher rates of rehospitalisations for all causes and higher mortality than those with HFrEF, which was driven by non-cardiovascular causes. Coexisting chronic medical conditions had a substantial impact on patient prognoses. Rates of rehospitalisation and mortality were highest in patients with coexisting chronic kidney disease, chronic obstructive pulmonary disease, dementia, and liver disease. Chronic kidney disease, which was prevalent in more than 50% of patients with heart failure, contributed to double the number of rehospitalisations and deaths within 1-year after discharge compared with any other coexisting chronic medical condition. Additionally, the proportion of patients with new onset heart failure and dispensed GRMT improved over the study period, but patients with coexisting chronic kidney disease had markedly lower dispensing rates than those without chronic kidney disease.

Implications of all the available evidence

Trends in the prognosis of individuals with heart failure are not uniform across global settings, and generally prognosis remains poor. In England, there have been reductions in rehospitalisation from 2019 to 2022. Higher rates of emergency rehospitalisation and mortality were observed in patients with HFpEF than in those with HFrEF, and effective therapies for these patients remain scarce. Improved management of coexisting chronic medical conditions and implementation of GRMT for patients with chronic kidney disease, regardless of heart failure classification, present pronounced opportunities to improve public health policy and clinical practice surrounding heart failure.

Introduction

Heart failure affects more than 64 million individuals worldwide and is associated with poor quality of life, recurrent admission to hospital, and high mortality risk.[1,2] The management of heart failure entails substantial health-care expenditure, with the annual global costs estimated at over US$100 billion in 2012,[3] and projections suggesting a 2·5-times increase by 2030.[4] In the UK, heart failure is responsible for around 2% of the National Health Service (NHS) annual budget and 5% of all emergency hospitalisations. Data from 2018 indicate that the prevalence of heart failure is increasing, which is driven by ageing and population growth;[5] therefore, prevention and reducing rehospitalisations because of heart failure are important priorities for many health systems worldwide.

Heart failure with reduced ejection fraction (HFrEF) and heart failure with preserved ejection fraction (HFpEF) have distinct causes, prognoses, treatments, and clinical outcomes, but most population-wide epidemiological studies do not distinguish between them.[2,6,7]

To date, there is incomplete understanding of the direct and indirect effects of the COVID-19 pandemic on hospitalisation and mortality among individuals with HFrEF and HFpEF. Epidemiological trends in 2014–22 might have been influenced by the availability of new guideline-recommended treatments for heart failure that reduce hospitalisations and cardiovascular deaths, including angiotensin receptor neprilysin (ARN) inhibitors for HFrEF and sodium-glucose cotransporter 2 (SGLT2) inhibitors for HFrEF and HFpEF.[8–12] Despite the advent of these treatments, mortality from heart failure has increased in the USA.[13,14] Whereas, the current epidemiology of heart failure in the UK is not well characterised, although evidence suggests that specialist care for heart failure was maintained in England despite disruptions from the COVID-19 pandemic.[15]

To address this evidence gap, we aimed to characterise the epidemiology of people admitted to hospital with HFrEF and HFpEF, including the period covering the COVID-19 pandemic, using whole-population electronic

health records made available in 2021, including 57 million individuals in England.

Methods

Study design and population

In this retrospective, cohort study, we used 19 linked electronic health record datasets with whole-population coverage from the NHS England Secure Data Environment, accessed via the British Heart Foundation Data Science Centre CVD-COVID-UK/COVID-IMPACT Consortium. We accessed data from primary care (the General Practice Extraction Service Data for Pandemic Planning and Research [GDPPR]), secondary care (Hospital Episode Statistics [HES]), the Office for National Statistics Civil Registration of Deaths, NHS Business Services Authority dispensed medicines, and seven audits from the National Institute for Cardiovascular Outcomes Research (NICOR) National Cardiac Audit Programme, including the National Heart Failure Audit (NHFA; appendix pp 9–10).

Among all individuals of known sex, we identified patients with heart failure as the primary diagnosis in any consultant episode of an in-patient admission to an NHS hospital from Jan 1, 2019, to Dec 31, 2022. We excluded individuals with less than 1 year of medical history records in primary or secondary care; admissions to NHS hospitals for which less than 10% of heart failure cases were linkable to the NHFA to ensure high data quality and maintain generalisability for the population of England (appendix pp 20–21); individuals younger than 18 years at the time of the heart failure hospitalisation; and patients who died in hospital during the index heart failure admission (appendix p 22).

We categorised patients into new onset heart failure and chronic decompensated heart failure (see appendix p 11 for the diagnostic codes). Patients with new onset heart failure were defined as those with a first heart failure admission during the study period and no previous documented diagnosis of heart failure in primary or secondary care within at least 1 year before the first heart failure admission. Patients with chronic decompensated heart failure were those with a previous diagnosis of heart failure in GDPPR or HES before the index heart failure admission.

To classify patients with HFrEF or HFpEF, we used recorded left ventricular ejection fraction (LVEF; ≤40% for HFrEF and >40% for HFpEF) obtained using a transthoracic echocardiography, angiography, nuclear imaging, CT, or MRI or an explicitly documented diagnosis across seven NICOR audits and primary care data from GDPPR (appendix pp 20–21).

The North East-Newcastle and North Tyneside 2 research ethics committee provided ethical approval for the CVD-COVID-UK/COVID-IMPACT research programme (20/NE/0161) to access, within secure trusted research environments, unconsented, whole-population, de-identified data from electronic health records collected as part of patients' routine health care. In accordance with data anonymisation requirements of NHS England, analyses were performed on the exact number of individuals but all counts are rounded to the nearest five. This study is in accordance with RECORD guidelines (appendix pp 3–5).

Procedures

We extracted covariates with relevance to prognosis in heart failure, which were age, sex, ethnicity (derived from the latest available non-missing value across primary care [GDPPR] and secondary care [HES-APC], with preference given to primary care in the event of a match on the same date as secondary care), socioeconomic status (defined according to the Index of Multiple Deprivation 2019), and smoking status. We also extracted clinical measurements, including a previous COVID-19 diagnosis, New York Heart Association class, systolic blood pressure, BMI, estimated glomerular filtration rate (eGFR) from NICOR data and GDPRR as the most recent measurement within 1 year before the index heart failure admission, and B-type natriuretic peptide (BNP) and N-terminal pro B-type natriuretic peptide (NT-proBNP) from the NHFA as recorded at the time of index heart failure admission.

We ascertained the presence of 18 coexisting chronic medical conditions at index heart failure admission from the full history of patients' previous general practitioner visits, outpatient appointments, or inpatient admissions, following guidance from the Delphi Consensus study (appendix p 6).[16]

We extracted individual-level information on guideline-recommended medical therapy (GRMT) dispensed within 6 months after discharge (allowing for up-titration). We selected medications from those recommended by clinical practice guidelines to extend survival and reduce hospitalisations in heart failure: β blockers, angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), ARN inhibitors, mineralocorticoid receptor antagonists (MRAs), and SGLT2 inhibitors.[2] We also extracted data on loop diuretics used for symptom management.

Missing data distributions and imputation methods are reported in the appendix (p 8). We used multiple imputation by chained equations to impute missing values for systolic blood pressure, BMI, eGFR, smoking, and New York Heart Association class, creating five imputed datasets. We did not impute missing values for BNP or NT-proBNP due to the extent of missing data (>90%), and these covariates were not considered further for analyses.

Outcomes

We estimated incidence rates of 30-day and 1-year all-cause and cause-specific (cardiovascular, non-cardiovascular, and heart failure-related) emergency rehospitalisation and mortality after discharge. Follow-up occurred from discharge from the index admission to the

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For more on the CVD-COVID-UK/COVID-IMPACT Consortium see https://bhfdatasciencecentre.org/areas/cvd-covid-uk-covid-impact/

See Online for appendix

earliest occurrence of the event of interest, death, or end of data coverage (data available until Jan 31, 2024). We defined rehospitalisations as all non-elective admissions with at least one overnight stay that occurred after discharge from the index heart failure admission. We determined the cause of hospitalisation from the ICD-10 code in the primary position recorded at the first episode during admission. We ascertained the date and cause of

	Heart failure with reduced ejection fraction (n=101320)	Heart failure with preserved ejection fraction (n=71910)	Unknown heart failure classification (n=60090)	Total (n=233320)
New onset heart failure	31635 (31·2%)	23560 (32·8%)	27965 (46·5%)	83160 (35·6%)
Previous COVID-19 diagnosis	10355 (10·2%)	9425 (13·1%)	7015 (11·7%)	26795 (11·5%)
Age, years	75·2 (13·6)	80·2 (11·0)	81·0 (11·8)	78·2 (12·7)
Sex				
Female	36585 (36·1%)	39735 (55·3%)	33675 (56·0%)	110000 (47·1%)
Male	64735 (63·9%)	32170 (44·7%)	26415 (44·0%)	123325 (52·9%)
Ethnicity				
White	90820 (89·6%)	63190 (87·9%)	55420 (92·2%)	209430 (89·8%)
Black	3080 (3·0%)	2190 (3·0%)	1205 (2·0%)	6470 (2·8%)
Asian	5270 (5·2%)	5085 (7·1%)	2490 (4·1%)	12845 (5·5%)
Mixed	825 (0·8%)	500 (0·7%)	335 (0·6%)	1665 (0·7%)
Other	1070 (1·1%)	825 (1·1%)	490 (0·8%)	2385 (1·0%)
Unknown	255 (0·3%)	120 (0·2%)	155 (0·3%)	530 (0·2%)
Socioeconomic status quintile*				
1 (most deprived)	22085 (21·8%)	14840 (20·6%)	12810 (21·3%)	49735 (21·3%)
2	20810 (20·5%)	14410 (20·0%)	12070 (20·1%)	47290 (20·3%)
3	20645 (20·4%)	14815 (20·6%)	12465 (20·7%)	47925 (20·5%)
4	19590 (19·3%)	14085 (19·6%)	12060 (20·1%)	45735 (19·6%)
5 (least deprived)	17675 (17·4%)	13460 (18·7%)	10275 (17·1%)	41410 (17·7%)
Missing	520 (0·5%)	295 (0·4%)	415 (0·7%)	1225 (0·5%)
Smoking status				
Current	10210 (10·1%)	4465 (6·2%)	3935 (6·5%)	18610 (8·0%)
Former	30295 (29·9%)	20805 (28·9%)	15140 (25·2%)	66240 (28·4%)
Never	25745 (25·4%)	21195 (29·5%)	14315 (23·8%)	61255 (26·3%)
Missing	35070 (34·6%)	25445 (35·4%)	26705 (44·4%)	87215 (37·4%)
New York Heart Association class				
I	4690 (4·6%)	3480 (4·8%)	1970 (3·3%)	10140 (4·3%)
II	12885 (12·7%)	9560 (13·3%)	3695 (6·1%)	26140 (11·2%)
III	36925 (36·4%)	29540 (41·1%)	8805 (14·7%)	75265 (32·3%)
IV	23055 (22·8%)	18120 (25·2%)	4975 (8·3%)	46150 (19·8%)
Missing	23765 (23·5%)	11205 (15·6%)	40650 (67·6%)	75625 (32·4%)
BMI, kg/m²				
Mean	28·6 (7·3)	29·9 (8·2)	29·8 (8·3)	29·3 (7·9)
Missing	30535 (30·1%)	19150 (26·6%)	28380 (47·2%)	78065 (33·5%)
Systolic blood pressure, mm Hg				
Mean	127·1 (20·7)	134·2 (21·5)	134·7 (21·5)	131·1 (21·5)
Missing	16625 (16·4%)	7015 (9·8%)	26240 (43·7%)	49880 (21·4%)
Estimated GFR, mL/min per 1·73 m²				
Mean	59·5 (24·6)	56·2 (23·7)	60·5 (25·0)	58·7 (24·5)
Missing	1570 (1·5%)	385 (0·5%)	7215 (12·0%)	9165 (3·9%)
B-type natriuretic peptide, pg/mL				
Median	1177 (532–2653)	586 (283–1355)	563 (238–1431)	817 (360–2000)
Missing	94805 (93·6%)	66190 (92·0%)	58580 (97·5%)	219575 (94·1%)
N-terminal pro B-type natriuretic peptide, pg/mL				
Median	5494 (2396–10691)	3264 (1648–6389)	2077 (809–4058)	3910 (1797–8086)
Missing	100210 (98·9%)	70680 (98·3%)	59870 (99·6%)	230760 (98·9%)
				(Table continues on next page)

	Heart failure with reduced ejection fraction (n=101 320)	Heart failure with preserved ejection fraction (n=71 910)	Unknown heart failure classification (n=60 090)	Total (n=233 320)
(Continued from previous page)				
Medications dispensed after discharge from hospital				
β blocker	80 245 (79·2%)	44 715 (62·2%)	31 045 (51·7%)	156 005 (66·9%)
ACE inhibitor	46 275 (45·7%)	22 375 (31·1%)	16 840 (28·0%)	85 485 (36·6%)
ARB	14 495 (14·3%)	10 965 (15·2%)	7350 (12·2%)	32 810 (14·1%)
ARNI	17 170 (16·9%)	800 (1·1%)	810 (1·3%)	18 775 (8·0%)
ACE inhibitor, ARB, or ARNI	71 010 (70·1%)	33 230 (46·2%)	24 300 (40·4%)	128 545 (55·1%)
MRA	52 430 (51·7%)	20 035 (27·9%)	11 610 (19·3%)	84 075 (36·0%)
Loop diuretic	84 100 (83·0%)	62 665 (87·1%)	46 665 (77·7%)	193 425 (82·9%)
SGLT2 inhibitor	18 885 (18·6%)	4850 (6·7%)	2785 (4·6%)	26 520 (11·4%)
Number of pre-existing chronic medical conditions				
0	585 (0·6%)	80 (0·1%)	180 (0·3%)	850 (0·4%)
1	2510 (2·5%)	505 (0·7%)	915 (1·5%)	3930 (1·7%)
2	5450 (5·4%)	1615 (2·2%)	2490 (4·1%)	9555 (4·1%)
3	8630 (8·5%)	3545 (4·9%)	4560 (7·6%)	16 735 (7·2%)
4	11 905 (11·7%)	6610 (9·2%)	6995 (11·6%)	25 510 (10·9%)
≥5	72 240 (71·3%)	59 550 (82·8%)	44 955 (74·8%)	176 740 (75·8%)
History of discharge from hospital to a care home	5300 (5·2%)	4920 (6·8%)	6045 (10·1%)	16 265 (7·0%)

Data are mean (SD), median (IQR), or n (%). All counts are rounded to the nearest five. For variables with missing data, summary statistics are shown using observed values and the number and proportion of missing values (within 1 year before the index hospitalisation for heart failure). ACE=angiotensin-converting enzyme. ARB=angiotensin receptor blocker. ARNI=angiotensin receptor-neprilysin inhibitor. GFR=glomerular filtration rate. MRA=mineralocorticoid receptor antagonist. SGLT2=sodium-glucose cotransporter 2. *Socioeconomic status was defined as the Index of Multiple Deprivation 2019.

Table: Baseline characteristics of patients admitted to hospital with heart failure

death from linked death records using the ICD-10 underlying cause of death code.

Statistical analysis

In patients with new onset heart failure, monthly incidence rates of rehospitalisation and mortality were estimated at the mean age of the study population using quasi-Poisson models, and stratified by HFrEF and HFpEF.[17] We used quasi-Poisson models to estimate annual changes in outcome rates, incorporating the month of index heart failure admission as a continuous linear term and adjusting for age as a linear term and admission during lockdown periods in England (first lockdown from March 23 to May 13, 2020 [individuals gradually permitted to leave home for outdoor recreation], second lockdown from Nov 5 to Dec 20, 2020, and third lockdown from Jan 6 to March 29, 2021[18]) as a binary term, offset for observation time. We did post-hoc sensitivity analyses with Joinpoint regression to calculate annual percentage change in rates of rehospitalisation and mortality[19] and Fine–Gray subdistribution hazard models, accounting for the competing risk of death, with identical covariate adjustment. We also did a further post-hoc sensitivity analysis, which excluded NHS hospitals with less than 50% of heart failure cases linkable to the NHFA, to assess the effect of NHFA coverage on our results.

We quantified trends in the implementation of GRMT in patients with new onset heart failure by calculating the proportion of patients for whom these medications were dispensed after discharge. Analyses were stratified by HFrEF, HFpEF, coexisting chronic kidney disease (selected due to known challenges in optimal GRMT implementation in these patients; defined as a documented diagnosis of stage 3a to 5 or stage 1–2 with albuminuria, or two historic measurements of an eGFR of less than 60 mL/min per 1·73 m² at least 90 days apart; appendix p 6),[20] and baseline eGFR (≥60, 30 to <60, and <30 mL/min per 1·73 m²).

As GDPPR, compiled by NHS England for pandemic-related research, is restricted to individuals alive from Nov 1, 2019, we did all modelling with the required adjustment or analysis of coexisting chronic medical conditions in patients admitted between Nov 1, 2019, and Dec 31, 2022. We used Cox proportional hazards models to estimate adjusted hazard ratios (HRs) and 95% CIs for differences in rates of 1-year all-cause and cause-specific rehospitalisation and mortality after discharge between patients with HFrEF and HFpEF. We investigated associations across subgroups of age (<70, 70–79, 80–89, and ≥90 years), sex, and socioeconomic status. We further estimated HRs to quantify associations of each coexisting chronic medical condition with 1-year rehospitalisation and mortality after discharge, separately in patients with HFrEF and HFpEF. For selected conditions that commonly precipitate rehospitalisation and mortality in those with heart failure,[21,22] we computed
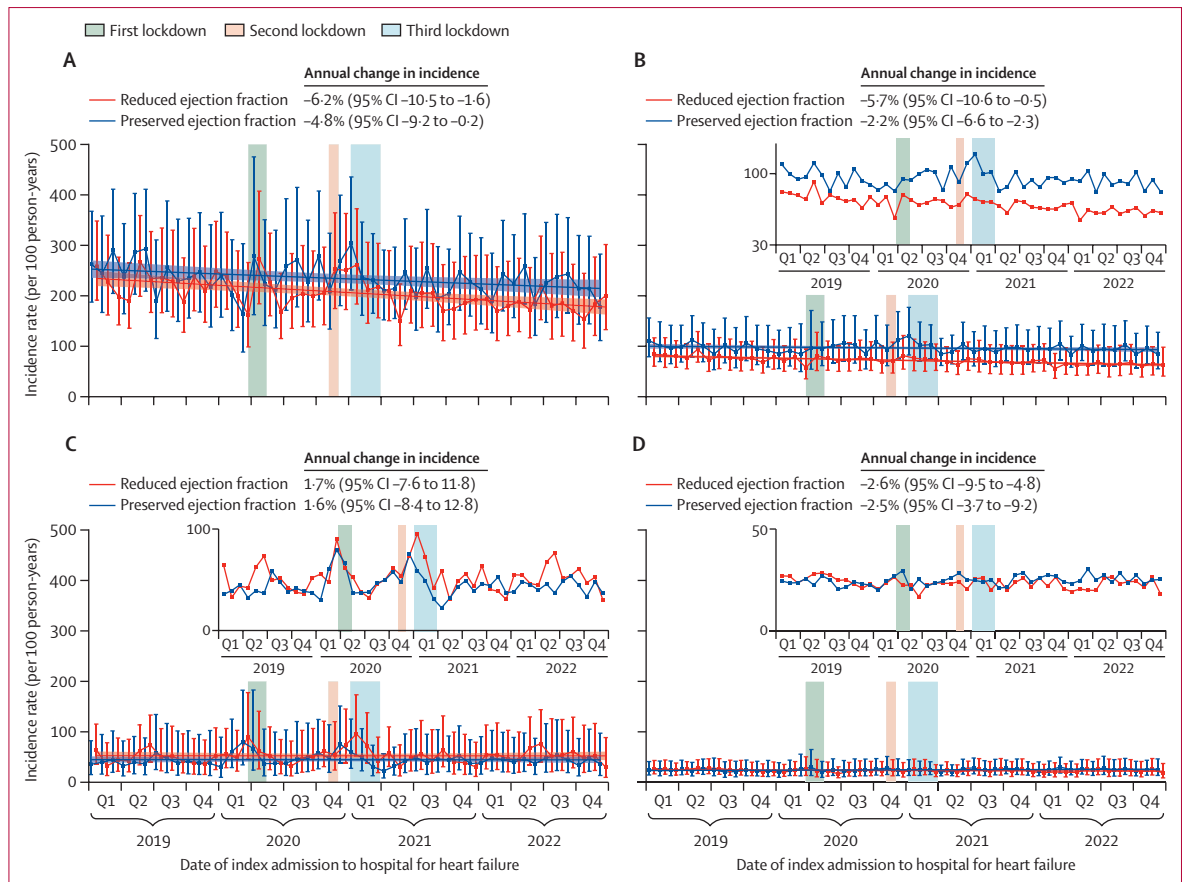
Figure 1: **Temporal trends in incidence rates of all-cause rehospitalisation and mortality after discharge in patients with new onset heart failure and reduced (n=31 635) or preserved ejection fraction (n=23 560)**
Bars show 95% CI. (A) 30-day rehospitalisation. (B) 1-year rehospitalisation. (C) 30-day mortality. (D) 1-year mortality. Trends in incidence are shown in the top right on an expanded y-axis (B–D). Estimated rates might exceed one per person–year due to censoring at 30 days (A, C) or at the time of the first event (A–D). Estimates were calculated at the mean population age (76·4 years). Incidence rates are adjusted for age and admission during COVID-19 lockdowns in England (the first lockdown occurred from March 23 to May 13, 2020, second lockdown from Nov 5 to Dec 20, 2020, and third lockdown from Jan 6 to March 29, 2021). Q=quarter.

population-attributable fractions adjusted for available confounders to quantify the percentage of outcomes attributable to each condition.[23] HRs were estimated in patients with new onset heart failure or chronic decompensated heart failure, or both. The confounders we adjusted for in multivariate modelling were selected based on clinical expertise (appendix p 7). As a sensitivity analysis to assess potential bias, we used multiple imputation by chained equations with five imputed datasets to impute heart failure classification for patients with missing data, drawing on previously published methods.[24] The proportional hazards assumption was assessed by log–log plots and Kaplan–Meier curves. All analyses were done using Spark SQL (version 3.3.0), Python (version 3.9.5), and R (version 4.1.3). All clinical codes and scripts are available on Github.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Among 233 320 patients identified who survived the index heart failure admission across 335 NHS hospitals between Jan 1, 2019, and Dec 31, 2022, 101 320 (43·4%) had HFrEF, 71 910 (30·8%) had HFpEF, and 60 090 (25·8%) had an unknown classification (table). 128 615 (55·1%) had an emergency rehospitalisation and 75 235 (32·2%) died within 1 year of discharge from the index heart failure admission. Median follow-up was 365 days (IQR 228–365) for the whole study population and 107 days (40–215) for patients that died within 1 year of discharge. Patients with new onset heart failure (83 160 [35·6%]) were generally slightly younger, more often female, and had fewer coexisting chronic medical conditions than patients with chronic decompensated heart failure (150 160 [64·4%]; appendix pp 12–14).

Compared with patients with HFrEF, those with HFpEF were older (mean 80·2 years [SD 11·0] vs 75·2 years [13·6]), had higher BMI (mean 29·9 kg/m² [8·2] vs 28·6 kg/m² [7·3]), were more often female

	Reduced ejection fraction (reference group; events/N)	Preserved ejection fraction (events/N)	Reduced ejection fraction (reference group; crude event rate per 100 person-years)	Preserved ejection fraction (crude event rate per 100 person-years)		Hazard ratio (95% CI)
Rehospitalisation						
All-cause	37185/74580	34445/56735	86·9	121·4		1·20 (1·18–1·22)
Cardiovascular	18750/74580	16960/56735	36·0	45·0		1·19 (1·17–1·22)
Non-cardiovascular	26975/74580	26455/56735	55·3	79·6		1·22 (1·20–1·24)
Heart failure	12825/74580	12580/56735	23·2	31·5		1·25 (1·22–1·29)
COVID-19*	1635/64225	1700/47310	3·1	4·5		1·26 (1·17–1·35)
Mortality						
All-cause	20800/74580	18025/56735	34·0	39·4		1·07 (1·05–1·09)
Cardiovascular	12055/74580	8875/56735	19·7	19·4		0·94 (0·92–0·97)
Non-cardiovascular	8750/74580	9150/56735	14·3	20·0		1·25 (1·21–1·29)
Heart failure	3260/74580	2015/56735	5·3	4·4		0·74 (0·69–0·78)
COVID-19*	1170/64225	1025/47310	2·2	2·7		1·05 (0·96–1·15)

0·50   0·75   1·00   1·25   1·50   1·75   2·00

Risk for those with reduced ejection fraction   Risk for those with preserved ejection fraction

Figure 2: **Rates of 1-year all-cause and cause-specific rehospitalisation and mortality in patients with new onset and chronic decompensated heart failure**
Patients were admitted to hospital between Nov 1, 2019, and Dec 31, 2022. Cofounders adjusted for in the analyses are shown in the appendix (p 7). *Analyses of death due to COVID-19 were done in patients with no history of COVID-19 diagnosis at index admission for heart failure. COVID-19-related rehospitalisation and mortality are included within the non-cardiovascular category. All counts are rounded to the nearest five.

(39735 [55·3%] *vs* 36585 [36·1%]), had five or more chronic medical conditions (59550 [82·8%] *vs* 72240 [71·3%]; table), were more likely to have diabetes (27825 [38·7%] *vs* 35850 [35·4%]), chronic kidney disease (44515 [61·9%] *vs* 53775 [53·1%]), hypertension (65130 [90·6%] *vs* 83865 [82·8%]), atrial fibrillation or flutter (48000 [66·8%] *vs* 58400 [57·6%]), and were less likely to have ischaemic heart disease (39990 [55·6%] *vs* 63710 [62·9%]; shown by calendar year in the appendix pp 15–16). The prevalence of key characteristics (including demographic factors and coexisting chronic medical conditions) remained generally consistent across the study period (appendix pp 15–16). Patients with unknown heart failure were more likely than those with HFrEF or HFpEF to have missing data for all covariates, to be older females, and to present with new onset heart failure (table).

In patients with new onset heart failure, there were reductions in all-cause 30-day (–5·2% [95% CI –7·7 to –2·6] in 2019–22) and 1-year rehospitalisation rates (–3·9% [–6·6 to –1·2]). Declining 30-day rehospitalisation rates affected patients with HFpEF (–4·8% [–9·2 to –0·2]) and HFrEF (–6·2% [–10·5 to –1·6]), although 1-year rates were not statistically significant for patients with HFpEF (–2·2% [–6·6 to 2·3] *vs* –5·7% [–10·6 to –0·5] for HFrEF; figure 1A, B; appendix pp 23–24). Overall reductions in rehospitalisation over the study period were also observed in patients with unknown heart failure (appendix pp 25–26). Trends in rates of rehospitalisation in patients with HFrEF or HFpEF estimated by Joinpoint regression and Fine–Gray models were consistent with those estimated by quasi-Poisson models (appendix p 17).

There were no temporal trends in incidence rates of 30-day or 1-year mortality after discharge over the study period (figure 1C, D). Transient increases in 30-day all-cause and non-cardiovascular mortality were observed immediately preceding COVID-19 lockdowns in England, with swift reductions noted subsequently after lockdowns (figure 1, appendix pp 23–24). These patterns were also observed for patients with HFrEF and HFpEF, and unknown heart failure (appendix pp 25–26).

For patients with new onset or chronic decompensated heart failure, the rates of all-cause (HR 1·20 [95% CI 1·18–1·22]) and cause-specific rehospitalisation were uniformly higher in those with HFpEF than those with HFrEF (figure 2). Patients with HFpEF also had higher rates of 1-year all-cause mortality after discharge (HR 1·07 [1·05–1·09]), driven by excess risk of non-cardiovascular death (HR 1·25 [1·21–1·29]). Conversely, rates of cardiovascular and heart failure-related death were higher among patients with HFrEF than those with HFpEF. There were no significant differences in the rates of COVID-19-related death between patients with HFrEF and HFpEF (HR 1·05 [0·96–1·15]). HRs for all-cause rehospitalisation and mortality in patients with HFpEF were largest among those of younger age (<70 years) and higher socioeconomic status (appendix p 28). Analyses of new onset heart failure and chronic decompensated heart failure separately showed consistent patterns with each other and the main analysis (appendix pp 29–30). Patients with unknown heart failure had markedly higher rates of mortality than those with HFrEF and HFpEF, which was mostly driven by non-cardiovascular causes (appendix pp 31–32). HRs for rehospitalisation and mortality were similar to the main

analysis in analyses in which HFrEF or HFpEF was imputed in individuals with unknown heart failure (appendix p 33). Analyses restricted to 185 hospitals with 50% or more of heart failure cases linkable to the NHFA led to 188 835 patients eligible for inclusion in this study. These data showed no major changes in patient characteristics (appendix p 18), temporal trends in rehospitalisation and mortality outcomes after discharge (appendix p 34), or differences in rehospitalisation and mortality rates between patients with HFrEF and HFpEF (appendix p 35) compared with data in which hospitals with 10% or more of heart failure cases linkable to the NHFA were excluded.

The highest rates of rehospitalisation and mortality were observed in patients with coexisting chronic kidney disease, chronic obstructive pulmonary disease, dementia, and liver disease, regardless of heart failure classification (figure 3). Coexisting atrial fibrillation or flutter was not associated with higher rates of rehospitalisation or mortality. The population-attributable fractions for chronic kidney disease were double that of any other selected coexisting chronic medical condition, contributing to 6·5% (95% CI 5·6–7·4) of rehospitalisations within 1 year in patients with HFrEF and 5·0% (4·1–5·9) of rehospitalisations in those with HFpEF (appendix p 19). Coexisting chronic kidney disease also contributed to 15·3% (13·7–16·9) of deaths within 1 year in patients with HFrEF and 11·3% (9·5–13·0) of deaths in those with HFpEF.

In HFrEF, the dispensing of ARN inhibitors increased from 4·5% in patients admitted in January, 2019, to 37·3% in December, 2022 (figure 4A). The dispensing of SGLT2 inhibitors rose from 1·6% to 66·0% during the same time period, surpassing MRAs and ARN inhibitors and ACE inhibitor or ARB. In HFpEF, only dispensing of SGLT2 inhibitors increased during the study period, reaching 21·5% in December, 2022 (figure 4B). In patients with HFrEF, those without chronic kidney disease had higher dispensing rates than those with chronic kidney disease, specifically of MRAs (260 [73·4%] of 355 vs 90 [46·3%] of 190), SGLT2 inhibitors (260 [72·3%] vs 105 [54·2%]), and ARN inhibitors (170 [47·1%] vs 35 [18·9%]; numbers rounded to the nearest five but percentages are shown based on the analysis of the exact number of individuals) in December, 2022 (figure 4C, E). The COVID-19 pandemic appeared to affect patients with HFrEF and chronic kidney disease the most, as evidenced by marked reductions in medications dispensed to patients admitted to hospital in March, 2020 (figure 4E). These patterns were consistent across analyses by baseline eGFR, with incremental reductions in dispensing for patients with eGFR from 30 to less than 60 mL/min per 1·73 m² and eGFR of less than 30 mL/min per 1·73 m² (appendix p 42). By the end of the study, 130 (36·7%) of 355 patients with HFrEF and without chronic kidney disease had therapy comprising an ARN inhibitor, β blocker, MRA, and an SGLT2 inhibitor,

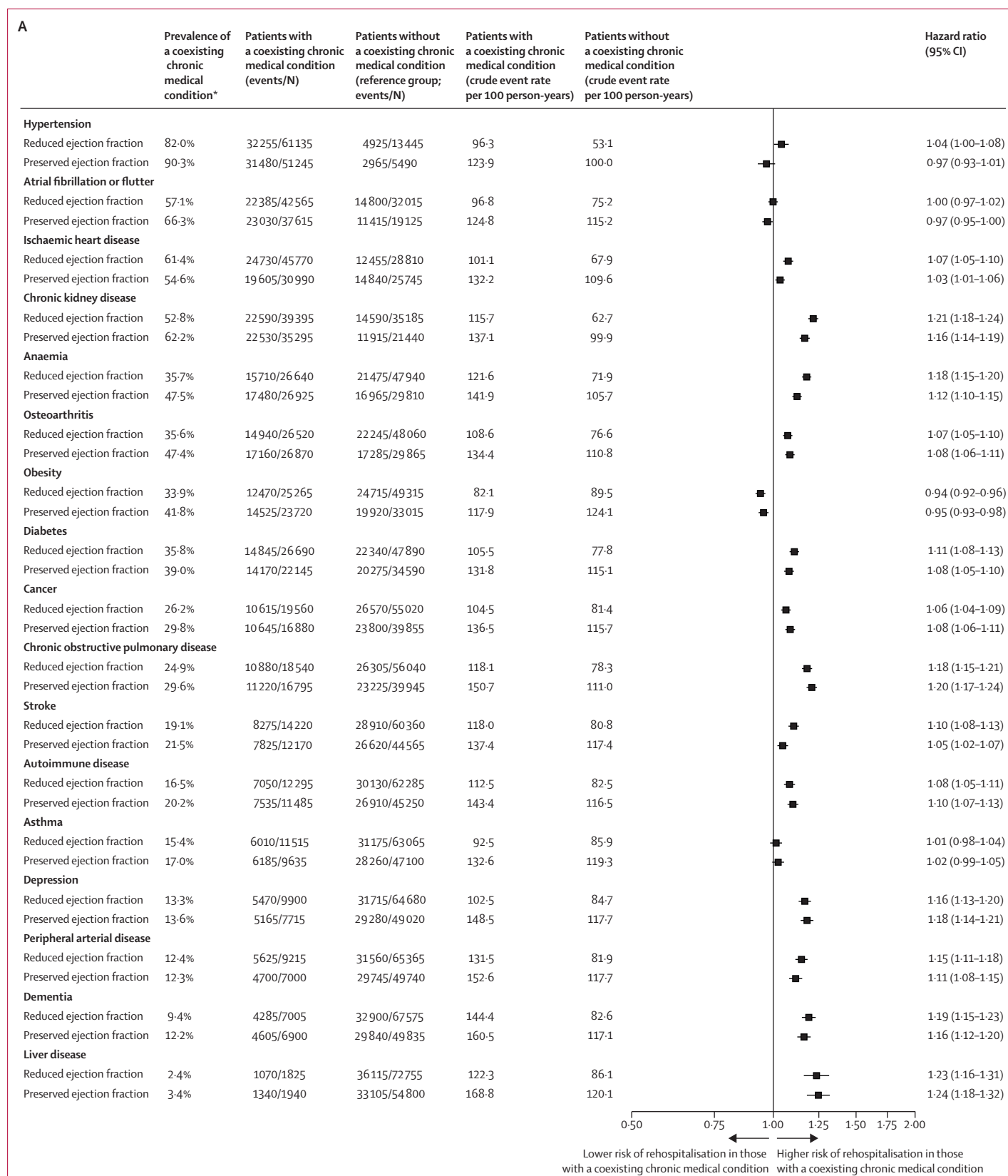compared with 25 (12·6%) of 190 patients with HFrEF and chronic kidney disease.

Discussion

Comparing health outcomes among patients who survived the index hospitalisation for HFrEF and HFpEF between Jan, 2019, and Dec, 2022, using whole-population data with 57 million individuals, our study shows reductions in rehospitalisation, neutral mortality rates (ie, no temporal trends), and overall improvements in implementation of GRMT after discharge from hospital during this period. Compared with HFrEF, patients with HFpEF had higher rates of all-cause rehospitalisation and overall mortality driven by non-cardiovascular causes. These rates were further amplified in patients with coexisting chronic medical conditions, particularly chronic kidney disease which contributed to double the rehospitalisations and deaths compared with any other coexisting chronic medical condition. Additionally, the proportion of patients receiving GRMT after discharge was lower among those with coexisting chronic kidney disease. This finding is especially pertinent given that the safety and relative effects of newer therapies are not modified by kidney function, but the absolute benefits might be greater in patients with chronic kidney disease due to higher rates of rehospitalisation and mortality.[25–29]
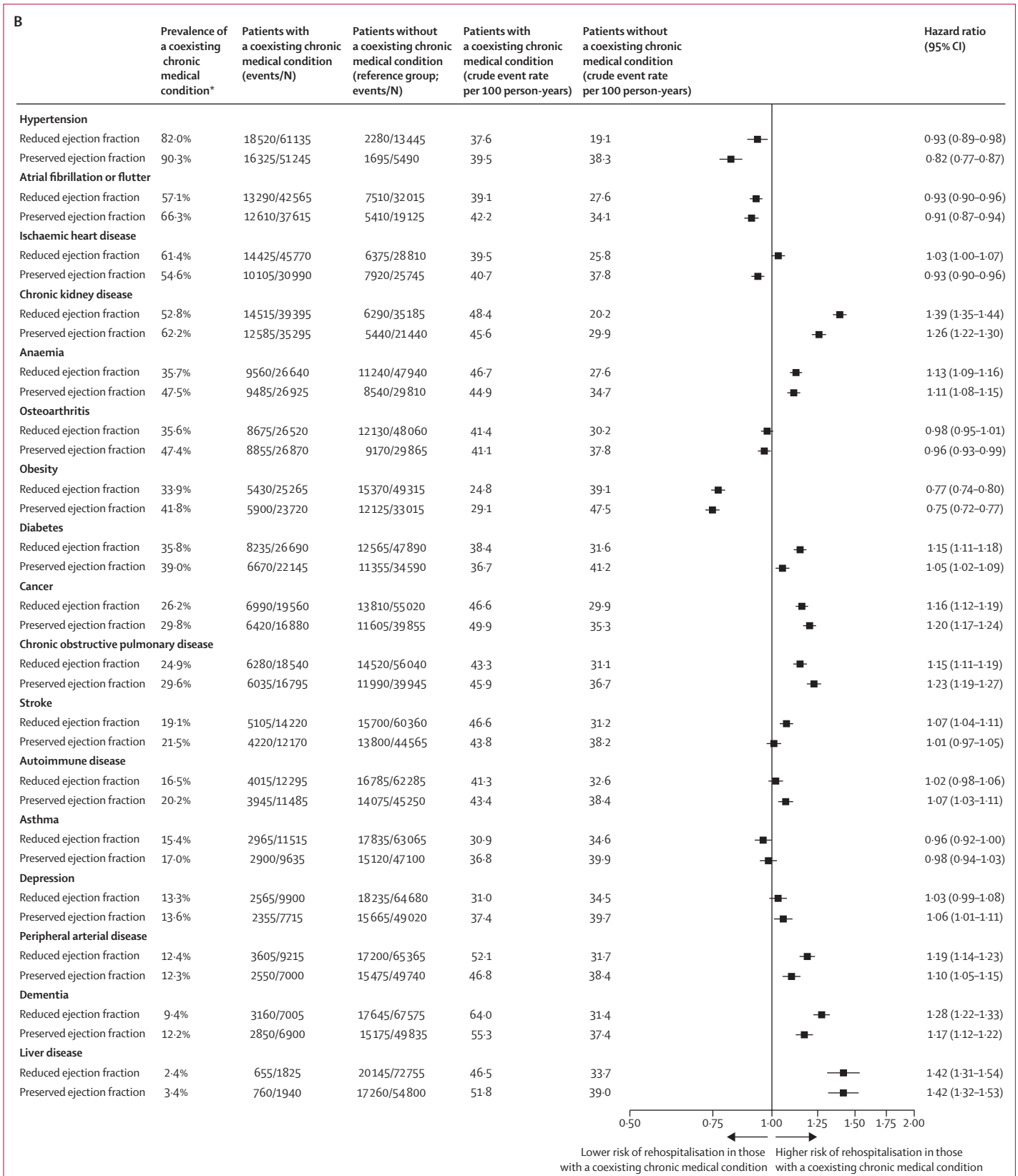
To our knowledge, this study is the first to report whole-population trends in rehospitalisation for patients with HFrEF and HFpEF separately, showing declining trends in 30-day and 1-year rehospitalisation for HFrEF, and 30-day rehospitalisation for HFpEF despite the COVID-19 pandemic. These findings suggest a reversal of previous worsening trends observed between 1998 and 2015 among individuals with heart failure in the UK,[17,30] possibly due to an improvement in heart failure management in the UK, including widespread implementation of effective new GRMT. Changes in care patterns during the pandemic, including increased ambulatory care or use of virtual wards for heart failure, might have also contributed to the observed trends. Despite these improvements, the high overall rates of rehospitalisation highlight the crucial need for heart failure prevention, in terms of primary prevention in individuals at high risk and reducing readmissions in those with established heart failure.

The stable mortality rates observed in our study differ from the declines in mortality among individuals with heart failure between 1996 and 2020 that have been reported in Denmark[31] and data from the USA reporting a complete reversal in previously declining mortality trends with mortality from heart failure higher in 2021 than in 1999.[14] These differences suggest that, even among high-income countries, health trajectories for heart failure are not uniform and are likely to be influenced by setting, health-care access, sociodemographic factors, and health system response to the COVID-19

A

	Prevalence of a coexisting chronic medical condition*	Patients with a coexisting chronic medical condition (events/N)	Patients without a coexisting chronic medical condition (reference group; events/N)	Patients with a coexisting chronic medical condition (crude event rate per 100 person-years)	Patients without a coexisting chronic medical condition (crude event rate per 100 person-years)		Hazard ratio (95% CI)
Hypertension							
Reduced ejection fraction	82·0%	32255/61135	4925/13445	96·3	53·1		1·04 (1·00–1·08)
Preserved ejection fraction	90·3%	31480/51245	2965/5490	123·9	100·0		0·97 (0·93–1·01)
Atrial fibrillation or flutter							
Reduced ejection fraction	57·1%	22385/42565	14800/32015	96·8	75·2		1·00 (0·97–1·02)
Preserved ejection fraction	66·3%	23030/37615	11415/19125	124·8	115·2		0·97 (0·95–1·00)
Ischaemic heart disease							
Reduced ejection fraction	61·4%	24730/45770	12455/28810	101·1	67·9		1·07 (1·05–1·10)
Preserved ejection fraction	54·6%	19605/30990	14840/25745	132·2	109·6		1·03 (1·01–1·06)
Chronic kidney disease							
Reduced ejection fraction	52·8%	22590/39395	14590/35185	115·7	62·7		1·21 (1·18–1·24)
Preserved ejection fraction	62·2%	22530/35295	11915/21440	137·1	99·9		1·16 (1·14–1·19)
Anaemia							
Reduced ejection fraction	35·7%	15710/26640	21475/47940	121·6	71·9		1·18 (1·15–1·20)
Preserved ejection fraction	47·5%	17480/26925	16965/29810	141·9	105·7		1·12 (1·10–1·15)
Osteoarthritis							
Reduced ejection fraction	35·6%	14940/26520	22245/48060	108·6	76·6		1·07 (1·05–1·10)
Preserved ejection fraction	47·4%	17160/26870	17285/29865	134·4	110·8		1·08 (1·06–1·11)
Obesity							
Reduced ejection fraction	33·9%	12470/25265	24715/49315	82·1	89·5		0·94 (0·92–0·96)
Preserved ejection fraction	41·8%	14525/23720	19920/33015	117·9	124·1		0·95 (0·93–0·98)
Diabetes							
Reduced ejection fraction	35·8%	14845/26690	22340/47890	105·5	77·8		1·11 (1·08–1·13)
Preserved ejection fraction	39·0%	14170/22145	20275/34590	131·8	115·1		1·08 (1·05–1·10)
Cancer							
Reduced ejection fraction	26·2%	10615/19560	26570/55020	104·5	81·4		1·06 (1·04–1·09)
Preserved ejection fraction	29·8%	10645/16880	23800/39855	136·5	115·7		1·08 (1·06–1·11)
Chronic obstructive pulmonary disease							
Reduced ejection fraction	24·9%	10880/18540	26305/56040	118·1	78·3		1·18 (1·15–1·21)
Preserved ejection fraction	29·6%	11220/16795	23225/39945	150·7	111·0		1·20 (1·17–1·24)
Stroke							
Reduced ejection fraction	19·1%	8275/14220	28910/60360	118·0	80·8		1·10 (1·08–1·13)
Preserved ejection fraction	21·5%	7825/12170	26620/44565	137·4	117·4		1·05 (1·02–1·07)
Autoimmune disease							
Reduced ejection fraction	16·5%	7050/12295	30130/62285	112·5	82·5		1·08 (1·05–1·11)
Preserved ejection fraction	20·2%	7535/11485	26910/45250	143·4	116·5		1·10 (1·07–1·13)
Asthma							
Reduced ejection fraction	15·4%	6010/11515	31175/63065	92·5	85·9		1·01 (0·98–1·04)
Preserved ejection fraction	17·0%	6185/9635	28260/47100	132·6	119·3		1·02 (0·99–1·05)
Depression							
Reduced ejection fraction	13·3%	5470/9900	31715/64680	102·5	84·7		1·16 (1·13–1·20)
Preserved ejection fraction	13·6%	5165/7715	29280/49020	148·5	117·7		1·18 (1·14–1·21)
Peripheral arterial disease							
Reduced ejection fraction	12·4%	5625/9215	31560/65365	131·5	81·9		1·15 (1·11–1·18)
Preserved ejection fraction	12·3%	4700/7000	29745/49740	152·6	117·7		1·11 (1·08–1·15)
Dementia							
Reduced ejection fraction	9·4%	4285/7005	32900/67575	144·4	82·6		1·19 (1·15–1·23)
Preserved ejection fraction	12·2%	4605/6900	29840/49835	160·5	117·1		1·16 (1·12–1·20)
Liver disease							
Reduced ejection fraction	2·4%	1070/1825	36115/72755	122·3	86·1		1·23 (1·16–1·31)
Preserved ejection fraction	3·4%	1340/1940	33105/54800	168·8	120·1		1·24 (1·18–1·32)

0·50   0·75   1·00   1·25   1·50   1·75   2·00

← Lower risk of rehospitalisation in those with a coexisting chronic medical condition   Higher risk of rehospitalisation in those with a coexisting chronic medical condition →

(Figure 3 continues on next page)

B

	Prevalence of a coexisting chronic medical condition*	Patients with a coexisting chronic medical condition (events/N)	Patients without a coexisting chronic medical condition (reference group; events/N)	Patients with a coexisting chronic medical condition (crude event rate per 100 person-years)	Patients without a coexisting chronic medical condition (crude event rate per 100 person-years)		Hazard ratio (95% CI)
Hypertension							
Reduced ejection fraction	82·0%	18520/61135	2280/13445	37·6	19·1		0·93 (0·89–0·98)
Preserved ejection fraction	90·3%	16325/51245	1695/5490	39·5	38·3		0·82 (0·77–0·87)
Atrial fibrillation or flutter							
Reduced ejection fraction	57·1%	13290/42565	7510/32015	39·1	27·6		0·93 (0·90–0·96)
Preserved ejection fraction	66·3%	12610/37615	5410/19125	42·2	34·1		0·91 (0·87–0·94)
Ischaemic heart disease							
Reduced ejection fraction	61·4%	14425/45770	6375/28810	39·5	25·8		1·03 (1·00–1·07)
Preserved ejection fraction	54·6%	10105/30990	7920/25745	40·7	37·8		0·93 (0·90–0·96)
Chronic kidney disease							
Reduced ejection fraction	52·8%	14515/39395	6290/35185	48·4	20·2		1·39 (1·35–1·44)
Preserved ejection fraction	62·2%	12585/35295	5440/21440	45·6	29·9		1·26 (1·22–1·30)
Anaemia							
Reduced ejection fraction	35·7%	9560/26640	11240/47940	46·7	27·6		1·13 (1·09–1·16)
Preserved ejection fraction	47·5%	9485/26925	8540/29810	44·9	34·7		1·11 (1·08–1·15)
Osteoarthritis							
Reduced ejection fraction	35·6%	8675/26520	12130/48060	41·4	30·2		0·98 (0·95–1·01)
Preserved ejection fraction	47·4%	8855/26870	9170/29865	41·1	37·8		0·96 (0·93–0·99)
Obesity							
Reduced ejection fraction	33·9%	5430/25265	15370/49315	24·8	39·1		0·77 (0·74–0·80)
Preserved ejection fraction	41·8%	5900/23720	12125/33015	29·1	47·5		0·75 (0·72–0·77)
Diabetes							
Reduced ejection fraction	35·8%	8235/26690	12565/47890	38·4	31·6		1·15 (1·11–1·18)
Preserved ejection fraction	39·0%	6670/22145	11355/34590	36·7	41·2		1·05 (1·02–1·09)
Cancer							
Reduced ejection fraction	26·2%	6990/19560	13810/55020	46·6	29·9		1·16 (1·12–1·19)
Preserved ejection fraction	29·8%	6420/16880	11605/39855	49·9	35·3		1·20 (1·17–1·24)
Chronic obstructive pulmonary disease							
Reduced ejection fraction	24·9%	6280/18540	14520/56040	43·3	31·1		1·15 (1·11–1·19)
Preserved ejection fraction	29·6%	6035/16795	11990/39945	45·9	36·7		1·23 (1·19–1·27)
Stroke							
Reduced ejection fraction	19·1%	5105/14220	15700/60360	46·6	31·2		1·07 (1·04–1·11)
Preserved ejection fraction	21·5%	4220/12170	13800/44565	43·8	38·2		1·01 (0·97–1·05)
Autoimmune disease							
Reduced ejection fraction	16·5%	4015/12295	16785/62285	41·3	32·6		1·02 (0·98–1·06)
Preserved ejection fraction	20·2%	3945/11485	14075/45250	43·4	38·4		1·07 (1·03–1·11)
Asthma							
Reduced ejection fraction	15·4%	2965/11515	17835/63065	30·9	34·6		0·96 (0·92–1·00)
Preserved ejection fraction	17·0%	2900/9635	15120/47100	36·8	39·9		0·98 (0·94–1·03)
Depression							
Reduced ejection fraction	13·3%	2565/9900	18235/64680	31·0	34·5		1·03 (0·99–1·08)
Preserved ejection fraction	13·6%	2355/7715	15665/49020	37·4	39·7		1·06 (1·01–1·11)
Peripheral arterial disease							
Reduced ejection fraction	12·4%	3605/9215	17200/65365	52·1	31·7		1·19 (1·14–1·23)
Preserved ejection fraction	12·3%	2550/7000	15475/49740	46·8	38·4		1·10 (1·05–1·15)
Dementia							
Reduced ejection fraction	9·4%	3160/7005	17645/67575	64·0	31·4		1·28 (1·22–1·33)
Preserved ejection fraction	12·2%	2850/6900	15175/49835	55·3	37·4		1·17 (1·12–1·22)
Liver disease							
Reduced ejection fraction	2·4%	655/1825	20145/72755	46·5	33·7		1·42 (1·31–1·54)
Preserved ejection fraction	3·4%	760/1940	17260/54800	51·8	39·0		1·42 (1·32–1·53)

0·50 0·75 1·00 1·25 1·50 1·75 2·00

Lower risk of rehospitalisation in those with a coexisting chronic medical condition ← | → Higher risk of rehospitalisation in those with a coexisting chronic medical condition

pandemic. Overall, our study extends previous epidemiological data by providing detailed insights into temporal patterns of rehospitalisation by heart failure classification during 2019–22.

Contrary to previous epidemiological surveys, we found that patients with HFpEF showed worse prognoses after discharge than those with HFrEF.[32,33] Higher rates of rehospitalisation in those with HFpEF were consistent across causes for admission to hospital, whereas higher mortality was driven by non-cardiovascular causes. Developments in management and faster implementation of newer therapies for HFrEF in England compared with other countries[32,34] might have contributed to improvements in overall survival for these patients. Additionally, the greater burden of coexisting chronic medical conditions in patients with HFpEF than in those with HFrEF (notably, chronic kidney disease, diabetes, obesity, and hypertension) is associated with worse prognosis and complicates heart failure management and treatment.[35] The elevated rehospitalisation and mortality rates in HFpEF underscore the need for primary prevention strategies, including blood pressure control, addressing overweight or obesity, and mitigating other risk factors, alongside ongoing efforts to identify effective treatments to reduce rehospitalisation in these patients.

Our analyses of whole-population data on dispensed medications indicate there has been more rapid and widespread implementation of GRMT in England than in the USA,[34] particularly with ARN inhibitors and SGLT2 inhibitors in HFrEF. These trends coincide with evidence-based recommendations by the UK National Institute for Health and Care Excellence and updates in treatment guidelines.[2] Large randomised trials of ARN inhibitors and SGLT2 inhibitors have established the combined initiation of an ARN inhibitor, β blocker, MRA, and SGLT2 inhibitor as the guideline-recommended therapeutic standard in patients with HFrEF,[36] possibly extending survival by up to 3 years compared with conventional therapy.[37] Whereas, contemporary evidence-based GRMT for those with HFpEF includes only SGLT2 inhibitors.[2] These new insights into the treatment of patients with HFrEF or HFpEF suggest that implementation of optimal GRMT in England was far from complete by the end of our study, since only one in four (36·7%) patients with HFrEF had quadruple therapy, and one in five (21·5%) patients with HFpEF had an SGLT2 inhibitor. Additionally, increased uptake of SGLT2 inhibitors in patients with chronic kidney disease who do not have heart failure is likely to be an important strategy to prevent heart failure in individuals at high risk.

Our results have also provided new insight into the adverse effect of chronic kidney disease on the prognosis and management of HFrEF and HFpEF. We observed population-attributable fractions for chronic kidney disease that were double those of any other coexisting chronic medical condition in patients with HFrEF and HFpEF, both for rehospitalisation and mortality. The effect of coexisting chronic medical conditions on clinical outcomes at a whole-population scale has not been previously quantified. Furthermore, we found that patients with heart failure and chronic kidney disease had lower dispensing of GRMT than patients without coexisting chronic kidney disease. These findings were most pronounced in HFrEF, for which there was markedly slower implementation of newer evidence-based therapies and disruption in dispensing at the onset of the COVID-19 pandemic. Our results highlight a substantial risk–treatment paradox for patients with heart failure and coexisting chronic kidney disease, which might owe to the withholding, withdrawal, or cessation of GRMT due to safety concerns and potential adverse outcomes.[20] Given the safety and consistent benefits of ARN inhibitors and SGLT2 inhibitors on heart failure outcomes and chronic kidney disease progression across the spectrum of kidney function,[25–28,38,39] addressing the underuse of these medications should be a health-care priority.

The strengths of this study include the novel linkage and analysis of multiple electronic health record sources encompassing 96% of the population in England. These linked datasets were crucial in creating the largest, nationally representative population of patients with hospitalised heart failure. In particular, our study is the first to report on routinely collected and linked data, including dispensing data, with multiple audits from the NICOR National Cardiac Audit Programme, permitting stratified analyses of prognoses and treatments in HFrEF and HFpEF.

The potential limitations of this study merit consideration. First, our study population was restricted to patients admitted to hospital due to heart failure, likely skewing towards more advanced heart failure, and included only those who survived the initial heart failure admission, necessitating further investigation of in-hospital mortality. Second, our analyses were limited by missing data on LVEF values, thus restricting our ability to reliably classify heart failure with mid-range ejection fraction (HFmrEF).[40] Although this phenotype is recognised across practice guidelines, patients with HFmrEF are recommended the same treatments and care as those with HFpEF.[2] Reliance on a single measure of LVEF for stratification of heart failure might have resulted in misclassification; however, we found strong similarities between our patient characteristics and those in other cohorts and major clinical trials involving clinician-validated diagnoses,[9,12,32] and any

Figure 3: Associations of coexisting chronic medical conditions with 1-year all-cause rehospitalisation (A) and mortality (B) in patients with heart failure

Patients were admitted to hospital between Nov 1, 2019, and Dec 31, 2022.
*Coexisting chronic medical conditions are ordered according to their prevalence in these patients combined. All counts are rounded to the nearest five.
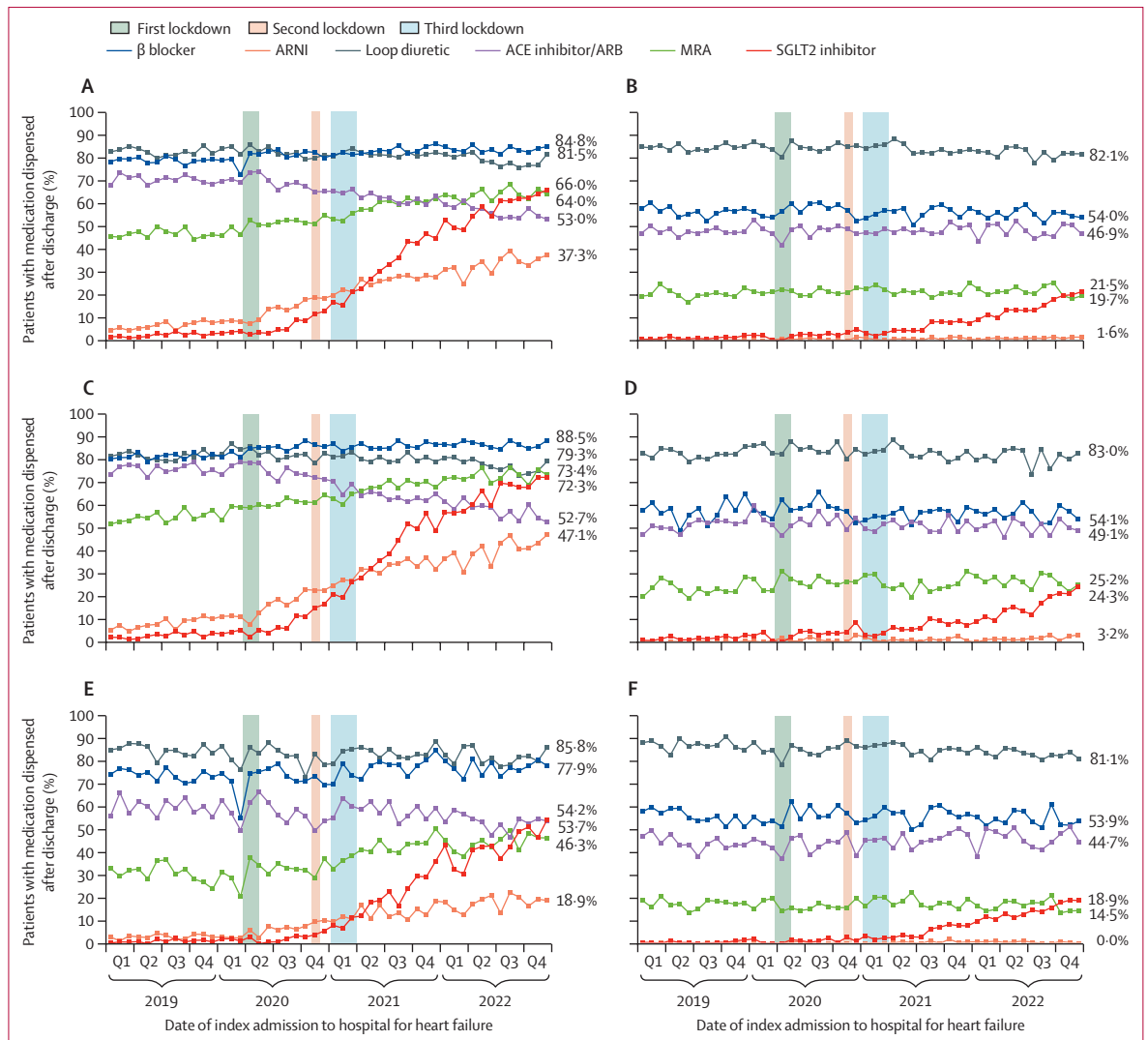
Figure 4: Temporal trends in dispensing of guideline-recommended medical therapy after discharge from hospital in patients with heart failure and reduced (n=31 635) or preserved ejection fraction (n=23 560)

Reduced ejection fraction (A) or preserved ejection fraction (B) overall. Reduced ejection fraction (C) or preserved ejection fraction (D) without chronic kidney disease. Reduced ejection fraction (E) or preserved ejection fraction (F) with chronic kidney disease. Proportion of patients with medication dispensed within 6 months after discharge from the index hospitalisation for heart failure. The first COVID-19 lockdown in England occurred from March 23 to May 13, 2020 (individuals permitted to leave home for outdoor recreation), the second lockdown from Nov 5 to Dec 20, 2020, and the third lockdown from Jan 6 to March 29, 2021. ACE=angiotensin-converting enzyme. ARB=angiotensin receptor blocker. ARNI=angiotensin receptor-neprilysin inhibitor. MRA=mineralocorticoid receptor antagonist. Q=quarter. SGLT2=sodium-glucose cotransporter 2.

misclassification would likely attenuate observed differences, leading to more conservative (rather than exaggerated) comparisons. Furthermore, around a quarter (25·8%) of heart failure patients in our study had unknown heart failure, particularly among older adults, and those previously discharged to care homes (and therefore more likely to have been admitted to geriatric wards). Nevertheless, the ability to compare outcomes for HFpEF and HFrEF in most patients and the robustness of our results in sensitivity analyses distinguishes our study from most previous population-wide studies.

Improving LVEF recording in electronic health records and national audits is essential for more comprehensive whole-population analyses of HFrEF and HFpEF. Third, even with careful and comprehensive adjustment for known confounders, the observational nature of our analysis constrains any causal inference, with residual confounding possible due to imperfectly measured, imputed-with-error, or known-but-unmeasured confounders.

In summary, rates of rehospitalisation in patients with HFrEF and HFpEF in England have substantially decreased in 2019–22. Rates of rehospitalisation were

higher in those with HFpEF than in those with HFrEF, possibly indicating improved management of HFrEF due to swift implementation of GRMT. Our study suggests that patients with chronic kidney disease, who represent more than 50% of this population, are at high risk and remain undertreated. Improved management of coexisting chronic medical conditions, particularly in HFpEF in which the rates of rehospitalisation for all causes and non-cardiovascular mortality are higher than in HFrEF, and enhanced implementation of GRMT in those with coexisting chronic kidney disease, regardless of heart failure classification, present crucial priorities to improve public health policy and clinical practice for heart failure.

Data sharing
The data used in this study are available in the NHS England Secure Data Environment service, but are not publicly available (https://digital.nhs.uk/services/secure-data-environment-service). The CVD-COVID-UK/COVID-IMPACT Consortium, led by the British Heart Foundation Data Science Centre (https://bhfdatasciencecentre.org/), received approval to access data within the Secure Data Environment service from the Independent Group Advising on the Release of Data (https://digital.nhs.uk/about-nhs-digital/corporate-information-and-documents/independent-group-advising-on-the-release-of-data) using an application made in the Data Access Request Service Online system (DARS-NIC-381078-Y9C5K; https://digital.nhs.uk/services/data-access-request-service-dars/dars-products-and-services). The CVD-COVID-UK/COVID-IMPACT Approvals and Oversight Board (https://bhfdatasciencecentre.org/areas/cvd-covid-uk-covid-impact/) subsequently granted approval for this specific project to access the data within the Secure Data Environment service. The de-identified data can be made available to accredited researchers by emailing bhfdsc@hdruk.ac.uk.

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