Patient emergency health-care use before hospital admission for COVID-19 and long-term outcomes in Scotland: a national cohort study

Patient emergency health-care use before hospital admission for COVID-19 and long-term outcomes in Scotland: a national cohort study

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Summary

Background It is unclear what effect the pattern of health-care use before admission to hospital with COVID-19 (index admission) has on the long-term outcomes for patients. We sought to describe mortality and emergency readmission to hospital after discharge following the index admission (index discharge), and to assess associations between these outcomes and patterns of health-care use before such admissions.

Methods We did a national, retrospective, complete cohort study by extracting data from several national databases and linking the databases for all adult patients admitted to hospital in Scotland with COVID-19. We used latent class trajectory modelling to identify distinct clusters of patients on the basis of their emergency admissions to hospital in the 2 years before the index admission. The primary outcomes were mortality and emergency readmission up to 1 year after index admission. We used multivariable regression models to explore associations between these outcomes and patient demographics, vaccination status, level of care received in hospital, and previous emergency hospital use.

Findings Between March 1, 2020, and Oct 25, 2021, 33 580 patients were admitted to hospital with COVID-19 in Scotland. Overall, the Kaplan-Meier estimate of mortality within 1 year of index admission was 29·6% (95% CI 29·1–30·2). The cumulative incidence of emergency hospital readmission within 30 days of index discharge was 14·4% (95% CI 14·0–14·8), with the number increasing to 35·6% (34·9–36·3) patients at 1 year. Among the 33 580 patients, we identified four distinct patterns of previous emergency hospital use: no admissions (n=18 772 [55·9%]); minimal admissions (n=12 057 [35·9%]); recently high admissions (n=1931 [5·8%]), and persistently high admissions (n=820 [2·4%]). Patients with recently or persistently high admissions were older, more multimorbid, and more likely to have hospital-acquired COVID-19 than patients with no or minimal admissions. People in the minimal, recently high, and persistently high admissions groups had an increased risk of mortality and hospital readmission compared with those in the no admissions group. Compared with the no admissions group, mortality was highest in the recently high admissions group (post-hospital mortality HR 2·70 [95% CI 2·35–2·81]; p<0·0001) and the risk of readmission was highest in the persistently high admissions group (3·23 [2·89–3·61]; p<0·0001).

Interpretation Long-term mortality and readmission rates for patients hospitalised with COVID-19 were high; within 1 year, one in three patients had died and a third had been readmitted as an emergency. Patterns of hospital use before index admission were strongly predictive of mortality and readmission risk, independent of age, pre-existing comorbidities, and COVID-19 vaccination status. This increasingly precise identification of individuals at high risk of poor outcomes from COVID-19 will enable targeted support.

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Introduction

It became clear during the course of the COVID-19 pandemic that patient demographics such as increasing age, multimorbidity, and severity of illness at presentation, are major risk factors for in-hospital mortality for COVID-19.[1,2] Although death is an important outcome to measure, patients and families might consider other person-centred outcomes (eg, hospital use) to be just as important, if not more so.[3] Data are emerging for the symptom burden and quality of life of these survivors, although data quality has been limited by convenience sampling[4] or incomplete population sampling,[1] leading to potential bias. Hospital readmission and health-care resource use, after discharge from hospitalisation for COVID-19, are measures that are highly person-centred, reasonably well recorded, easy to obtain, and not subject to such biases.[5] Health-care use after discharge varies enormously, with lower use among people with less severe COVID-19 illness.[6] The additional burden on secondary health-care resources that arises from subsequent use by people who survived hospitalisation for COVID-19 remains uncertain, particularly in relation

Research in context

Evidence before this study

We searched PubMed on June 14, 2022 for articles published in English, using the search terms ("SARS-CoV-2" OR "COVID-19" OR "Coronavirus") AND ("readmission" OR "hospital survivor") in the title or abstract. We searched for primary research articles documenting patterns of long-term mortality and readmission to hospital in patients who survived their index COVID-19 admission. Of 362 initial search results, 44 original research studies examined mortality or hospital readmission in non-pregnant adults. 20 studies had a maximum follow-up time of less than 3 months from discharge. Only five studies had follow-up greater than 6 months, and these were predominantly small, single-site cohort studies. These studies found that older patients, male patients, and those with comorbidities were more likely to die or be readmitted to hospital than other patients. Only one study quantified health-care use after COVID-19 diagnosis and none identified patterns of health-care use.

Added value of this study

The aim of this study was to systematically quantify the extent to which patients hospitalised with COVID-19 were at risk of dying or of being readmitted to hospital, in the context of the pattern of their emergency health-care use before COVID-19. In this national Scottish cohort we found that emergency readmission was common, with 35% of patients readmitted and one in three patients dying within 1 year of admission. Patients with a history of high use of health-care resource in the preceding 2 years were at higher risk of readmission and mortality independent of their age and multimorbidity, compared with patients with no or minimal resource use. Patients who had a high frequency of recent emergency admissions were at greatest risk of dying, both in hospital or after discharge. Patients who had persistently high emergency admissions also had high mortality and were at the highest risk of readmission.

Implications of all the available evidence

Patients hospitalised with COVID-19 experience high rates of mortality and health-care use in the year after hospital discharge. Defining preadmission trajectories of health-care use enables a more precise identification of individuals who are at high risk of poor outcomes compared with using age, comorbidities, and vaccination status. Such identification will enable early support to be appropriately targeted to these susceptible patients.

to patterns of hospital use by these patients before COVID-19. It is important to identify patients who are at high risk of mortality and readmission so that support can be instigated as early as possible.

Factors present before hospital admission, such as comorbidity and previous health-care use, have been shown to be stronger predictors of use of hospital resources than factors associated with the acute illness itself.[7] However, few studies have looked at longitudinal trajectories for use of hospitals at the population level.[8,9]

We hypothesised that trajectories of emergency admissions to hospital are a marker of clinical vulnerability that can help to identify patients at the highest risk of mortality and readmission, independent of age and comorbidities. We aimed to use national data for Scotland to ascertain if patterns of emergency use of a hospital in the 2 years before the index hospital admission with COVID-19 could identify patients at high risk of death and readmission.

See Online for appendix

Methods

Study design and participants

In this retrospective complete cohort study using linked national databases, we analysed individual-level routine health-care data for all patients aged 18 years or older who were admitted to hospital in Scotland after March 1, 2020, with COVID-19 acquired in the community or in hospital (index admission), and who died or were discharged before Oct 25, 2021. All patients were followed up until Nov 22, 2021, or until date of death, whichever came first.

Our data sources were the Scottish Morbidity Record general acute inpatient and day case (SMR01) dataset for hospital activity and mortality and the Scottish Morbidity Record outpatient (SMR00) dataset; Electronic Communication of Surveillance in Scotland for all positive microbiology laboratory specimen results; the Scottish Intensive Care Society Audit Group database, for all adult general intensive care activity; National Records Scotland for all deaths registered in Scotland; and Scottish COVID-19 Vaccination Data for COVID-19 vaccination events in Scotland since December, 2020 (appendix p 2).

Data from the different databases were provided and linked by Public Health Scotland.

Procedures

Hospital admission for COVID-19 was defined as admission within 14 days of a positive COVID-19 PCR test (index admission). Nosocomial infection was defined as a SARS-CoV-2-positive PCR test (using Electronic Communication of Surveillance in Scotland data) 5 or more days after hospital admission. To mitigate for inadequate testing provision at the start of the pandemic, we also included patients with COVID-19 that had been clinically coded in line with the International Classification of Diseases 10th Revision (ICD-10; appendix p 1). We categorised age into the following groups: younger than 50 years; 50–69 years; 70–79 years; and 80 years or older, on the basis of the univariable association between age and mortality, and consistent

with previous studies.[1] Socioeconomic deprivation was defined using quintiles of the Scottish Index of Multiple Deprivation 2020.[10] Race and ethnicity data were derived from the Scottish Census 2011,[11] and were aggregated as White or other owing to low frequencies of people selecting categories other than White. We used SMR01 data for acute hospital admissions to determine the number of comorbidities (using the list of comorbidities from the Charlson Comorbidity Index [CCI][12] for each patient. The acute-illness variables comprised admission to an intensive care unit (ICU), receipt of invasive ventilation, inotropic support, or renal replacement therapy, with data sourced from the Scottish Intensive Care Society Audit Group. COVID-19 pandemic waves were defined as follows: wave 1 was from March 1 to Aug 31, 2020 (the first admission of a patient with COVID-19 to hospital in Scotland was on March 3, 2020); wave 2 was from Sept 1, 2020 to April 30, 2021; and wave 3 was from May 1, 2021, to the end of the study period, on Nov 22, 2021. Patients were considered to be vaccinated against COVID-19 if the index admission was 3 weeks or more after the first COVID-19 vaccination or 2 weeks or longer after any booster.[13,14]

We extracted data from the Scottish Morbidity Record for emergency hospital admissions for the 2 years before the index admission for all patients. We categorised emergency hospital use by the number of days spent in hospital per 30-day period after emergency admission. Data for mortality and palliative discharge were taken from the National Records Scotland death records and we categorised palliative discharge as in-hospital mortality. We checked whether COVID-19 was mentioned on the death certificate as an underlying cause of death or as another condition.

The study received ethical approval from the South Central—Oxford C Research Ethics Committee in England (reference 13/SC/0149) and the Scotland A Research Ethics Committee (reference 20/SS/0028). Approval for access to the datasets was granted by the National Health Service (NHS) Scotland Public Benefit and Privacy Panel for Health and Social Care (reference 1920–0273).[1] We reported this study in accordance with the STROBE guidelines.

Outcomes

The primary outcomes were all-cause mortality (during the index admission and within 12 months after index discharge), and emergency readmission within 1 year after index discharge. The secondary outcome was use of hospital resources after index discharge.

Statistical analysis

The dataset was cleaned, recoded, linked, and analysed using R Core Team (version 3.6.4). Cells containing values for fewer than five patients were concealed to maintain patient anonymity. We did not do a sample size calculation as the sample size was fixed by the number of hospital admissions. We did a complete-case analysis; everyone without a vaccination record was classified as not vaccinated, so there were no missing data.

Using emergency admission to hospital as a potential marker of clinical vulnerability, we used latent class trajectory modelling to identify subgroups of patients with distinct trajectories of emergency health-care use. We modelled the frequency of emergency admission to hospital and the length of hospital stay within a 30-day period as a function of time in the 2 years before a patient's index admission. We used the R packages LCTMtools (version 0.1.3) and lcmm (version 2.0.2; appendix pp 1–2). We then applied the trajectories across all mortality and emergency readmissions.

To evaluate whether the temporal sequence in the trajectory improved model fit more than a simple count of emergency hospital use would have done, we also categorised the number of emergency-ward bed days during the previous 2 years, with a minimum unit of measurement of 0·5 days (0·5–7·0 days, 7·5–20·5 days and ≥21·0 days). For all models, we assessed performance by comparing trajectory clusters versus the number of bed days using the Bayesian information criterion (BIC). A change in BIC greater than 10 strongly favoured the model with the lower BIC.[15]

We used Kaplan-Meier estimates to report mortality and used cumulative incidence to report time to first admission at specified time points. We used logistic regression for in-hospital mortality with results presented as odds ratios (ORs). For survivors of hospitalisation for COVID-19, we used Cox proportional hazards regression analysis to account for differential follow-up, with results presented as hazard ratios (HRs). We used a cause-specific Cox proportional hazards approach to competing risk to model emergency hospital readmission, accounting for the competing risk of death. We included vaccination as a time-varying covariate to allow for effects in patients vaccinated after the index discharge. All patients had at least 4 weeks of follow-up after index hospital discharge and the maximum potential follow-up was 365 days. Patients alive on Nov 22, 2021 were censored.

We used three categories of health-care resource: outpatient appointments, admission to hospital as an inpatient (elective or emergency), and admission to hospital as a day case. We derived hospital care costs from the National Health Service (NHS) Scottish Costs Book,[16] and used costs per day. A same-day inpatient discharge was categorised as 0·5 days.

We calculated excess health-care use costs for each individual by comparing the costs for the 6 months after index discharge with the individual's baseline costs (defined as costs for the 18-month period between the 6 months and 2 years before index admission). We calculated these excess costs for all patients with at least 6 months follow-up before the censoring date, regardless of mortality status during this 6-month period to maximise the size of the cohort.

For the **STROBE guidelines** see https://www.strobe-statement.org/checklists/

	All	No admissions	Minimal admissions	Recently high admissions	Persistently high admissions	p value
Number of patients	33 580 (100%)	18 772 (55·9%)	12 057 (35·9%)	1931 (5·8%)	820 (2·4%)	
Age						<0·0001
Median, years	67·0 (53·0–80·0)	61·0 (48·0–75·0)	74·0 (59·0–83·0)	77·0 (67·0–85·0)	75·0 (62·0–84·0)	
18–59 years	12 279 (36·6%)	8626 (46·0%)	3168 (26·3%)	299 (15·5%)	186 (22·7%)	
60–69 years	5634 (16·8%)	3429 (18·3%)	1816 (15·1%)	284 (14·7%)	105 (12·8%)	
70–79 years	6964 (20·7%)	3386 (18·0%)	2844 (23·6%)	514 (26·6%)	220 (26·8%)	
≥80 years	8703 (25·9%)	3331 (17·7%)	4229 (35·1%)	834 (43·2%)	309 (37·7%)	
Sex						<0·0001
Female	16 427 (48·9%)	8764 (46·7%)	6243 (51·8%)	991 (51·3%)	429 (52·3%)	
Male	17 153 (51·1%)	10 008 (53·3%)	5814 (48·2%)	940 (48·7%)	391 (47·7%)	
Scotland-level quintile for the Scottish Index of Multiple Deprivation, 2020						<0·0001
1	10 507 (31·3%)	5635 (30·0%)	3939 (32·7%)	625 (32·4%)	308 (37·6%)	
2	8066 (24·0%)	4452 (23·7%)	2922 (24·2%)	503 (26·0%)	189 (23·0%)	
3	5781 (17·2%)	3197 (17·0%)	2123 (17·6%)	328 (17·0%)	133 (16·2%)	
4	4924 (14·7%)	2890 (15·4%)	1672 (13·9%)	247 (12·8%)	115 (14·0%)	
5	4208 (12·5%)	2523 (13·4%)	1386 (11·5%)	225 (11·7%)	74 (9·0%)	
Missing	29 206 (87·0%)	75 (0·4%)	15 (0·1%)	<5 (<0·5%)	<5 (<0·7%)	
Race or ethnicity						<0·0001
White	1498 (4·5%)	15308 (81·5%)	11245 (93·3%)	1855 (96·1%)	798 (97·3%)	
Other	2876 (8·6%)	1102 (5·9%)	355 (2·9%)	28 (1·5%)	13 (1·6%)	
Missing	4893 (14·6%)	2362 (12·6%)	457 (3·8%)	48 (2·5%)	9 (1·1%)	
Source of COVID-19 infection						<0·0001
Community	6696 (19·9%)	16100 (85·8%)	9108 (75·5%)	1233 (63·9%)	576 (70·2%)	
Nosocomial	17 686 (52·7%)	1765 (9·4%)	2317 (19·2%)	608 (31·5%)	203 (24·8%)	
Missing	9198 (27·4%)	907 (4·8%)	632 (5·2%)	90 (4·7%)	41 (5·0%)	
COVID-19 wave						<0·0001
Wave 1	6774 (20·2%)	3505 (18·7%)	2445 (20·3%)	489 (25·3%)	257 (31·3%)	
Wave 2	11 228 (33·4%)	9531 (50·8%)	6571 (54·5%)	1133 (58·7%)	451 (55·0%)	
Wave 3	9620 (28·6%)	5736 (30·6%)	3041 (25·2%)	309 (16·0%)	112 (13·7%)	
Vaccinated						<0·0001
Yes	12 732 (37·9%)	20 848 (62·1%)	15 129 (80·6%)	9331 (77·4%)	1639 (84·9%)	
No	20 848 (62·1%)	3643 (19·4%)	2726 (22·6%)	292 (15·1%)	113 (13·8%)	
Missing*	0	0	0	0	0	
Number of comorbidities†						<0·0001
0	67·0 (53·0–80·0)	8935 (47·6%)	2099 (17·4%)	145 (7·5%)	49 (6·0%)	
1	12 279 (36·6%)	5741 (30·6%)	3328 (27·6%)	429 (22·2%)	122 (14·9%)	
≥2	5634 (16·8%)	4096 (21·8%)	6630 (55·0%)	1357 (70·3%)	649 (79·1%)	
Acute myocardial infarction						<0·0001
Yes	3663 (10·9%)	17 595 (93·7%)	10 126 (84·0%)	1566 (81·1%)	630 (76·8%)	
No	29 917 (89·1%)	1177 (6·3%)	1931 (16·0%)	365 (18·9%)	190 (23·2%)	
Congestive heart failure						<0·0001
Yes	3229 (9·6%)	17 995 (95·9%)	10 273 (85·2%)	1476 (76·4%)	607 (74·0%)	
No	30 351 (90·4%)	777 (4·1%)	1784 (14·8%)	455 (23·6%)	213 (26·0%)	
Peripheral vascular disease						<0·0001
Yes	2403 (7·2%)	18 067 (96·2%)	10 807 (89·6%)	1627 (84·3%)	676 (82·4%)	
No	31 177 (92·8%)	705 (3·8%)	1250 (10·4%)	304 (15·7%)	144 (17·6%)	
Cerebrovascular disease						<0·0001
Yes	4590 (13·7%)	17 345 (92·4%)	9644 (80·0%)	1454 (75·3%)	547 (66·7%)	
No	28 990 (86·3%)	1427 (7·6%)	2413 (20·0%)	477 (24·7%)	273 (33·3%)	

(Table continues on next page)

	All	No admissions	Minimal admissions	Recently high admissions	Persistently high admissions	p value
(Continued from previous page)						
Dementia						<0·0001
Yes	2487 (7·4%)	18 035 (96·1%)	10 705 (88·8%)	1671 (86·5%)	682 (83·2%)	
No	31 093 (92·6%)	737 (3·9%)	1352 (11·2%)	260 (13·5%)	138 (16·8%)	
Chronic pulmonary disease						<0·0001
Yes	8754 (26·1%)	15 208 (81·0%)	7981 (66·2%)	1203 (62·3%)	434 (52·9%)	
No	24 826 (73·9%)	3564 (19·0%)	4076 (33·8%)	728 (37·7%)	386 (47·1%)	
Rheumatic disease						<0·0001
Yes	1172 (3·5%)	18 314 (97·6%)	11 520 (95·5%)	1808 (93·6%)	766 (93·4%)	
No	32 408 (96·5%)	458 (2·4%)	537 (4·5%)	123 (6·4%)	54 (6·6%)	
Peptic ulcer disease						<0·0001
Yes	1356 (4·0%)	18 312 (97·5%)	11 386 (94·4%)	1772 (91·8%)	754 (92·0%)	
No	32 224 (96·0%)	460 (2·5%)	671 (5·6%)	159 (8·2%)	66 (8·0%)	
Hemiplegia or paraplegia						<0·0001
Yes	691 (2·1%)	188 (1·0%)	361 (3·0%)	85 (4·4%)	57 (7·0%)	
No	32 889 (97·9%)	18 584 (99·0%)	11 696 (97·0%)	1846 (95·6%)	763 (93·0%)	
Renal disease						<0·0001
Yes	4663 (13·9%)	17 446 (92·9%)	9578 (79·4%)	1355 (70·2%)	538 (65·6%)	
No	28 917 (86·1%)	1326 (7·1%)	2479 (20·6%)	576 (29·8%)	282 (34·4%)	
HIV or AIDS						0·030
Yes	33 547 (99·9%)	21 (0·1%)	9 (0·1%)	<5 (<1·0%)	<5 (<1·0%)	
No	33 (0·1%)	18 751 (99·9%)	12 048 (99·9%)	NR‡	NR‡	
Liver disease						<0·0001
None	31 625 (94·2%)	18 173 (96·8%)	11 097 (92·0%)	1695 (87·8%)	660 (80·5%)	
Mild	1412 (4·2%)	459 (2·4%)	714 (5·9%)	140 (7·3%)	99 (12·1%)	
Moderate or severe	543 (1·6%)	140 (0·7%)	246 (2·0%)	96 (5·0%)	61 (7·4%)	
Diabetes						<0·0001
None	26 549 (79·1%)	15 52 (83·9%)	8959 (74·3%)	1318 (68·3%)	520 (63·4%)	
Without complications	6090 (18·1%)	2800 (14·9%)	2598 (21·5%)	475 (24·6%)	217 (26·5%)	
With complications	941 (2·8%)	220 (1·2%)	500 (4·1%)	138 (7·1%)	83 (10·1%)	
Malignancy (excluding skin neoplasm)						<0·0001
None	28 839 (85·9%)	16 984 (90·5%)	9730 (80·7%)	1449 (75·0%)	676 (82·4%)	
Non-metastatic	3484 (10·4%)	1408 (7·5%)	1632 (13·5%)	328 (17·0%)	116 (14·1%)	
Metastatic	1257 (3·7%)	380 (2·0%)	695 (5·8%)	154 (8·0%)	28 (3·4%)	
Median bed days during emergency admissions in the previous 2 years	0·0 (0·0–6·0)	0 (0–0)	6 (1–17)	31 (13–58)	100 (65–150)	<0·0001

Date are median (IQR) or n/N (%). Patients with COVID-19 were admitted to hospital in Scotland after March 1, 2020, and discharged before Oct 25, 2021. Recently high admissions were defined as rapidly increasing admissions in the 6 months before index COVID-19 admission. Persistently high admissions were defined as a sustained pattern of high admissions in the 2 years before index COVID-19 admission. *All patients without a vaccination record were recorded as not vaccinated. †We included only comorbidities listed in the Charlson Comorbidities Index. ‡Not reported to conceal the number of people with HIV/AIDS to maintain their anonymity.

Table: **Patient trajectory for emergency admissions to hospital in the 2 years preceding index admission**

Role of the funding source

The funders had no role in data collection, analysis, interpretation, writing of the manuscript, or the decision to submit for publication.

Results

Between March 1, 2020, and Oct 25, 2021, 33 580 patients were admitted with COVID-19 to hospitals in Scotland, or developed COVID-19 while admitted (appendix p 3). There were four distinct trajectories of emergency health-care use in the preceding 2 years for these patients (table; appendix p 3). The no emergency admissions cluster (18 772 [55·9%] of 33 580), which was the largest cluster, comprised individuals who had not been admitted to hospital. The minimal admissions cluster (n=12 057 [35·9%]), which was the second largest cluster, comprised patients who had stable, low-level previous emergency admissions. The recently high admissions

cluster (n=1931 [5·8%]) comprised patients whose emergency admissions had increased rapidly in the 6 months before the index admission. The persistently high admissions cluster (n=820 [2·4%]) comprised patients with a sustained pattern of high emergency admissions in the 2 years before index admission.

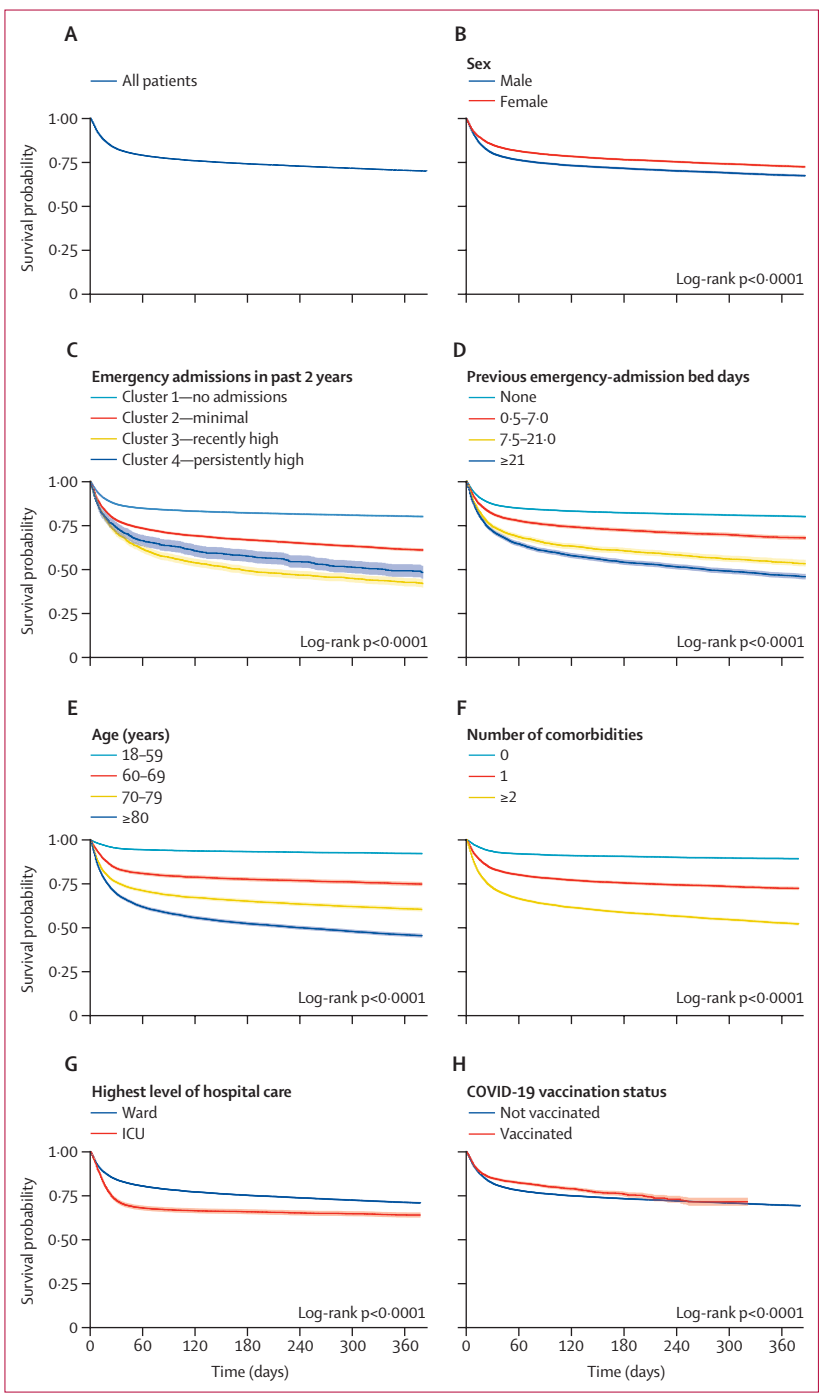


Figure 1: **Kaplan-Meier plots**
Survival at 1 year after index admission to hospital with COVID-19: overall (A); and stratified by sex (B); emergency admissions to hospital within the preceding 2 years (C); days in a hospital bed during emergency admissions in the preceding 2 years (D); age (E); number of comorbidities listed in the Charlson Comorbities Index[12] (F); highest level of hospital care provided (G); and COVID-19 vaccination status before admission (H). ICU=intensive care unit. For numbers at risk and numbers censored, see appendix (pp 8–12).

Demographic and illness features were distinctly different between clusters. Compared with other clusters, patients in the no admissions cluster were younger (median age 61 years in cluster 1 *vs* 74–77 years in clusters 1–3), were predominantly male (n=10 008 [53·3%]), and had a lower prevalence of comorbidity. The recently high admissions cluster included 834 (43·2%) patients who were aged 80 years or older, and this cluster contained the highest amounts of nosocomial infections (608 [31·5%] in the recently high admissions cluster *vs* 1765 [9·4%] in the no admissions cluster). Patients in the persistently high admissions cluster were also elderly (309 [37·7%] aged ≥80 years]) and were the most comorbid among the groups, with 649 (79·1%) of 820 patients having two or more comorbidities. In the persistently high admissions cluster, the proportions of patients with cerebrovascular disease (273 [33·3%]), chronic pulmonary disease (386 [47·1%]), and renal disease (282 [34·4%]) were substantially higher than in the other clusters. Despite having a similar age distribution to patients in the recently high admissions and persistently high admissions clusters, patients in the minimal admissions cluster were less multimorbid, more likely to have contracted COVID-19 in the community, and more likely to have been admitted in wave 3 of the pandemic.

29 282 (87·2%) patients received ward care and 4298 (12·8%) received ICU care (appendix p 3). The proportion of patients admitted to an ICU in the no admissions cluster was much higher than in the other clusters (3075 [16·4%] in the no admissions cluster, 1071 [8·9%] in the minimal admissions cluster, 106 [5·5%] in the recently high admissions cluster, and 46 [5·6%] in the persistently high admissions cluster). Patients in the no admissions cluster received substantially higher amounts of organ support (1031 [6·9%] received invasive mechanical ventilation; 357 [1·9%] received renal replacement therapy; and 1306 [7·0%] received vasopressors) compared with all other clusters (appendix p 3). In the no admissions cluster, more patients received a tracheostomy and had a longer stay in ICU compared with patients in all other clusters, although their median overall length of hospital stay was shorter (5 days [IQR 2–14] in the no admissions cluster 1 *vs* 18 days [7–41] in the recently high admissions cluster). Overall, the Kaplan-Meier estimate of mortality within 1 year of index admission was 29·6% (95% CI 29·1–30·2; figure 1; appendix p 4), and it was estimated that more than half of these deaths would occur within 30 days of index admission (17·3% of patients [95% CI 16·9–17·7]).

In terms of in-hospital mortality, 6709 (20·0%) of 33 580 people died during their index admission, with COVID-19 being the most common underlying cause of death (5564 [82·9%]; appendix p 4), followed by circulatory causes (338 [5·0%]), and neoplasm (282 [4·2%]). In-hospital mortality varied by cluster

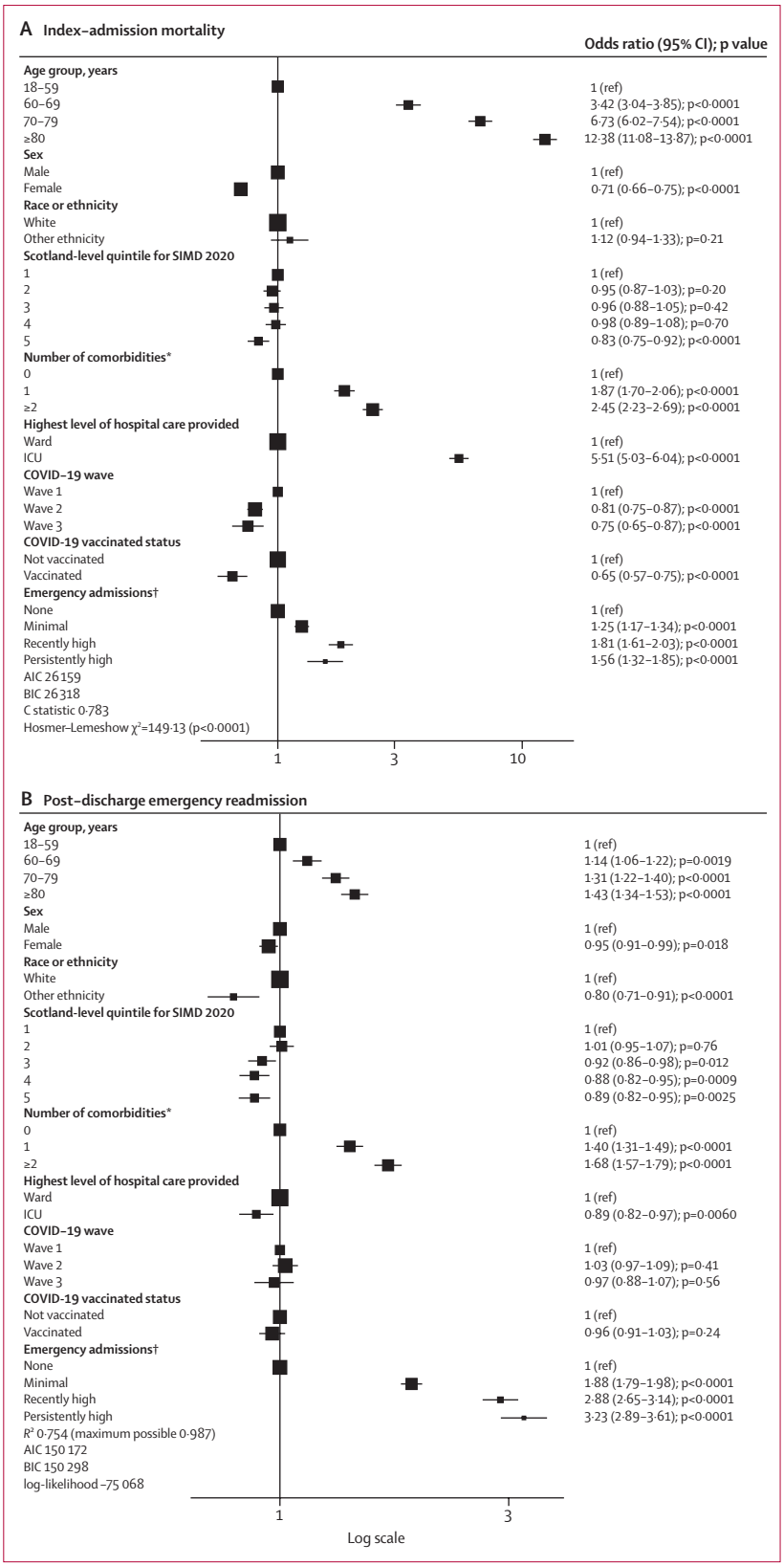
category and was lowest in the no admissions cluster (14·4%), higher in minimal admissions cluster (25·1%), and highest in the recently high admissions cluster (36·6%) and the persistently high admissions cluster (32·4%; appendix p 3).

The median duration of available follow-up for mortality and readmission after index hospital discharge was 298 days (IQR 134–385). 24193 (90·0%) of 26871 patients were discharged to a private residence and a further 1651 (6·1%) patients were discharged to an institution (eg, nursing home or residential care home; appendix p 5). For patients who survived index admission and but died after discharge, the median time to death was 54 days (IQR 10–179). Overall mortality after index hospital discharge was 3·2% (95% CI 3·0–3·4) at 30 days, 5·5% (5·2–5·8) at 90 days, and 11·7% (11·3–12·2) at 1 year (appendix p 4). Mortality rates at 1 year after index discharge increased with age (2·8% [95% CI 2·5–3·2] in ages 18–59 years *vs* 27·5% [26·1–28·9] in ages ≥80 years). Mortality was lower for patients who had survived the ICU compared with survivors who had been managed on the ward (4·9% [95% CI 4·0–5·9] in ICU patients *vs* 12·6% [12·1–13·1] in ward patients).

1-year mortality was considerably higher in patients who had survived index admission and had previous minimal admissions compared with patients with no admissions (17·6% [95% CI 16·7–18·6] in the minimal admissions cluster *vs* 5·9% [5·5–6·4] in the no admissions cluster). Patients in the recently high admissions cluster had very high mortality even if they survived their initial COVID-19 admission (1-year mortality 33·2% [95% CI 30·1–36·1]). Among patients overall who died after index discharge, 1015 (37·6%) of 2699 patients died during subsequent readmission to hospital, and 1684 (62·4%) patients died in the community. COVID-19 was the most common underlying cause of death (488 [18·1%]), followed by neoplasm (602 [22·3%]) and circulatory causes (571 [21·1%]; appendix p 5).

There was a univariable association between the preadmission trajectory cluster and in-hospital and postdischarge long-term mortality, which persisted after adjusting for potential confounders (figure 2). For both mortality outcomes, patients in the no admissions cluster had a lower mortality risk than patients in all the other clusters. Compared with the no admissions cluster, mortality was highest among patients in the recently high admissions cluster (in-hospital mortality OR 1·81 [95% CI 1·61–2·03]; post-discharge mortality HR 2·70 [2·35–2·81]).

The cumulative incidence of patients with at least one emergency readmission to hospital was 14·4% (95% CI 14·0–14·8) by day 30 after discharge from the index admission, 21·4% (21·0–22·0) by day 90, and 35·6% (34·9–36·3) by 1 year (figure 3; appendix p 6). Median time to first readmission was 38 days (IQR 8–131) and the most common cause was COVID-19 (1471 [17·7%] of 8301), followed by respiratory causes (996 [12·0%]) and



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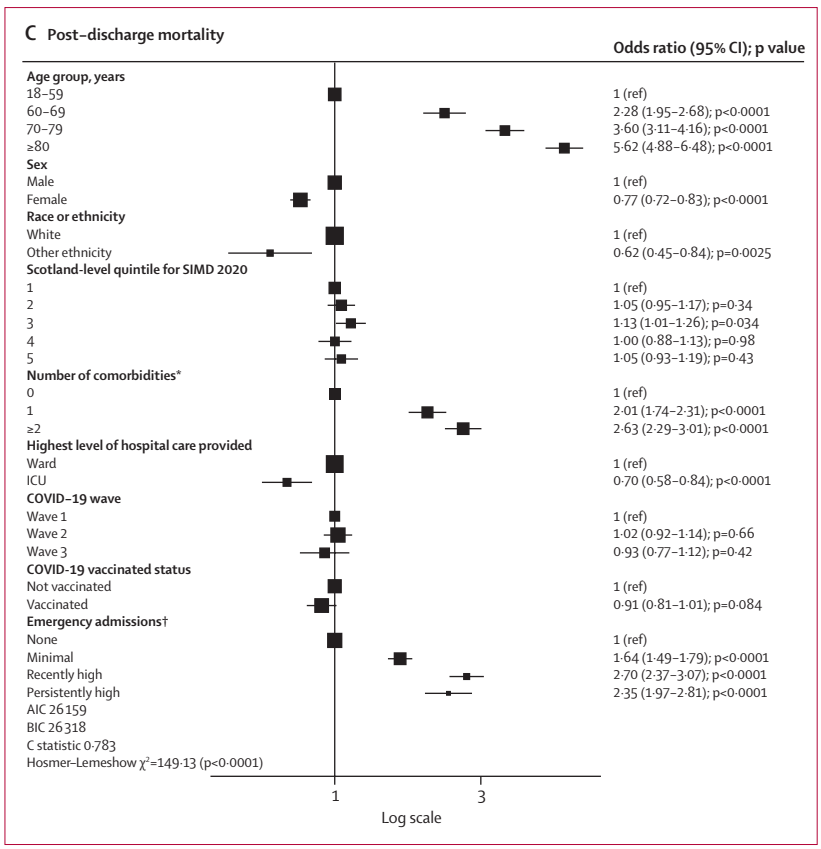

Figure 2: **Mortality and readmission outcomes**
(A) Logistic regression for in-hospital mortality after index admission. (B) Cox regression for emergency readmission to hospital of index-admission survivors. (C) Cox regression for mortality after index discharge. AIC=Akaike information criterion. BIC=Bayesian information criterion. ICU=intensive care unit. SIMD=Scottish Index of Multiple Deprivation. *We included only comorbidities listed in the Charlson Comorbities Index.[12] †Refers to the number of half-days in a hospital emergency bed during the 2 years before index submission; minimal admissions=0·5–7·0 days; recently high=7·5–20·5 days; persistently high=21·0 or more days.

circulatory causes (855 [10·3%]; appendix p 7). Most of these readmissions were unscheduled and numbers were higher in patients who were older and who had multimorbidity than in other patients (figure 4). The number of emergency readmissions to hospital was lower for patients admitted to an ICU than to a ward at index admission (readmissions within 30 days 10·9% [95% CI 9·8–12·1] in ICU patients *vs* 14·8% [14·3–15·2] in ward patients; readmissions within 1 year 26·5% [24·7–28·4] in ICU patients *vs* 36·7% [36·0–37·5] in ward patients). Trajectory cluster was significantly associated with risk of readmission, even after adjustment for patient demographics. This association was highest in the persistently high admissions cluster (ref cluster 1; cluster 2 HR 1·88 [95% CI 1·79–1·98]; cluster 3 2·88 [2·65–3·14]; cluster 4 3·23 [2·89–3·61]; figure 3).

Trajectory clusters improved model fit for deaths after index discharge (BIC 49625 *vs* bed-days 49667) and emergency readmissions (BIC 64338 *vs* bed-days 64494) but there was no difference for index mortality (BIC 26318 *vs* bed-days 26310; appendix pp 7, 16).

In terms of health-care costs after index discharge, for patients with at least 6 months of potential follow-up before the censoring date, the mean excess health-care use per person per year compared with baseline was £3631 (95% CI 3322–3957; figure 4; appendix p 8). Costs were greatest in the first month after discharge and then plateaued between 6 and 9 months after discharge. Costs were higher with increased age and comorbidity. Post-discharge costs were higher than baseline across all clusters except the persistently high admissions cluster. Although absolute postdischarge costs were especially high for patients in the persistently high admissions cluster (£23427 [95% CI 20726–26478]), these costs were substantially lower than the baseline costs for this cluster (£45987 [43134–49052], relative reduction 49·1%). Relative cost increase from baseline was highest in patients in the no admissions cluster (excess £3069 [95% CI 2803–3381], relative increase 581·3%).

Discussion

In this national, complete cohort of patients hospitalised with COVID-19 between March 1, 2020 and Oct 25, 2021, 20% of patients died during their index admission and a further 12% of patients died within 1 year after index discharge. Hospital readmission rates and hospital-resource use were high, with one in four patients readmitted within 3 months and nearly half of all survivors readmitted within 1 year. Pre-COVID-19 hospital resource trajectories were strongly associated with risk of in-hospital mortality, postdischarge, and readmission, independent of age and pre-existing comorbidity.

All-cause mortality after discharge was lower than the 9% mortality at 60 days reported in studies with a short-term follow-up in the USA and England,[17,18] and similar to the 6-month mortality rate of 9·7% in Germany.[19] COVID-19 remained a common cause of early death after hospital discharge, accounting for nearly two thirds of deaths in the first 2 weeks. Neoplasm was the second most common cause of death, reflecting the high burden of malignancy in Scotland.[20]

Our study reports long-term hospital readmission and health-care resource use on a national basis for survivors of hospitalisation for COVID-19. This is an important, unbiased, person-centred outcome. Rates for readmission to hospital after COVID-19 have varied considerably between countries (4·2% of patients readmitted within 30 days in Spain;[21] 9–20%[6,22] of patients readmitted within 60 days in the USA; and 23% of patients readmitted within 60 days in England[18]), which might reflect underlying differences in health-care organisations. Similar to our findings, other studies reported COVID-19 pneumonia as the most common cause for readmission (30% in the USA[17] and 54% in Spain[21]); however, we found circulatory causes were also common.

Our findings that increasing age and comorbidity were associated with readmission is consistent with literature related to both COVID-19[21] and non-COVID-19.[23] We

found that being male was a risk factor for readmission, which contrasts with evidence that women might not recover from COVID-19 as well as men do.[4] Patients admitted to an ICU in the UK for COVID-19 have been younger and less comorbid than patients admitted for other respiratory infections;[24,25] however, we found that ICU survivors had lower rates of posthospital mortality and readmission than ward survivors had, despite adjusting for age, comorbidity, previous health-care resource use, and other important confounders. These findings contrast with previous COVID-19[18] and non-COVID-19 studies,[7] which found that ICU survivors had higher death and readmission rates than ward patients. We hypothesise that this difference reflects the underlying increased physiological reserve of the young, non-morbid patients who survived. The fact that this was a national study reduces the potential for selection bias (which can affect prospective studies), but there might be residual confounding that we have been unable to account for.

We found that patients who had received at least one COVID-19 vaccination were at reduced risk of dying, both in hospital and after hospital discharge. Although this reduction might seem obvious, given the wealth of literature on vaccine effectiveness, it is important to highlight two points. First, the first people to be vaccinated were elderly and susceptible patients. Second, all patients had to meet an illness-severity threshold for hospital admission to be included in this study, which could potentially bias outcomes for vaccine effectiveness. Despite this possibility, it was reassuring to see that, even in patients who required hospitalisation for COVID-19, risk of mortality was reduced for those who were vaccinated.

Few studies have explored sequelae of hospitalisation for COVID-19 in the context of pre-illness trajectories. In the cohort as a whole, the trajectory indicated that before admission there was a period of increased heath-care costs, which was surprising for an infectious illness. This increase could be a marker for the worsening of underlying health problems or for health-care contact that lead to COVID-19 infection. There were four distinct patterns of pre-COVID-19 hospital use in the previous 2 years: no hospital admissions, minimal admissions, recent high use, and persistent high use. These clusters were strongly associated with the amount of post-hospital health-care use. Patients with no emergency admissions in the previous 2 years had lower readmission rates than the other groups despite higher rates of admission to an ICU, suggesting that this group of patients had substantial physiological reserves. Patients with high health-care use had much higher rates of both mortality and readmission than other patients had. Both of the high-use clusters (ie, clusters 3 and 4) had high proportions of elderly patients and patients with multimorbidity, and malignancy was also over-represented, suggesting that these factors might have contributed to health-care use more than COVID-19 had. Furthermore,

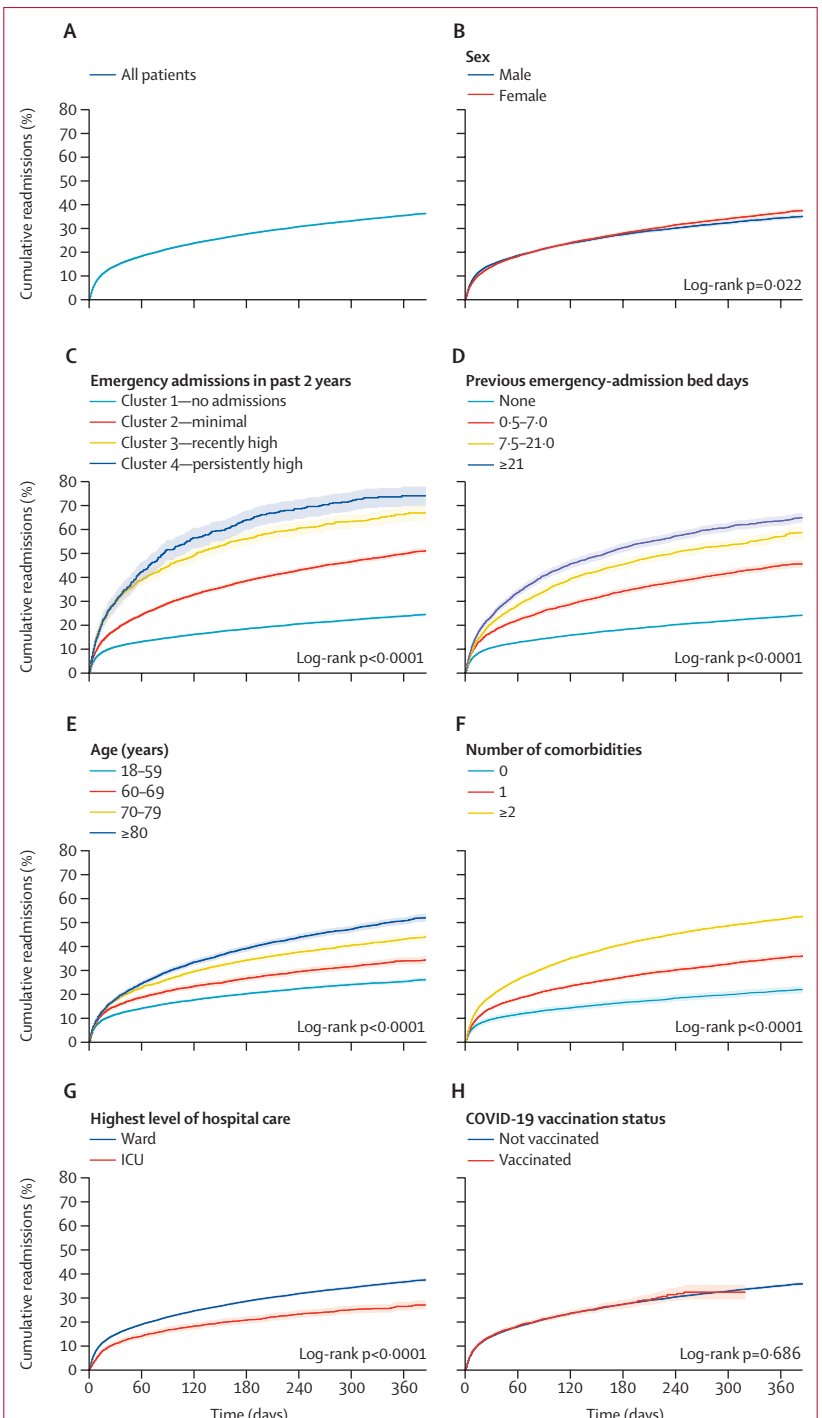

Figure 3: **Cumulative emergency hospital readmissions 1 year after index hospital admission with COVID-19**
Readmission to hospital within 1 year of discharge from index hospital admission with COVID-19: overall (A); and stratified by sex (B); emergency admissions to hospital within the preceding 2 years (C); days in a hospital bed during emergency admissions in the preceding 2 years (D); age (E); number of comorbidities listed in the Charlson Comorbities Index[12] (F); highest level of hospital care provided (G); and COVID-19 vaccination status before admission (H). For numbers at risk and numbers censored, see the appendix (p 6). HR=hazard ratio.

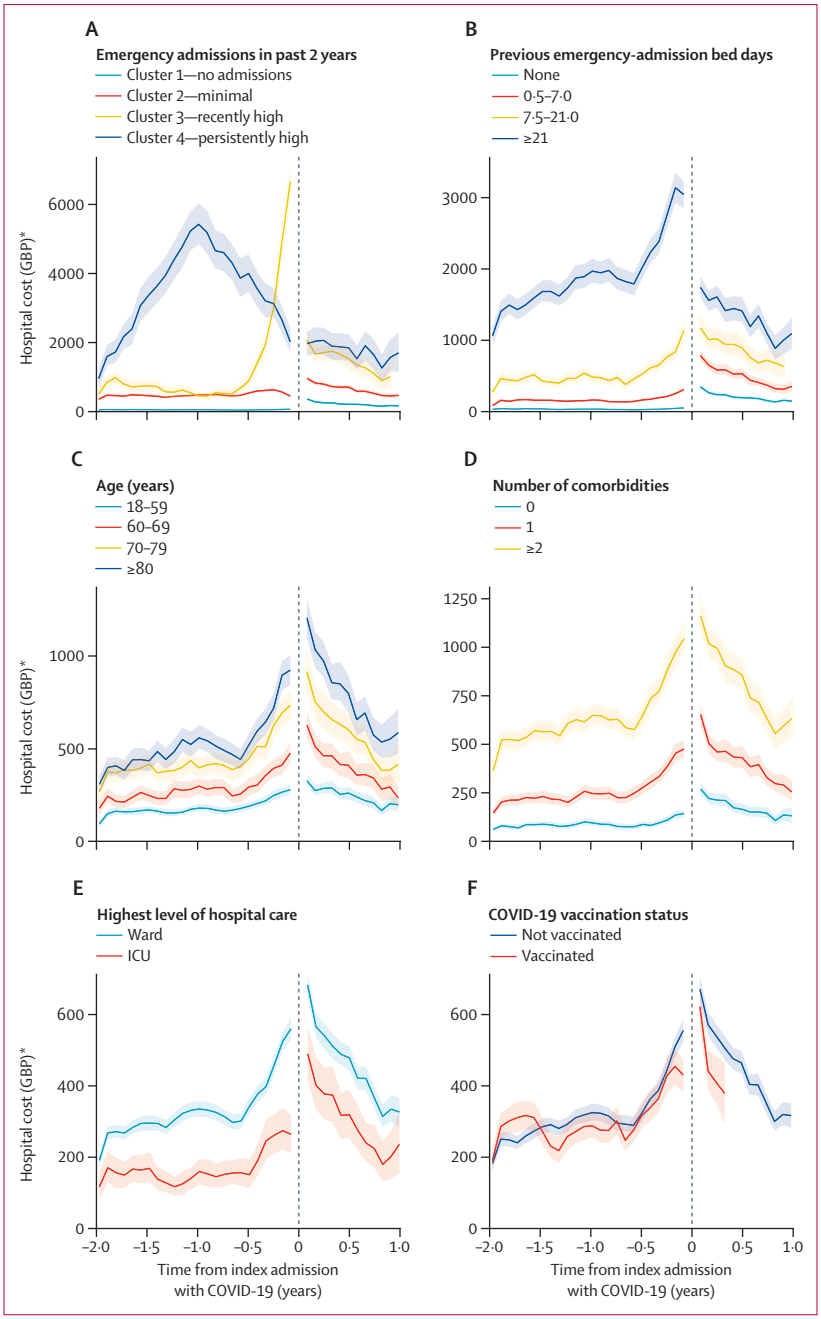

Figure 4: **Hospital costs in the 2 years preceding admission for COVID-19, and in the year after discharge**
Hospital costs are per patient per 30-day period and are for emergency care, elective inpatient, outpatient, and day-case costs after index admission, based on 2019 prices. Costs stratified by: emergency admissions to hospital within the preceding 2 years (A); days in a hospital bed during emergency admissions in the preceding 2 years (B); age (C); number of comorbidities listed in the Charlson Comorbities Index[12] (D); highest level of hospital care provided (E); and COVID-19 vaccination status before admission (F).

rates of nosocomial COVID-19 were high in these groups, highlighting their underlying ill health.

Health-care use and costs are known to increase with proximity to death.[26,27] Routine data sources have become increasingly important in describing patient journeys for COVID-19. There are specific tools with which to assess frailty, such as the Clinical Frailty Scale;[28] however, these tools are not contained in UK secondary-care routine health-care datasets, which are collected for purposes other than research. Chronological age and multimorbidity are often used as surrogates for frailty and, in England, adults that accounted for the top 5% of costs were older than the remainder of the population and had at least one long-term health condition.[29] However, although frailty is greatly associated with age, there is wide interindividual variation, and multimorbidity might not adequately represent the reduced physiological reserve represented by frailty. The inclusion of preadmission emergency trajectories in our analysis of routine health-care datasets has helped to identify susceptible patients at high risk of death, or emergency readmission, or both, over and above using age and comorbidity alone. Furthermore, the pattern of the trajectories improved the models further than a simple count of previous emergency use would have. Clinically, identifying these patients might provide the opportunity to put in place additional community support on discharge from hospital, and might also facilitate earlier discussions with patients regarding treatment-escalation plans, should they become increasingly unwell.

Our study has a number of strengths. Through linking data from national datasets that captured all acute hospitalisations, PCR tests for SARS-CoV-2 infection, and outpatient attendances, we were able to report population-level estimates and to minimise selection bias and loss to follow-up. We benchmarked post-discharge health-care resource use within individuals by using the preadmission period as a comparator, which gave us better control of confounding than using a control population would have. In contrast to other studies, we were able to account for historic health-care resource use and explore its effect on outcomes. We differentiated nosocomial and community acquisition of COVID-19, which is important, as both the underlying patient demographics and the severity of COVID-19 disease might have been different between the two.

The findings of our study should be interpreted in the context of several limitations. Laboratory testing capacity changed during the pandemic. We mitigated against the inadequate testing capacity in the initial stages by using clinically ICD-10-coded COVID-19 in addition to laboratory-confirmed diagnoses. We were unable to directly attribute the cause of readmission to the original COVID-19 presentation. However, after acute COVID-19, patients can experience a diverse range of symptoms, so an all-readmissions outcome is arguably better than a cause-specific one. Scotland's ethnic composition is predominantly White and our study might have been underpowered to detect differences in readmission and mortality rates for other ethnic groups. Changes in health-care service provision and population behaviour as a result of the pandemic will have affected the use of health services and subsequent health costs, which will

affect trajectories. We looked at secondary health-care use only, and only for patients in whom COVID-19 was severe enough to result in hospital admission. As such, we are unable to generalise our findings to COVID-19 cases treated in the community. We were unable to look at primary health-care use, and patients who did not need secondary-care admission might still have had substantial health-care needs and contact with primary-care services. We were unable to address the secondary effects of COVID-19 on the provision of other secondary-care services that have inevitably been affected by the pandemic. Restricting our study to secondary-care datasets might have biased the ascertainment of comorbidity. We were unable to explore patients' social support in the community, which is likely to have influenced emergency admissions.

The effect on hospital services of post-acute sequelae of COVID-19 has been substantial. High mortality and readmission rates were seen predominantly in elderly comorbid patients with high pre-COVID hospital use, particularly those with escalating hospital use in the 6 months before admission. These rates highlight the need for post-COVID-19 recovery services to be tailored not only to the sequelae of COVID-19, but also towards supporting pre-existing health conditions and frailty.

Contributors

ABD, JF, EMH, and NIL conceptualised this study. GL, AL, LuN, AB, BP, RM, RB, CM, DR, and WO did the data curation. ABD, JF, MT, CE, SD, LiN, CAS, RP, SS, EMH, and NIL analysed the data. ABD, JKB, and MGS were responsible for funding acquisition. ABD, JF, EMH, and NIL wrote the original draft. All authors were involved in writing, reviewing, and editing the manuscript. ABD, JF, EMH, and NIL accessed and verified the data. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Declaration of interests

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Data sharing

The data used in this study are managed by Public Health Scotland and we are not able to share the data. Applications for access to the data can be made to the NHS Scotland Public Benefit and Privacy Panel for Health and Social Care and eDRIS at https://www.informationgovernance.scot.nhs.uk/pbpphsc/. The analytical code we used is available at https://github.com/SurgicalInformatics/scot_covid_trajectories.

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References

1 Docherty AB, Harrison EM, Green CA, et al. Features of 20 133 UK patients in hospital with COVID-19 using the ISARIC WHO Clinical Characterisation Protocol: prospective observational cohort study. *BMJ* 2020; **369:** m1985.

2 Knight SR, Ho A, Pius R, et al. Risk stratification of patients admitted to hospital with COVID-19 using the ISARIC WHO Clinical Characterisation Protocol: development and validation of the 4C Mortality Score. *BMJ* 2020; **370:** m3339.

3 Auriemma CL, Harhay MO, Haines KJ, Barg FK, Halpern SD, Lyon SM. What matters to patients and their families during and after critical illness: a qualitative study. *Am J Crit Care* 2021; **30:** 11–20.

4 Evans RA, McAuley H, Harrison EM, et al. Physical, cognitive, and mental health impacts of COVID-19 after hospitalisation (PHOSP-COVID): a UK multicentre, prospective cohort study. *Lancet Respir Med* 2021; **9:** 1275–87.

5 Donaghy E, Salisbury L, Lone NI, et al. Unplanned early hospital readmission among critical care survivors: a mixed methods study of patients and carers. *BMJ Qual Saf* 2018; **27:** 915–27.

6 Moynihan R, Sanders S, Michaleff ZA, et al. Impact of COVID-19 pandemic on utilisation of healthcare services: a systematic review. *BMJ Open* 2021; **11:** e045343.

7 Lone NI, Gillies MA, Haddow C, et al. Five-year mortality and hospital costs associated with surviving intensive care. *Am J Respir Crit Care Med* 2016; **194:** 198–208.

8 Welstead M, Jenkins ND, Russ TC, Luciano M, Muniz-Terrera G. A systematic review of frailty trajectories: their shape and influencing factors. *Gerontologist* 2021; **61:** e463–75.

9 Stow D, Matthews FE, Hanratty B. Frailty trajectories to identify end of life: a longitudinal population-based study. *BMC Med* 2018; **16:** 171.

10 Scottish Government. Scottish index of multiple deprivation 2020. 2020. https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/#:~:text=The%20Scottish%20Index%20of%20Multiple%20Deprivation%20is%20a%20relative%20measure,mean%20fewer%20resources%20or%20opportunities (accessed April 29, 2023).

11 National Records of Scotland. Scotland's Census. Ethnicity 2011. Aug 3, 2021 https://www.scotlandscensus.gov.uk/census-results/at-a-glance/ethnicity/ (accessed April 29, 2023).

12 Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987; **40:** 373–83.

13 Hall VJ, Foulkes S, Saei A, et al. COVID-19 vaccine coverage in health-care workers in England and effectiveness of BNT162b2 mRNA vaccine against infection (SIREN): a prospective, multicentre, cohort study. *Lancet* 2021; **397:** 1725–35.

14 UK Health Security Agency. COVID-19 vaccine surveillance report—week 14. April 7, 2022. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1067158/vaccine-surveillance-report-week-14.pdf (accessed April 29, 2023).

15 Bauldry S. Structural equation modelling. Thousand Oaks, CA: SAGE Publishing, 2020.

16 Public Health Scotland Data and Intelligence. Finance—costs. 2021. https://beta.isdscotland.org/topics/finance/costs/ (accessed April 29, 2023).

17 Donnelly JP, Wang XQ, Iwashyna TJ, Prescott HC. Readmission and death after initial hospital discharge among patients with COVID-19 in a large multihospital system. *JAMA* 2021; **325:** 304–06.

18 Ayoubkhani D, Khunti K, Nafilyan V, et al. Post-covid syndrome in individuals admitted to hospital with COVID-19: retrospective cohort study. *BMJ* 2021; **372:** n693.

19 Günster C, Busse R, Spoden M, et al. 6-month mortality and readmissions of hospitalized COVID-19 patients: a nationwide cohort study of 8679 patients in Germany. *PLoS One* 2021; **16:** e0255427.

20 National Records of Scotland. Vital events reference tables 2018. Deaths—causes. June 26, 2019. https://www.nrscotland.gov.uk/files/statistics/vital-events-ref-tables/2018/vital-events-ref-tables-18-publication.pdf (accessed April 29, 2023).

21 Ramos-Martínez A, Parra-Ramírez LM, Morrás I, et al. Frequency, risk factors, and outcomes of hospital readmissions of COVID-19 patients. *Sci Rep* 2021; **11:** 13733.

22 Lavery AM, Preston LE, Ko JY, et al. Characteristics of hospitalized COVID-19 patients discharged and experiencing same-hospital readmission—United States, March–August 2020. *MMWR Morb Mortal Wkly Rep* 2020; **69:** 1695–99.

23 McPhail SM. Multimorbidity in chronic disease: impact on health care resources and costs. *Risk Manag Healthc Policy* 2016; **9:** 143–56.

24 Public Health Scotland. Scottish Intensive Care Society Audit Group report on COVID-19, 2020—as at 23 September 2021. Oct 21, 2021. https://publichealthscotland.scot/publications/scottish-intensive-care-society-audit-group-report-on-covid-19/scottish-intensive-care-society-audit-group-report-on-covid-19-as-at-23-september-2021/ (accessed April 29, 2023).

25 Doidge JC, Gould DW, Ferrando-Vivas P, et al. Trends in intensive care for patients with COVID-19 in England, Wales, and Northern Ireland. *Am J Respir Crit Care Med* 2021; **203:** 565–74.

26 Bardsley M, Georghiou T, Spence R, Billings J. Factors associated with variation in hospital use at the end of life in England. *BMJ Support Palliat Care* 2019; **9:** 167–74.

27 Hazra NC, Rudisill C, Gulliford MC. Determinants of health care costs in the senior elderly: age, comorbidity, impairment, or proximity to death? *Eur J Health Econ* 2018; **19:** 831–42.

28 Rockwood K, Song X, MacKnight C, et al. A global clinical measure of fitness and frailty in elderly people. *CMAJ* 2005; **173:** 489–95.

29 Tanke MAC, Feyman Y, Bernal-Delgado E, et al. A challenge to all. A primer on inter-country differences of high-need, high-cost patients. *PLoS One* 2019; **14:** e0217353.