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Methods: We undertook a national, complete retrospective cohort study using linked databases in all adult patients hospitalised in Scotland with COVID-19. We used latent
class trajectory modelling to identify distinct clusters of patients based on emergency hospital admissions in the two years before COVID-19 admission. Primary outcomes were mortality and emergency readmission up to 12 months after hospitalisation. 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 utilisation.

Findings: Between 01/03/2020 and 25/10/2021 33,580 patients were admitted to hospital in Scotland with COVID-19. Overall, 29.6% (95% CI 29.1%, 30.2%) of patients died within a year of COVID-19 hospital admission. Within 30 days of hospital discharge, 14.4% (95% CI 14.0%, 14.8%) of patients had experienced at least one emergency hospital readmission, increasing to 35.6% (34.9%, 36.3%) at one year. There were four distinct patterns of previous emergency hospital use: C1 “no admissions” (n=18,772, 55.9%); C2 “Minimal admissions” (n=12,057, 35.9%), C3 “Recently high” (n=1,931, 5.8%) and C4 “Persistently high” (n=820, 2.4%). Patients in high utilisation clusters (C3 and C4) were older, more multimorbid and more likely to have hospital-acquired COVID-19. All cluster groups had increased risk of mortality and hospital readmission relative to cluster C1. Mortality was highest in patients in “Recently high” C3, (C1 ref: post-hospital mortality HR 2.70 (95% CI 2.35, 2.81)) and readmission risk was highest in “Persistently high” C4 (ref C1: C4 HR 3.23 (95% CI 2.89, 3.61)).

Interpretation: Longer term mortality and readmission rates for patients hospitalised with COVID-19 have been high, with one in three dying within a year and a third readmitted as an emergency. Pre-illness hospital resource trajectories were strongly predictive of mortality and readmission risk, independent of age, pre-existing comorbidity and vaccination status. This more precise identification of individuals at high risk of poor outcomes from COVID-19 will enable targeted support.
Patient emergency healthcare trajectories preceding COVID-19 hospitalisation and longer term outcomes: a national cohort study

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Research in Context

Evidence before this study:
We searched PubMed on 14th June 2022, 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 longer-term mortality, and readmission to hospital in patients who survived their index COVID-19 admission. Of 362 initial results, 44 original research studies examined mortality and/or hospital readmission in non-pregnant adults. Twenty studies had a maximum follow up time of less than three months from discharge. Only five had follow-up greater than six months, and these were predominantly smaller, single site cohorts. These studies found that older patients, male patients and those with comorbidities were more likely to die or be readmitted to hospital. Only one study quantified healthcare utilisation after COVID-19 diagnosis and none identified patterns of healthcare utilisation.

Added value of this study:
The aim of this study was to quantify systematically the extent to which patients hospitalised with COVID-19 were at risk of dying or being readmitted to hospital, in the context of the pattern of their pre-COVID-19 emergency healthcare utilisation.

In this national cohort we found that emergency readmission was common, with 35% of patients readmitted and one in three patients dying within a year of admission. Patients with a history of high healthcare resource use in the preceding two years were at higher risk of readmission and mortality independent of their age and multimorbidity, compared to those patients with no or minimal resource use. Those patients with a high frequency of recent emergency admissions were at greatest risk of dying in-hospital and after discharge. Patients with persistently high emergency admissions also had high mortality and were at highest risk of readmission.

Implications of all the available evidence:
Patients hospitalised with COVID-19 experience high rates of mortality and healthcare use in the year following hospital discharge. Defining pre-admission trajectories of healthcare use enables more precise identification, over and above age, comorbidity and vaccination status, of individuals who are at high risk of poor outcomes. This will enable early support to be appropriately targeted to these vulnerable patients.
Introduction

It has become clear over the course of the COVID-19 pandemic, that patient demographics such as increasing age and multimorbidity, and severity of illness at presentation are major risk factors for COVID-19 in-hospital mortality.\(^1\)\(^2\) Whilst death is important as an outcome, patients and families may consider other person-centred outcomes to be as important, if not more so, than death.\(^3\)

Although data are emerging relating to the symptom burden and quality of life for these survivors, this has been limited by convenience sampling\(^4\) or incomplete population sampling,\(^7\) leading to a potential for bias. Hospital readmission and health care resource use following initial COVID-19 hospitalisation discharge are measures that are highly person-centred, relatively well recorded and easy to obtain and not subject to similar biases.\(^5\) There is considerable variation in post-discharge healthcare use, with lower utilisation among people with less severe COVID-19 illness.\(^6\) The additional burden of people surviving a COVID-19 hospitalisation on subsequent secondary care resources remains uncertain, particularly in the context of patients’ pre-COVID hospital use. It is important to identify patients 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 healthcare utilisation have previously been shown to be stronger predictors of hospital resource than those associated with the acute illness.\(^7\). However, few studies have looked at longitudinal trajectories of hospital utilisation at population level.\(^8\)\(^9\)

We hypothesised that trajectories of emergency hospital admissions are a marker of vulnerability that can help to identify those patients at highest risk of mortality and readmission independent of age and comorbidity. We aimed to use national Scottish data to ascertain if patterns of emergency hospital use in the two years preceding the index hospital admission with COVID-19 could identify patients at high risk of death and readmission.

Methods

Study design, setting and participants

We analysed routine healthcare data for all patients ≥18 years admitted to hospital in Scotland with either community or hospital acquired COVID-19 after 1\(^{st}\) March 2020 who died or were discharged before 25\(^{th}\) October 2021. All patients were followed up until 22\(^{nd}\) November 2021 or until date of death (whichever was earlier). The study received ethical approval from the South Central—Oxford C Research Ethics Committee in England (Ref: 13/SC/0149) and by the Scotland A Research Ethics
Committee (Ref: 20/SS/0028). Approval for access to datasets was granted by the Public Benefit and Privacy Panel for Health and Social Care (PBPP ref: 1920-0273). Approval for access to data can be requested through the PBPP. We reported according to STROBE guidelines.

Datasets

The Scottish Morbidity Record (SMR01) contains national data on hospital activity and mortality, and outpatient activity (SMR00). Electronic Communication of Surveillance in Scotland (ECOSS) holds all positive microbiology laboratory specimen results. Scottish Intensive Care Society Audit Group (SICSAG) contains all adult general intensive care activity. National Records Scotland (NRS) record all deaths registered in Scotland. Scottish COVID-19 Vaccination dataset contains COVID-19 vaccination events in Scotland since December 2020 (online supplement for further details).

Variables

COVID-19 hospitalisation was defined by an admission within 14 days of a positive COVID-19 PCR test. Nosocomial infection was defined as a positive PCR test (ECOSS) ≥5 days after hospital admission. To mitigate the lack of testing at the start of the pandemic, clinically ICD-10 coded COVID-19 were also included (see online supplement). We categorised age into the following groups: <50, 50-69, 70-79, 80+, based on the univariable association with age and mortality and consistent with previous studies. Socioeconomic deprivation was defined using quintiles of Scottish Index of Multiple Deprivation (SIMD Version 2020). Ethnicity was derived from categories of the Scottish Census 2011 and aggregated due to low frequencies as “White” or “Other”. We derived measures of comorbidity from acute hospital admissions (SMR01) using Charlson comorbidities. Acute illness variables comprised admission to Intensive Care Units (ICU), receipt of invasive ventilation, inotropic support, or renal replacement therapy. The first wave of the pandemic was defined as 01/03/2020 to 31/08/2020 (first patient admitted to hospital in Scotland in March 2020); the second wave was defined as 01/09/2020 to 30/04/2021; and the third wave was defined as 01/05/21 to the end of the study period. Patients were considered vaccinated if the COVID-19 admission was ≥3 weeks after first vaccination or ≥2 weeks after any booster.

Pre-COVID-19 hospital emergency healthcare trajectories

We extracted emergency hospital admissions from SMR01 records for two years prior to the index COVID-19 admission for all patients. We categorised emergency hospital usage into the number of days spent in hospital during emergency hospital admissions per 30 day period.
Outcomes

The primary outcomes were all-cause mortality (during index COVID-19 hospitalisation, and 12-month post-discharge), and emergency readmission up to 12 months after COVID-19 hospitalisation. The secondary outcome was post-discharge hospital resource use.

Mortality

Mortality was derived from linkage to NRS death records. Palliative discharge marked on SMR01 was included within hospital mortality. We explored whether COVID-19 was mentioned in the death certificate, either as “underlying condition” or “other”.

Statistical analysis

The dataset was cleaned, recoded, linked and analysed using R v3.6.4 (R Core Team version 3.6.4, Vienna, Austria). Cells containing values from <5 patients were suppressed. No sample size calculation was performed as this was fixed by the number of admissions. A complete case analysis was performed. Analytical code is at https://github.com/SurgicalInformatics/scot_covid_trajectories.

Pre-COVID trajectory clustering

Using emergency hospital admissions as a potential marker of vulnerability, we used latent class trajectory modelling (LCTM) to identify subgroups of patients with distinct trajectories of emergency healthcare use. We modelled length of stay in hospital (during emergency admissions) in a 30-day period as a function of time in the two years (24 points) prior to a patient’s COVID-19 admission. We used R packages “LCTMtools” and “lcmm” (see online supplement for further details). We then applied these trajectories across all mortality and emergency re-admissions.

In order to evaluate whether the temporal sequence in the trajectory improved model fit over a simple count of emergency hospital use, we also categorised number of emergency bed-days in the previous two years: “0 days”, “0.5-7 days”, “7.5-21 days” and “21+ days”. For all models, we assessed performance comparing trajectory clusters and number of bed days using the Bayesian information criterion (BIC). A change in BIC >10 strongly favours the model with the lower BIC.

Mortality and time to first readmission

We used Kaplan-Meier estimates to report mortality, and cumulative incidence to report time to first admission at specified time points. We used logistic regression for early in-hospital mortality. For hospital survivors, we used Cox Proportional Hazards regression analysis to account for differential follow-up, with results presented as hazard ratios (HR). We used the 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 index hospital discharge. All patients had at least four weeks follow-up from hospital discharge. The maximum potential follow-up was 365 days. Patients alive on 22nd November 2021 were censored.

**Healthcare resource use**

There were three categories of healthcare resource: outpatient appointments, inpatient hospital admissions (elective/emergency), and day case admission. We derived hospital case costs from the NHS Scottish Costs Book\(^4\), using per diem costing. A same day inpatient discharge was assigned 0.5 days.

We calculated excess costs within individuals by comparing 6-month post-index discharge costs with an individual’s baseline costs defined as the costs for the eighteen month period between two years and six months prior to the index COVID-19 admission. We calculated excess costs for all patients with potential six months follow up in order to maximise the size of the cohort.

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

**Results**

Between 01/03/2020 and 25/10/2021, 33,580 patients were admitted with COVID-19 to hospitals in Scotland, or developed COVID-19 during a hospital admission (figure E1). There were four distinct trajectories of emergency healthcare use in the preceding 2 years (table 1, figure E2, appendix A).

More than half of patients had had no emergency hospital admissions in the previous 2 years, comprising the largest cluster (C1 “No emergency admissions”, n=18,772, 55.9%). C2 was the second largest group (“Minimal admissions”, n=12,057, 35.9%), and comprised patients with stable low level preceding hospital use. C3 (“Recently high”, n=1,931, 5.8%) had rapidly increasing hospital admissions in the six months before the index COVID-19 admission. Patients in C4 (“Persistently high”, n=820, 2.4%) had a more sustained pattern of high healthcare use over the two preceding years.

Demographic and illness features were distinct between clusters. Patients in the “No emergency admissions” cluster C1 were younger than other clusters (median age 61 years vs 74-77 years in other clusters), had a predominance of males and a lower prevalence of comorbidity. The “Recently high” Cluster C3 consisted of the oldest group (43.2% of patients age 80+) and had the highest levels of nosocomial infections (nosocomial 33.0% vs “No admissions” 9.9%). Patients in the “Persistently high” Cluster C4 were also elderly (80+ years 37.7%, n=309) and were the most comorbid, with
79.1% of patients having 2+ Charlson comorbidities. Proportions of patients with cerebrovascular
disease (33.3%), chronic pulmonary disease (47.1%), renal disease (34.4%) were noticeably higher in
this cluster compared with other clusters. Despite having an age distribution similar to the “Recently
high” and “Persistently high” clusters, patients in the “Minimal admissions” cluster C2 were less
multimorbid, more likely to have contracted COVID-19 in the community, and more likely to be
admitted in Wave 3.

29,282 (87.2%) of patients received a maximum of ward level care, and 4,298 (12.8%) received ICU
care (table E1). The proportion of patients admitted to ICU in the “No emergency admissions”
cluster (16.4%) was much higher than the other clusters (C2 8.9%, C3 5.5%, C4 5.6%). Patients in the
“No emergency admissions” C1 received significantly higher organ support (C1 invasive mechanical
ventilation (IMV) 6.9%, Renal Replacement Therapy (RRT) 1.9%, vasopressors 7.0%) than all other
clusters (table 2). More C1 patients received a tracheostomy, and their ICU length of stay was longer.
Hospital length of stay was shortest in “No emergency admissions” C1 (med 5d (Inter Quartile Range
(IQR) 2,14) vs C3 18d (IQR 7, 41)), despite the longer ICU stays in C1.

Trajectory clusters and mortality

Overall, 29.6% (95% CI 29.1%, 30.2%, n=9,114) of patients died within a year of COVID-19 hospital
admission (figure 1, table E2). Over half of these events occurred within 30 days (17.3%, 95% CI
16.9%, 17.7%; n=7,035).

In-hospital mortality: 6,709 (20.0%) people died during their index hospital admission, and COVID-19
was the commonest underlying cause of death (n=5,564, 82.9%) (table E3). Circulatory (n=338, 5.0%)
and neoplasm (n=282, 4.2%) were other causes. In-hospital mortality increased according to cluster
category: lowest in C1 (14.4%), higher in C2 (25.1%), and highest in C3 (36.6%) and C4 (32.4%) (table
E1). Hospital length of stay was considerably shorter for survivors (median 6 days, IQR 2, 17)
compared with non-survivors (median 12 days, IQR 6, 27).

Long-term post-hospital discharge mortality: The median duration of available follow-up for
mortality and readmission from index hospital discharge was 298 days (IQR 134, 385). 90.0%
(n=24,193) of patients were discharged to a private residence, and a further 6.1% (n=1,651) were
discharged to an institution (table E4). For those who were discharged after their index admission
but subsequently died, the median time to death was 54 days (IQR 10, 179) and overall mortality at
30 days after hospital discharge was 3.2% (95%CI 3.0%, 3.4%), at 90 days was 5.5% (5.2%, 5.8%), and
12-months 11.7% (11.3%, 12.2%) (figure E3). This increased with age (12-month mortality 18-59
years 2.8% (2.5%, 3.2%) vs 80+ years 27.5% (26.1%, 28.9%)). 12-month mortality was lower (4.9%
(4.0%, 5.9%)) for ICU survivors compared with those managed on the ward (12.6% (12.1%, 13.1%)).
Mortality was considerably higher for hospital survivors with low levels of recent emergency hospital use (“Minimal admissions” C2, 12-month mortality 17.6%, 95%CI 16.7%, 18.6%) compared with survivors with no recent emergency admissions (C1, 12-month mortality 5.9%, 95% CI 5.5%, 6.4%). Patients with high recent hospital use (C3) had very high mortality even after surviving their initial COVID-19 admission (12-month mortality 33.2% (95% CI 30.1%, 36.1%). Of those who died post-initial-discharge, 37.6% (n=1,015) of patients died during a subsequent readmission to hospital, and 62.4% (n=1,684) died in the community. COVID-19 was the commonest underlying cause of death (n=488, 18.1%), followed by neoplasm (n=602, 22.3%) and circulatory (n=571, 21.1%) (table E5).

**Trajectory cluster and mortality association:** There was a univariable association between pre-admission trajectory cluster with both in-hospital mortality and post-discharge long-term mortality, which persisted after adjusting for potential confounders (figure 2). For both mortality outcomes, all cluster groups had increased risk of mortality relative to patients in C1. Mortality was highest in patients in “Recently high” C3, (C1 ref: in-hospital mortality Odds Ratio (OR) 1.81 (95% Confidence Interval (CI) 1.61, 2.03), post-hospital mortality HR 2.70 (95% CI 2.35, 2.81)).

**Emergency hospital readmission**

By day 30, 14.4% (95% CI 14.0%, 14.8%) of patients had experienced at least one emergency hospital readmission after their index COVID admission (day 90 21.4% (95% CI 21.0, 22.0%), 12 months 35.6% (34.9%, 36.3%) (figure 3, Table E6). In those readmitted, the median time to first readmission was 38 days (IQR 8, 131). The commonest cause of first readmission was COVID-19 (n=1,471, 17.7%) followed by respiratory (n=996, 12.0%) and circulatory causes (n=855, 10.3%) (table E7). The majority of post-COVID readmissions were unscheduled, and were higher for older patients and those with multimorbidity (figure 4). Emergency hospital readmissions were lower for patients admitted to ICU (30 days 10.9% (9.8%, 12.1%), 12 months 26.5% (24.7%, 28.4%)) compared with the ward (30 days 14.8% (14.3%, 15.2%), 12 months 36.7% (36.0%, 37.5%)). Trajectory clusters were significantly associated with readmission risk, which persisted after adjustment for patient demographics. This was highest in “Persistently high” C4 (ref C1; C2 HR 1.88 (95% CI 1.79, 1.98); C3 HR 2.88 (95% CI 2.65, 3.14); C4 HR 3.23 (95% CI 2.89, 3.61), figure 3).

**Trajectory clusters vs emergency bed days**

Trajectory clusters improved model fit for post-discharge deaths (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) (table E8, figure E4).
Post-hospital discharge resource use

Healthcare costs

For patients with at least six months potential follow-up, the mean excess post-discharge healthcare use was £3,631 (95% CI £3,322, £3,957) per person per year compared with baseline (figure 4, table E8). Costs were greatest in the first month after discharge, plateauing between 6-9 months post-discharge. Costs increased with age and comorbidity. Post-discharge costs were higher than baseline across all clusters except the “Persistently high” C4 cluster. Whilst absolute post-discharge costs were especially high for patients in C4 (£23,427, 95% CI £20,726, £26,478), these were substantially lower than this cluster’s baseline costs (£45,987, 95% CI £43,134, £49,052, relative reduction 49.1%), and the relative increase was highest in those with no emergency admissions in the previous 2 years (C1 excess £3,069 (95%CI £2,803, £3,381), relative increase 581.3%).

Discussion

In this national, complete cohort of patients hospitalised with COVID-19 between March 2020 and October 2021, 20% of patients died during their index admission, and a further 12% died within the year after hospital discharge. Readmission rates and resource use were high, with one in four patients readmitted within three months and nearly half of all survivors readmitted within a year. Pre-illness hospital resource trajectories were strongly associated with in-hospital mortality, post-discharge death, and readmission risk, independent of age and pre-existing comorbidity. Post-discharge all-cause mortality was lower than in shorter-term studies from the USA and England (60-day mortality 9%), and similar to the 9.7% six month mortality found in Germany. COVID-19 remained a common cause of early death after hospital discharge, accounting for nearly two thirds of deaths in the first two weeks. Neoplasm was the second most common cause of death, reflecting the high burden of malignancy in Scotland. Our study has reported longer-term hospital readmission and health care resource use on a national basis for hospital survivors of COVID-19. This is an important, unbiased person-centred outcome. Readmission rates after COVID-19 have varied considerably between countries: 30 days Spain 4.2% readmissions; 60 days USA 9% - 20%, England 23%, which may reflect differences in underlying healthcare organisation. Similar to our findings, other studies reported COVID-19 pneumonia as the most common cause for readmission (USA 30%, Spain 54%), however we found circulatory causes were also common.
Our findings that increasing age and comorbidity were significantly associated with readmission is consistent with both COVID and non-COVID literature.\textsuperscript{21,23} We found that being male was a risk factor for readmission, which contrasts with evidence that women may not recover as well from COVID-19 than men.\textsuperscript{4} Patients admitted to ICU in the UK for COVID-19 have been younger and less comorbid than for other respiratory infections,\textsuperscript{24,25} however we found that ICU survivors had lower rates of post-hospital mortality and readmission than ward survivors despite adjusting for age, comorbidity, previous health care resource and other important confounders. These findings are in contrast to previous COVID\textsuperscript{18} and non-COVID studies\textsuperscript{7} which found that ICU survivors experienced greater death rates and readmission compared with ward patients. We hypothesise that this reflects the underlying robust physiology of the young non-morbid patients who survived. This was a national study, which reduces the potential for selection bias which may affect prospective studies, but it may be that there is residual confounding which we have been unable to account for.

We found that patients who had received at least one COVID-19 vaccine were at lower risk of dying both in hospital and after hospital discharge. Whilst this may seem obvious given the wealth of literature regarding vaccine effectiveness, it is important to highlight two points. Firstly, those who were vaccinated first were elderly and vulnerable patients. Secondly, all patients had to meet an illness severity threshold for hospital admission to be included in this study, which could potentially bias vaccine effectiveness. Despite this, it was reassuring to see that even for patients requiring hospitalisation with COVID-19, the risk of mortality was lower for those who were vaccinated.

Few studies have explored sequelae of hospitalisation in the context of pre-illness trajectories. In the cohort as a whole, the pattern of trajectory indicated a period of time before admission with increasing health care costs, which was surprising for an infectious illness. This could be a marker for underlying health problems worsening or health care contact leading to COVID-19 infection. There were four distinct patterns of pre-COVID-19 hospital utilisation: no hospital admissions in the previous two years, minimal admissions, recent high use, and sustained high use. These clusters were strongly associated with post hospital utilisation. Patients with no emergency admissions in the previous two years had significantly lower readmission rates despite higher rates of admission to ICU, suggesting that this was a group of patients with significant physiological reserve. Patients with high utilisation had much higher rates of both mortality and readmission. Both high utilisation clusters (C3 and C4) had high proportions of elderly and multi-morbid patients, and malignancy was also over-represented, suggesting that these may have driven healthcare utilisation more than COVID-19. Furthermore, rates of nosocomial COVID-19 were high in these groups, highlighting their underlying ill health.
Healthcare utilisation and costs are known to increase with proximity to death. Routine data sources have become increasingly important in describing patient journeys through COVID-19. There are specific tools to assess frailty, however these are not contained in UK secondary care routine healthcare datasets which are collected for purposes other than research. Chronological age and multi-morbidity are often used as surrogates for frailty, and in England, adults accounting for the top 5% of costs were significantly older and had at least one long term condition. However although frailty is greatly associated with age, there is wide inter-individual variation, and multimorbidity may not adequately represent the reduced physiological reserve represented by frailty. Inclusion of pre-admission emergency trajectories in our analysis of routine healthcare datasets has helped to identify vulnerable patients at high risk of death and/or emergency readmission, over and above age and comorbidity. Furthermore, the pattern of trajectories improved the models further than a simple count of previous emergency use. Clinically, identifying these patients may provide the opportunity to put in place additional community support on discharge from hospital. Importantly, it may also facilitate earlier discussions with patients regarding treatment escalation plans should they become more unwell.

Our study had a number of strengths. Through use of linkage to national datasets capturing all acute hospitalisations, laboratory tests for SARS-CoV-2 and outpatient attendances, we were able to report population level estimates, minimising selection bias and loss to follow-up. We benchmarked post-discharge resource use within individuals using the pre-admission period as a comparator, which gave better control of confounding compared with using a control population. In contrast to other studies, we were able to account for historic healthcare resource use and explore its impact on outcomes. We have differentiated nosocomial and community acquisition of COVID-19, which is important as both underlying patient demographics and severity of COVID-19 disease may have been different.

The findings of our study should be interpreted in the context of several limitations. Laboratory testing capacity changed during the pandemic. We mitigated against this 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, post-acute COVID-19 symptoms are diverse, and so an ‘all readmission’ outcome is arguably better than cause-specific outcomes. Scotland has a predominantly white ethnic constituency, and we may be underpowered to detect differences in readmission and mortality in other ethnic groups. Changes in health care service provision and population behaviour as a result of the pandemic will have impacted on use of health services and subsequent costs, which will impact trajectories. We looked at secondary care utilisation 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 community COVID-19. We were unable to look at primary care utilisation, and patients who do not need secondary care admission may still have significant healthcare needs and contact with primary care services. We were unable to address secondary impacts of COVID-19 on the provision of other secondary care services which have inevitably been affected by the pandemic. Restriction to secondary care datasets may have biased comorbidity ascertainment. We were unable to explore patients’ social support in the community, which is likely to have influenced emergency admissions.

The impact of post-acute COVID-19 illness sequelae has been substantial on hospital services. High mortality and readmission rates were seen predominantly in elderly comorbid patients with high pre-COVID hospital utilisation, particularly those with escalating utilisation in the six months prior to admission. This highlights the need for post-COVID-19 recovery services to be tailored not only to the sequelae of COVID-19, but also to support pre-existing health conditions and frailty.

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Declaration of Interests
AL BBSRC, UKRI; SD nil; ABD Wellcome Trust, NIHR, DHSC, CSO; CAS nil; CE nil; DR nil; EMH nil; GL nil; JF nil; LNorris nil; LNorman nil; SS nil; WO nil; RMB nil; MT nil; CM nil; MGS NIHR, MRC, Health Protection Research Unit in Emerging and Zoonotic Infections, University of Liverpool; JKB MRC, Wellcome Trust, CSO, Fiona Elizabeth Agnew Trust, BBSRC, Baillie Gifford and Baillie Gifford Science Pandemic Hub.

Data sharing statement
These data are managed by Public Health Scotland (PHS) and we are not able to share data used in this study. However, the datasets can be applied for through the NHS Scotland Public Benefit and Privacy Panel for Health and Social Care (HSC-PBPP) and the electronic Data Research and Innovation Service (eDRIS) at https://www.informationgovernance.scot.nhs.uk/pbpphsc/.

Decision to submit
ABD, JF and EMH had the final responsibility for the decision to submit the manuscript to the journal.
References


**Author Contributions**

Conceptualisation: ABD, JF, EMH, NIL; data curation and linkage: GL, AL, LN, AB, BP, RM, RB, CM, DR, WO; formal analysis: ABD, JF, CE, SD, LN, CAS, RP, SS, EMH, NIL; funding acquisition: ABD, JKB, MGS; writing original draft: ABD, JF, EMH, NIL; writing review and editing: all authors.

Access and verified data: ABD, JF, EMH, NIL

**Figure Legends**

**Figure 1:** Kaplan Meier curves survival probability up to 1 year after index COVID-19 hospital admission. A: overall 29.6% (95% CI 29.1%, 30.2%; n=9,114) died within one year; then stratified by B: sex; C: clusters of emergency hospital use in preceding 2 years (C1 to C4); D: hospital bed-days during emergency admissions in preceding 2 years; E: age group; F: Charlson comorbidity count; G: Highest level of care (ICU, ward); H: vaccination status pre-admission.

**Figure 2:** A: Logistic regression for in-hospital mortality; B: Cox regression for emergency readmission for hospital survivors; C: Cox regression for post-discharge mortality. A: n = 30,639; AIC = 26,159; C-statistic = 0.783, H&L = Chi-sq(8) 149.13 (p<0.001). B: n = 23,722; number of events = 7,929; R-squared = 0.75 (Max possible = 0.987); AIC = 150,172; BIC = 150,298; log-likelihood = -75,068. C: n= 23,722; number of events = 2,687; R-squared = 0.066 (Max possible = 0.745); AIC = 49,519; BIC = 49,625; log-likelihood = -24,742.

**Figure 3:** Cumulative incidence of emergency hospital readmission up to 1 year after index COVID-19 hospital admission. A: Overall 35.6% (34.9%, 36.3%) patients were readmitted within one year; then stratified by B: sex; C: clusters of emergency hospital use in preceding 2 years (C1 to C4); D: hospital bed-days during emergency admissions in preceding 2 years; E: age group; F: Charlson comorbidity count; G: Highest level of care (ICU, ward); H: vaccination status pre-admission.

**Figure 4:** Patterns of hospital costs (emergency/elective inpatient, outpatient, day-case) in the two years preceding COVID-19 admission, and year following discharge. Hospital costs per patient per 30 day period. Stratified by: A: clusters of emergency hospital use in preceding 2 years (C1 to C4); B: hospital bed-days during emergency admissions in preceding 2 years; C: age group; D: Charlson comorbidity count; E: Highest level of care (ICU, ward); F: vaccination status pre-admission.

**Table 1:** Baseline characteristics of patients admitted to hospital with COVID-19 in Scotland after 1st March 2020 and discharged before 25th October 2021, stratified by pre-admission trajectory cluster. N=33,580.
Patient emergency healthcare trajectories preceding COVID-19 hospitalisation and longer term outcomes: a national cohort study

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Abstract:

Background: The impact of pre-illness health care trajectories on longer-term person-centred outcomes for patients hospitalised with COVID-19 remains unclear. We sought to describe mortality and emergency hospital readmission following COVID-19 hospitalisation and assess the association with trajectories of healthcare use prior to COVID-19 admission.

Methods: We undertook a national, complete retrospective cohort study using linked databases in all adult patients hospitalised in Scotland with COVID-19. We used latent class trajectory modelling to identify distinct clusters of patients based on emergency hospital admissions in the two years before COVID-19 admission. Primary outcomes were mortality and emergency readmission up to 12 months after hospitalisation. 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 utilisation.

Findings: Between 01/02/2020 and 25/10/2021 33,580 patients were admitted to hospital in Scotland with COVID-19. Overall, 29.6% (95% CI 29.1%, 30.2%) of patients died within a year of COVID-19 hospital admission. Within 30 days of hospital discharge, 14.4% (95% CI 14.0%, 14.8%) of patients had experienced at least one emergency hospital readmission, increasing to 35.6% (34.9%, 36.3%) at one year.

There were four distinct patterns of previous emergency hospital use: C1 “no admissions” (n=18,772, 55.9%); C2 “Minimal admissions” (n=12,057, 35.9%), C3 “Recently high” (n=1,931, 5.8%) and C4 “Persistently high” (n=820, 2.4%). Patients in high utilisation clusters (C3 and C4) were older, more multimorbid and more likely to have hospital-acquired COVID-19. All cluster groups had increased risk of mortality and hospital readmission relative to cluster C1. Mortality was highest in patients in “Recently high” C3, (C1 ref: post-hospital mortality HR 2.70 (95% CI 2.35, 2.81)) and readmission risk was highest in “Persistently high” C4 (ref C1: C4 HR 3.23 (95% CI 2.89, 3.61)).

Interpretation: Longer term mortality and readmission rates for patients hospitalised with COVID-19 have been high, with one in three dying within a year and a third readmitted as an emergency. Pre-illness hospital resource trajectories were strongly predictive of mortality and readmission risk, independent of age, pre-existing comorbidity and vaccination status. This more precise identification of individuals at high risk of poor outcomes from COVID-19 will enable targeted support.

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Research in Context

Evidence before this study:
We searched PubMed on 14th June 2022, 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 longer-term mortality, and readmission to hospital in patients who survived their index COVID-19 admission. Of 362 initial results, 44 original research studies examined mortality and/or hospital readmission in non-pregnant adults. Twenty studies had a maximum follow up time of less than three months from discharge. Only five had follow-up greater than six months, and these were predominantly smaller, single site cohorts. These studies found that older patients, male patients and those with comorbidities were more likely to die or be readmitted to hospital. Only one study quantified healthcare utilisation after COVID-19 diagnosis and none identified patterns of healthcare utilisation.

Added value of this study:
The aim of this study was to quantify systematically the extent to which patients hospitalised with COVID-19 were at risk of dying or being readmitted to hospital, in the context of the pattern of their pre-COVID-19 emergency healthcare utilisation.

In this national cohort we found that emergency readmission was common, with 35% of patients readmitted and one in three patients dying within a year of admission. Patients with a history of high healthcare resource use in the preceding two years were at higher risk of readmission and mortality independent of their age and multimorbidity, compared to those patients with no or minimal resource use. Those patients with a high frequency of recent emergency admissions were at greatest risk of dying in-hospital and after discharge. Patients with persistently high emergency admissions also had high mortality and were at highest risk of readmission.

Implications of all the available evidence:
Patients hospitalised with COVID-19 experience high rates of mortality and healthcare use in the year following hospital discharge. Defining pre-admission trajectories of healthcare use enables more precise identification, over and above age, comorbidity and vaccination status, of individuals who are at high risk of poor outcomes. This will enable early support to be appropriately targeted to these vulnerable patients.
Introduction

It has become clear over the course of the COVID-19 pandemic, that patient demographics such as increasing age and multimorbidity, and severity of illness at presentation are major risk factors for COVID-19 in-hospital mortality.\textsuperscript{1,2} Whilst death is important as an outcome, patients and families may consider other person-centred outcomes to be as important, if not more so, than death.\textsuperscript{3}

Although data are emerging relating to the symptom burden and quality of life for these survivors, this has been limited by convenience sampling\textsuperscript{4} or incomplete population sampling,\textsuperscript{1} leading to a potential for bias. Hospital readmission and health care resource use following initial COVID-19 hospitalisation discharge are measures that are highly person-centred, relatively well recorded and easy to obtain and not subject to similar biases.\textsuperscript{5} There is considerable variation in post-discharge healthcare use, with lower utilisation among people with less severe COVID-19 illness.\textsuperscript{6} The additional burden of people surviving a COVID-19 hospitalisation on subsequent secondary care resources remains uncertain, particularly in the context of patients’ pre-COVID hospital use. It is important to identify patients 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 healthcare utilisation have previously been shown to be stronger predictors of hospital resource than those associated with the acute illness,\textsuperscript{7}. However, few studies have looked at longitudinal trajectories of hospital utilisation at population level.\textsuperscript{8,9}

We hypothesised that trajectories of emergency hospital admissions are a marker of vulnerability that can help to identify those patients at highest risk of mortality and readmission independent of age and comorbidity. We aimed to use national Scottish data to ascertain if patterns of emergency hospital use in the two years preceding the index hospital admission with COVID-19 could identify patients at high risk of death and readmission.

Methods

Study design, setting and participants

We analysed routine healthcare data for all patients ≥18 years admitted to hospital in Scotland with either community or hospital acquired COVID-19 after 1\textsuperscript{st} March 2020 who died or were discharged before 25\textsuperscript{th} October 2021. All patients were followed up until 22\textsuperscript{nd} November 2021 or until date of death (whichever was earlier). Approval for access to datasets was granted by the Public Benefit and
Approval for access to data can be requested through the PBPP. We reported according to STROBE guidelines.

Datasets

The Scottish Morbidity Record (SMR01) contains national data on hospital activity and mortality, and outpatient activity (SMR00). Electronic Communication of Surveillance in Scotland (ECOSS) holds all positive microbiology laboratory specimen results. Scottish Intensive Care Society Audit Group (SICSAG) contains all adult general intensive care activity. National Records Scotland (NRS) record all deaths registered in Scotland. Scottish COVID-19 Vaccination dataset contains COVID-19 vaccination events in Scotland since December 2020 (online supplement for further details).

Variables

COVID-19 hospitalisation was defined by an admission within 14 days of a positive COVID-19 PCR test. Nosocomial infection was defined as a positive PCR test (ECOSS) ≥5 days after hospital admission. To mitigate the lack of testing at the start of the pandemic, clinically ICD-10 coded COVID-19 were also included (see online supplement). We categorised age into the following groups: <50, 50-69, 70-79, 80+, based on the univariable association with age and mortality and consistent with previous studies. Socioeconomic deprivation was defined using quintiles of Scottish Index of Multiple Deprivation (SIMD Version 2020). Ethnicity was derived from categories of the Scottish Census 2011 and aggregated due to low frequencies as “White” or “Other”. We derived measures of comorbidity from acute hospital admissions (SMR01) using Charlson comorbidities. Acute illness variables comprised admission to Intensive Care Units (ICU), receipt of invasive ventilation, inotropic support, or renal replacement therapy. The first wave of the pandemic was defined as 01/03/2020 to 31/08/2020 (first patient admitted to hospital in Scotland in March 2020); the second wave was defined as 01/09/2020 to 30/04/2021; and the third wave was defined as 01/05/21 to the end of the study period (See online supplement for further details). Patients were considered vaccinated if the COVID-19 admission was ≥3 weeks after first vaccination or ≥2 weeks after any booster, and not longer than nine months after last dose, as protection against severe symptomatic disease is significantly longer than against mild disease.

Pre-COVID-19 hospital emergency healthcare trajectories

We extracted emergency hospital admissions from SMR01 records for two years prior to the index COVID-19 admission for all patients. We categorised emergency hospital usage into the number of days spent in hospital during emergency hospital admissions per 30 day period in order to incorporate time before admission, frequency of admissions and duration of admissions.
Outcomes

The primary outcomes were all-cause mortality (during index COVID-19 hospitalisation, and 12-month post-discharge), and emergency readmission up to 12 months after COVID-19 hospitalisation. The secondary outcome was post-discharge hospital resource use.

Mortality

Mortality was derived from linkage to NRS death records. Palliative discharge marked on SMR01 was included within hospital mortality. We explored whether COVID-19 was mentioned in the death certificate, either as “underlying condition” or “other”.

Post-discharge hospital resource use

There were three categories of healthcare resource: outpatient appointments, inpatient hospital admissions (elective/emergency), and day case admission. We derived hospital case costs from the NHS Scottish Costs Book\(^4\) converted to 2021 costs, using per diem costing. A same day inpatient discharge was assigned 0.5 days.

Statistical analysis

The dataset was cleaned, recoded, linked and analysed using R v3.6.4 (R Core Team version 3.6.4, Vienna, Austria\(^5\)). Cells containing values from <5 patients were suppressed. No sample size calculation was performed as this was fixed by the number of admissions. A complete case analysis was performed. Analytical code is at https://github.com/SurgicalInformatics/scot_covid_trajectories.

Pre-COVID trajectory clustering

Using emergency hospital admissions as a potential marker of vulnerability, we used latent class trajectory modelling (LCTM) to identify subgroups of patients with distinct trajectories of emergency healthcare use. We modelled length of stay in hospital (during emergency admissions) in a 30-day period as a function of time in the two years (24 points) prior to a patient’s COVID-19 admission. We used R packages “LCTMtools” and “lcmm” (see online supplement for further details). We then applied these trajectories across all mortality and emergency re-admissions.

In order to evaluate whether the temporal sequence in the trajectory improved model fit over a simple count of emergency hospital use, we also categorised number of emergency bed-days in the previous two years: “0 days”, “0.5-7 days”, “7.5-21 days” and “21+ days”. For all models, we assessed performance comparing trajectory clusters and number of bed days using the Bayesian information criterion (BIC). A change in BIC >10 strongly favours the model with the lower BIC.\(^6\)
Mortality and time to first readmission

We used Kaplan-Meier estimates to report mortality, and cumulative incidence to report time to first admission at specified time points. We used logistic regression for early in-hospital mortality. For hospital survivors, we used Cox Proportional Hazards regression analysis to account for differential follow-up, with results presented as hazard ratios (HR). We used the 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 index hospital discharge. All patients had at least four weeks follow-up from hospital discharge. The maximum potential follow-up was 365 days. Patients alive on 22nd November 2021 were censored.

Healthcare resource use

Post-discharge hospital resource use

There were three categories of healthcare resource: outpatient appointments, inpatient hospital admissions (elective/emergency), and day case admission. We derived hospital case costs from the NHS Scottish Costs Book, using per diem costing. A same day inpatient discharge was assigned 0.5 days. We calculated excess costs within individuals by comparing 6-month post-index discharge costs with an individual’s baseline costs defined as the costs for the eighteen month period between two years and six months prior to the index COVID-19 admission. We calculated excess costs for all patients with potential six months follow up in order to maximise the size of the cohort.

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

Results

Between 01/03/2020 and 25/10/2021, 33,580 patients were admitted with COVID-19 to hospitals in Scotland, or developed COVID-19 during a hospital admission (figure E1). There were four distinct trajectories of emergency healthcare use in the preceding 2 years (table 1, figure E2, appendix A). More than half of patients had had no emergency hospital admissions in the previous 2 years, comprising the largest cluster (C1 “No emergency admissions”, n=18,772, 55.9%). C2 was the second largest group (“Minimal admissions”, n=12,057, 35.9%), and comprised patients with stable low level preceding hospital use. C3 (“Recently high”, n=1,931, 5.8%) had rapidly increasing hospital admissions in the six months before the index COVID-19 admission. Patients in C4 (“Persistently
high”, n=820, 2.4%) had a more sustained pattern of high healthcare use over the two preceding years.

Demographic and illness features were distinct between clusters. Patients in the “No emergency admissions” cluster C1 were younger than other clusters (median age 61 years vs 74-77 years in other clusters), had a predominance of males and a lower prevalence of comorbidity. The “Recently high” Cluster C3 consisted of the oldest group (43.2% of patients age 80+) and had the highest levels of nosocomial infections (nosocomial 33.0% vs “No admissions” 9.9%). Patients in the “Persistently high” Cluster C4 were also elderly (80+ years 37.7%, n=309) and were the most comorbid, with 79.1% of patients having 2+ Charlson comorbidities. Proportions of patients with cerebrovascular disease (33.3%), chronic pulmonary disease (47.1%), renal disease (34.4%) were noticeably higher in this cluster compared with other clusters. Despite having an age distribution similar to the “Recently high” and “Persistently high” clusters, patients in the “Minimal admissions” cluster C2 were less multimorbid, more likely to have contracted COVID-19 in the community, and more likely to be admitted in Wave 3.

29,282 (87.2%) of patients received a maximum of ward level care, and 4,298 (12.8%) received ICU care (table E1). The proportion of patients admitted to ICU in the “No emergency admissions” cluster (16.4%) was much higher than the other clusters (C2 8.9%, C3 5.5%, C4 5.6%). Patients in the “No emergency admissions” C1 received significantly higher organ support (C1 invasive mechanical ventilation [IMV] 6.9%, Renal Replacement Therapy [RRT] 1.9%, vasopressors 7.0%) than all other clusters (table 2). More C1 patients received a tracheostomy, and their ICU length of stay was longer.

Hospital length of stay was shortest in “No emergency admissions” C1 (med 5d [Inter Quartile Range (IQR) 2,14] vs C3 18d [IQR 7, 41]), despite the longer ICU stays in C1.

Trajectory clusters and mortality

Overall, 29.6% (95% CI 29.1%, 30.2%, n=9,114) of patients died within a year of COVID-19 hospital admission (figure 12, table E2). Over half of these events occurred within 30 days (17.3%, 95%CI 16.9%, 17.7%; n=7,035).

In-hospital mortality: 6,709 (20.0%) people died during their index hospital admission, and COVID-19 was the commonest underlying cause of death (n=5,564, 82.9%) (table E3). Circulatory (n=338, 5.0%) and neoplasm (n=282, 4.2%) were other causes. In-hospital mortality increased according to cluster category: lowest in C1 (14.4%), higher in C2 (25.1%), and highest in C3 (36.6%) and C4 (32.4%) (table E1). Hospital length of stay was considerably shorter for survivors (median 6 days, IQR 2, 17) compared with non-survivors (median 12 days, IQR 6, 27).
Long-term post-hospital discharge mortality: The median duration of available follow-up for mortality and readmission from index hospital discharge was 298 days (IQR 134, 385). 90.0% (n=24,193) of patients were discharged to a private residence, and a further 6.1% (n=1,651) were discharged to an institution (table E4). For those who were discharged after their index admission but subsequently died, the median time to death was 54 days (IQR 10, 179) and overall mortality at 30 days after hospital discharge was 3.2% (95%CI 3.0%, 3.4%), at 90 days was 5.5% (5.2%, 5.8%), and 12-months 11.7% (11.3%, 12.2%) (figure E3). This increased with age (12-month mortality 18-59 years 2.8% (2.5%, 3.2%) vs 80+ years 27.5% (26.1%, 28.9%)). 12-month mortality was lower (4.9% (4.0%, 5.9%)) for ICU survivors compared with those managed on the ward (12.6% (12.1%, 13.1%)).

Mortality was considerably higher for hospital survivors with low levels of recent emergency hospital use (“Minimal admissions” C2, 12-month mortality 17.6%, 95%CI 16.7%, 18.6%) compared with survivors with no recent hospital emergency admissions (C1, 12-month mortality 5.9%, 95% CI 5.5%, 6.4%). Patients with high recent hospital use (C3) had very high mortality even after surviving their initial COVID-19 admission (12-month mortality 33.2% (95% CI 30.1%, 36.1%). Of those who died post-initial-discharge, 37.6% (n=1,015) of patients died during a subsequent readmission to hospital, and 62.4% (n=1,684) died in the community. COVID-19 was the commonest underlying cause of death (n=488, 18.1%), followed by neoplasm (n=602, 22.3%) and circulatory (n=571, 21.1%) (table E5).

Trajectory cluster and mortality association: There was a univariable association between pre-admission trajectory cluster with both in-hospital mortality and post-discharge long-term mortality, which persisted after adjusting for potential confounders (figure 24). For both mortality outcomes, all cluster groups had increased risk of mortality relative to patients in C1. Mortality was highest in patients in “Recently high” C3, (C1 ref: in-hospital mortality Odds Ratio (OR) 1.81 (95% Confidence Interval (CI) 1.61, 2.03), post-hospital mortality HR 2.70 (95% CI 2.35, 2.81)).

Emergency hospital readmission

By day 30, 14.4% (95% CI 14.0%, 14.8%) of patients had experienced at least one emergency hospital readmission after their index COVID admission (day 90 21.4% (95% CI 21.0, 22.0%), 12 months 35.6% (34.9%, 36.3%) (figure 3, Table E6). In those readmitted, the median time to first readmission was 38 days (IQR 8, 131). The commonest cause of first readmission was COVID-19 (n=1,471, 17.7%) followed by respiratory (n=996, 12.0%) and circulatory causes (n=855, 10.3%) (table E7). The majority of post-COVID readmissions were unscheduled, and were higher for older patients and those with multimorbidity (figure 4). Emergency hospital readmissions were lower for patients admitted to ICU (30 days 10.9% (9.8%, 12.1%), 12 months 26.5% (24.7%, 28.4%)) compared with the ward (30 days 14.8% (14.3%, 15.2%), 12 months 36.7% (36.0%, 37.5%)). Trajectory clusters were...
significantly associated with readmission risk, which persisted after adjustment for patient demographics. This was highest in “Persistently high” C4 (ref C1; C2 HR 1.88 (95% CI 1.79, 1.98); C3 HR 2.88 (95% CI 2.65, 3.14); C4 HR 3.23 (95% CI 2.89, 3.61), figure 3).

Trajectory clusters vs emergency bed days
Trajectory clusters improved model fit for post-discharge deaths (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) (table E8, figure E4).

Post-hospital discharge resource use

Healthcare costs
For patients with at least six months potential follow-up, the mean excess post-discharge healthcare use was £3,631 (95% CI £3,322, £3,957) per person per year compared with baseline (figure 4, table E8). Costs were greatest in the first month after discharge, plateauing between 6-9 months post-discharge. Costs increased with age and comorbidity. Post-discharge costs were higher than baseline across all clusters except the “Persistently high” C4 cluster. Whilst absolute post-discharge costs were especially high for patients in C4 (£23,427, 95% CI £20,726, £26,478), these were substantially lower than this cluster’s baseline costs (£45,987, 95% CI £43,134, £49,052, relative reduction 49.1%), and the relative increase was highest in those with no previous emergency admissions in the previous 2 years (C1 excess £3,069 (95%CI £2,803, £3,381), relative increase 581.3%).

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

Post-discharge all-cause mortality was lower than in shorter-term studies from the USA and England (60-day mortality 9%),17,18 and similar to the 9.7% six month mortality found 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 two weeks. Neoplasm was the second most common cause of death, reflecting the high burden of malignancy in Scotland.20
Our study has reported longer-term hospital readmission and health care resource use on a national basis for hospital survivors of COVID-19. This is an important, unbiased person-centred outcome. Readmission rates after COVID-19 have varied considerably between countries: 30 days Spain 4.2% readmissions\(^1\); 60 days USA 9\(^{\%}^{12} - 20\%^{\text{,}6,22}\) England 23\(^{\%}^{,18}\) which may reflect differences in underlying healthcare organisation. Similar to our findings, other studies reported COVID-19 pneumonia as the most common cause for readmission (USA 30\(^{\%}^{,17}\) Spain 54\(^{\%}^{21}\)), however we found circulatory causes were also common. Our findings that increasing age and comorbidity were significantly associated with readmission is consistent with both COVID and non-COVID literature\(^{21,23}\) We found that being male was a risk factor for readmission, which contrasts with evidence that women may not recover as well from COVID-19 than men\(^{4}\). Patients admitted to ICU in the UK for COVID-19 have been younger and less comorbid than for other respiratory infections\(^{,24,25}\) however we found that ICU survivors had lower rates of post-hospital mortality and readmission than ward survivors despite adjusting for age, comorbidity, previous health care resource and other important confounders. These findings are in contrast to previous COVID\(^{18}\) and non-COVID studies\(^{7}\) which found that ICU survivors experienced greater death rates and readmission compared with ward patients. We hypothesise that this reflects the underlying robust physiology of the young non-morbid patients who survived. This was a national study, which reduces the potential for selection bias which may affect prospective studies, but it may be that there is residual confounding which we have been unable to account for. We found that patients who had received at least one COVID-19 vaccine were at lower risk of dying both in hospital and after hospital discharge. Whilst this may seem obvious given the wealth of literature regarding vaccine effectiveness, it is important to highlight two points. Firstly, those who were vaccinated first were elderly and vulnerable patients. Secondly, all patients had to meet an illness severity threshold for hospital admission to be included in this study, which could potentially bias vaccine effectiveness. Despite this, it was reassuring to see that even for patients requiring hospitalisation with COVID-19, the risk of mortality was lower for those who were vaccinated. Few studies have explored sequelae of hospitalisation in the context of pre-illness trajectories. In the cohort as a whole, the pattern of trajectory indicated a period of time before admission with increasing health care costs, which was surprising for an infectious illness. This could be a marker for underlying health problems worsening or health care contact leading to COVID-19 infection. There were four distinct patterns of pre-COVID-19 hospital utilisation: no hospital admissions in the previous two years, minimal admissions, recent high use, and sustained high use. These clusters were strongly associated with post hospital utilisation. Patients with no emergency admissions in the previous two years had significantly lower readmission rates despite higher rates of admission to
ICU, suggesting that this was a group of patients with significant physiological reserve. Patients with high utilisation had much higher rates of both mortality and readmission. Both high utilisation clusters (C3 and C4) had high proportions of elderly and multi-morbid patients, and malignancy was also over-represented, suggesting that these may have driven healthcare utilisation more than COVID-19. Furthermore, rates of nosocomial COVID-19 were high in these groups, highlighting their underlying ill health.

Healthcare utilisation and costs are known to increase with proximity to death.26,27 Routine data sources have become increasingly important in describing patient journeys through COVID-19. There are specific tools to assess frailty, however these are not contained in UK secondary care routine healthcare datasets which are collected for purposes other than research. Chronological age and multi-morbidity are often used as surrogates for frailty, and in England, adults accounting for the top 5% of costs were significantly older and had at least one long term condition.28 However although frailty is greatly associated with age, there is wide inter-individual variation, and multimorbidity may not adequately represent the reduced physiological reserve represented by frailty. Inclusion of pre-admission emergency trajectories in our analysis of routine healthcare datasets has helped to identify vulnerable patients at high risk of death and/or emergency readmission, over and above age and comorbidity. Furthermore, the pattern of trajectories improved the models further than a simple count of previous emergency use. Clinically, identifying these patients may provide the opportunity to put in place additional community support on discharge from hospital. Importantly, it may also facilitate earlier discussions with patients regarding treatment escalation plans should they become more unwell.

Our study had a number of strengths. Through use of linkage to national datasets capturing all acute hospitalisations, laboratory tests for SARS-CoV-2 and outpatient attendances, we were able to report population level estimates, minimising selection bias and loss to follow-up. We benchmarked post-discharge resource use within individuals using the pre-admission period as a comparator, which gave better control of confounding compared with using a control population. In contrast to other studies, we were able to account for historic healthcare resource use and explore its impact on outcomes. We have differentiated nosocomial and community acquisition of COVID-19, which is important as both underlying patient demographics and severity of COVID-19 disease may have been different.

The findings of our study should be interpreted in the context of several limitations. Laboratory testing capacity changed during the pandemic. We mitigated against this 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, post-acute COVID-19
symptoms are diverse, and so an ‘all readmission’ outcome is arguably better than cause-specific outcomes. Scotland has a predominantly white ethnic constituency, and we may be underpowered to detect differences in readmission and mortality in other ethnic groups. Changes in health care service provision and population behaviour as a result of the pandemic will have impacted on use of health services and subsequent costs, which will impact trajectories. We looked at secondary care utilisation 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 community COVID-19. We were unable to look at primary care utilisation, and patients who do not need secondary care admission may still have significant healthcare needs and contact with primary care services. We were unable to address secondary impacts of COVID-19 on the provision of other secondary care services which have inevitably been affected by the pandemic. Restriction to secondary care datasets may have biased comorbidity ascertainment. We were unable to explore patients’ social support in the community, which is likely to have influenced emergency admissions.

The impact of post-acute COVID-19 illness sequelae has been substantial on hospital services. High mortality and readmission rates were seen predominantly in elderly comorbid patients with high pre-COVID hospital utilisation, particularly those with escalating utilisation in the six months prior to admission. This highlights the need for post-COVID-19 recovery services to be tailored not only to the sequelae of COVID-19, but also to support pre-existing health conditions and frailty.

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**Author Contributions**
1. Conceptualisation: ABD, JF, EMH, NIL; data curation and linkage: GL, AL, LN, AB, BP, RM, RB, CM, DR, WO; formal analysis: ABD, JF, MT, CE, SD, LN, CAS, RP, SS, EMH, NIL; funding acquisition: ABD, JKB, MGS; writing original draft: ABD, JF, EMH, NIL; writing review and editing: all authors.
2. Access and verified data: ABD, JF, EMH, NIL

**Figure Legends**
1. Figure 1: Kaplan Meier curves survival probability up to 1 year after index COVID-19 hospital admission. A: overall 29.6% (95% CI 29.1%, 30.2%, n=9,114) died within one year; then stratified by B: sex; C: clusters of emergency hospital use in preceding 2 years (C1 to C4); D: hospital bed-days during emergency admissions in preceding 2 years; E: age group; F: Charlson comorbidity count; G: Highest level of care (ICU, ward); H: vaccination status pre-admission.
2. Figure 2: A: Logistic regression for in-hospital mortality; B: Cox regression for emergency readmission for hospital survivors; C: Cox regression for post-discharge mortality. A: n = 30,639; AIC = 26,159; C-statistic = 0.783, H&L = Chi-sq(8) 149.13 (p<0.001). B: n = 23,722; number of events = 7,929; R-squared = 0.75 (Max possible = 0.987); AIC = 150,172; BIC = 150,298; log-likelihood = -75,068. C: n = 23,722; number of events = 2,687; R-squared = 0.066 (Max possible = 0.745); AIC = 49,519; BIC = 49,625; log-likelihood = -24,742.
3. Figure 3: Cumulative incidence of emergency hospital readmission up to 1 year after index COVID-19 hospital admission. A: Overall 35.6% (34.9%, 36.3%) patients were readmitted within one year; then stratified by B: sex; C: clusters of emergency hospital use in preceding 2 years (C1 to C4); D: hospital bed-days during emergency admissions in preceding 2 years; E: age group; F: Charlson comorbidity count; G: Highest level of care (ICU, ward); H: vaccination status pre-admission.
4. Figure 4: Patterns of hospital costs (emergency/elective inpatient, outpatient, day-case) in the two years preceding COVID-19 admission, and year following discharge. Hospital costs per patient per 30 day period. Stratified by: A: clusters of emergency hospital use in preceding 2 years (C1 to C4); B: hospital bed-days during emergency admissions in preceding 2 years; C: age group; D: Charlson comorbidity count; E: Highest level of care (ICU, ward); F: vaccination status pre-admission.
Table 1: Baseline characteristics of patients admitted to hospital with COVID-19 in Scotland after 1st March 2020 and discharged before 25th October 2021, stratified by pre-admission trajectory cluster. N=33,580

<table>
<thead>
<tr>
<th>Dependent Cluster</th>
<th>C1: No admissions N=18,772</th>
<th>C2: Minimal admissions N=12,057</th>
<th>C3: Recently high N=1,931</th>
<th>C4: Persistently high N=820</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N (%)</td>
<td>18,772 (55.9)</td>
<td>12,057 (35.9)</td>
<td>1,931 (5.8)</td>
<td>820 (2.4)</td>
<td></td>
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<tr>
<td>Age Median (IQR)</td>
<td>61.0 (48.0 to 75.0)</td>
<td>74.0 (59.0 to 83.0)</td>
<td>77.0 (67.0 to 85.0)</td>
<td>75.0 (62.0 to 84.0)</td>
<td>&lt;0.001</td>
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<tr>
<td>Age group 18-59</td>
<td>8626 (46.0)</td>
<td>3168 (26.3)</td>
<td>299 (15.5)</td>
<td>186 (22.7)</td>
<td>&lt;0.001</td>
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<tr>
<td>60-69</td>
<td>3429 (18.3)</td>
<td>1816 (15.1)</td>
<td>284 (14.7)</td>
<td>105 (12.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>70-79</td>
<td>3386 (18.0)</td>
<td>2844 (23.6)</td>
<td>514 (26.6)</td>
<td>220 (26.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>80+</td>
<td>3331 (17.7)</td>
<td>4229 (35.1)</td>
<td>834 (43.2)</td>
<td>309 (37.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex Female</td>
<td>8764 (46.7)</td>
<td>6243 (51.8)</td>
<td>991 (51.3)</td>
<td>429 (52.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Scotland Level quintile for SIMD 2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5635 (30.0)</td>
<td>3939 (32.7)</td>
<td>625 (32.4)</td>
<td>308 (37.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2</td>
<td>4452 (23.7)</td>
<td>2922 (24.2)</td>
<td>503 (26.0)</td>
<td>189 (23.0)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3197 (17.0)</td>
<td>2123 (17.6)</td>
<td>328 (17.0)</td>
<td>133 (16.2)</td>
<td></td>
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<tr>
<td>4</td>
<td>2890 (15.4)</td>
<td>1672 (13.9)</td>
<td>247 (12.8)</td>
<td>115 (14.0)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2523 (13.4)</td>
<td>1386 (11.5)</td>
<td>225 (11.7)</td>
<td>74 (9.0)</td>
<td></td>
</tr>
<tr>
<td>(Missing)</td>
<td>75 (0.4)</td>
<td>15 (0.1)</td>
<td>&lt;5 (-)</td>
<td>&lt;5 (-)</td>
<td></td>
</tr>
<tr>
<td>Ethnicity White</td>
<td>15308 (81.5)</td>
<td>11245 (93.3)</td>
<td>1855 (96.1)</td>
<td>798 (97.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Other than white</td>
<td>1102 (5.9)</td>
<td>355 (2.9)</td>
<td>28 (1.5)</td>
<td>13 (1.6)</td>
<td></td>
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<tr>
<td>(Missing)</td>
<td>2362 (12.6)</td>
<td>457 (3.8)</td>
<td>48 (2.5)</td>
<td>9 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Source of COVID-19 infection Community</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Nosocomial</td>
<td>1765 (9.4)</td>
<td>2317 (19.2)</td>
<td>608 (31.5)</td>
<td>203 (24.8)</td>
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<tr>
<td>(Missing)</td>
<td>907 (4.8)</td>
<td>632 (5.2)</td>
<td>90 (4.7)</td>
<td>41 (5.0)</td>
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<tr>
<td>COVID-19 wave Wave 1</td>
<td>3505 (18.7)</td>
<td>2445 (20.3)</td>
<td>489 (25.3)</td>
<td>257 (31.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Wave 2</td>
<td>9531 (50.8)</td>
<td>6571 (54.5)</td>
<td>1133 (58.7)</td>
<td>451 (55.0)</td>
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<tr>
<td>Wave 3</td>
<td>5736 (30.6)</td>
<td>3041 (25.2)</td>
<td>309 (16.0)</td>
<td>112 (13.7)</td>
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<tr>
<td>Vaccinated Yes</td>
<td>3643 (19.4)</td>
<td>2726 (22.6)</td>
<td>292 (15.1)</td>
<td>113 (13.8)</td>
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</tr>
<tr>
<td>Number of Charlson comorbidities 0</td>
<td>8935 (47.6)</td>
<td>2099 (17.4)</td>
<td>145 (7.5)</td>
<td>49 (6.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1</td>
<td>5741 (30.6)</td>
<td>3328 (27.6)</td>
<td>429 (22.2)</td>
<td>122 (14.9)</td>
<td></td>
</tr>
<tr>
<td>2+</td>
<td>4096 (21.8)</td>
<td>6630 (55.0)</td>
<td>1357 (70.3)</td>
<td>649 (79.1)</td>
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<tr>
<td>Acute myocardial infarction Yes</td>
<td>1177 (6.3)</td>
<td>1931 (16.0)</td>
<td>365 (18.9)</td>
<td>190 (23.2)</td>
<td>&lt;0.001</td>
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<tr>
<td>Congestive heart failure Yes</td>
<td>777 (4.1)</td>
<td>1784 (14.8)</td>
<td>455 (23.6)</td>
<td>213 (26.0)</td>
<td>&lt;0.001</td>
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<tr>
<td>Peripheral vascular disease Yes</td>
<td>705 (3.8)</td>
<td>1250 (10.4)</td>
<td>304 (15.7)</td>
<td>144 (17.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cerebrovascular disease Yes</td>
<td>1427 (7.6)</td>
<td>2413 (20.0)</td>
<td>477 (24.7)</td>
<td>273 (33.3)</td>
<td>&lt;0.001</td>
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<tr>
<td>Dementia Yes</td>
<td>737 (3.9)</td>
<td>1352 (11.2)</td>
<td>260 (13.5)</td>
<td>138 (16.8)</td>
<td>&lt;0.001</td>
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<tr>
<td>Chronic pulmonary disease Yes</td>
<td>3564 (19.0)</td>
<td>4076 (33.8)</td>
<td>728 (37.7)</td>
<td>386 (47.1)</td>
<td>&lt;0.001</td>
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<tr>
<td>Rheumatic disease Yes</td>
<td>458 (2.4)</td>
<td>537 (4.5)</td>
<td>123 (6.4)</td>
<td>54 (6.6)</td>
<td>&lt;0.001</td>
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<tr>
<td>Peptic ulcer disease Yes</td>
<td>460 (2.5)</td>
<td>671 (5.6)</td>
<td>159 (8.2)</td>
<td>66 (8.0)</td>
<td>&lt;0.001</td>
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<tr>
<td>Hemiplegia or paraplegia Yes</td>
<td>188 (1.0)</td>
<td>361 (3.0)</td>
<td>85 (4.4)</td>
<td>57 (7.0)</td>
<td>&lt;0.001</td>
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<tr>
<td>Renal disease Yes</td>
<td>1326 (7.1)</td>
<td>2479 (20.6)</td>
<td>576 (29.8)</td>
<td>282 (34.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HIV/AIDS Yes</td>
<td>21 (0.1)</td>
<td>9 (0.1)</td>
<td>&lt;5 (-)</td>
<td>&lt;5 (-)</td>
<td>0.030</td>
</tr>
<tr>
<td>Liver disease None</td>
<td>18173 (96.8)</td>
<td>11097 (92.0)</td>
<td>1695 (87.8)</td>
<td>660 (80.5)</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>Mild</td>
<td>Moderate/Severe</td>
<td>Diabetes</td>
<td>Malignancy (ex. skin neoplasm)</td>
<td>Med-days during emergency admissions in previous 2 years</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------</td>
<td>-----------------</td>
<td>----------</td>
<td>------------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>459 (2.4)</td>
<td>714 (5.9)</td>
<td>140 (7.3)</td>
<td>99 (12.1)</td>
<td><strong>Median (IQR)</strong>: 0 (0 to 0)</td>
</tr>
<tr>
<td>Diabtes</td>
<td>140 (0.7)</td>
<td>246 (2.0)</td>
<td>96 (5.0)</td>
<td>61 (7.4)</td>
<td><strong>&lt;0.001</strong></td>
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<tr>
<td>None</td>
<td>15752 (83.9)</td>
<td>8959 (74.3)</td>
<td>1318 (68.3)</td>
<td>520 (63.4)</td>
<td><strong>&lt;0.001</strong></td>
</tr>
<tr>
<td>Without complications</td>
<td>2800 (14.9)</td>
<td>2598 (21.5)</td>
<td>475 (24.6)</td>
<td>217 (26.5)</td>
<td><strong>&lt;0.001</strong></td>
</tr>
<tr>
<td>With complications</td>
<td>220 (1.2)</td>
<td>500 (4.1)</td>
<td>138 (7.1)</td>
<td>83 (10.1)</td>
<td><strong>&lt;0.001</strong></td>
</tr>
<tr>
<td>Malignancy (ex. skin neoplasm)</td>
<td>None</td>
<td>16984 (90.5)</td>
<td>9730 (80.7)</td>
<td>1449 (75.0)</td>
<td>676 (82.4)</td>
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<tr>
<td>Non-metastatic</td>
<td>1408 (7.5)</td>
<td>1632 (13.5)</td>
<td>328 (17.0)</td>
<td>116 (14.1)</td>
<td><strong>&lt;0.001</strong></td>
</tr>
<tr>
<td>Metastatic</td>
<td>380 (2.0)</td>
<td>695 (5.8)</td>
<td>154 (8.0)</td>
<td>28 (3.4)</td>
<td><strong>&lt;0.001</strong></td>
</tr>
<tr>
<td>Editorial comments</td>
<td>Author response and changes made</td>
<td>Page number in revised paper</td>
<td></td>
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<tr>
<td>p-values should be given to two significant figures, but no longer than 4 decimal places (e.g. p&lt;0.0001).</td>
<td>Thank you. We have adapted our p-values</td>
<td>Table 1</td>
<td></td>
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<tr>
<td>For means, please provide standard deviation (or error, as appropriate).</td>
<td>We believe all our continuous data are skewed, and have provided median interquartile range (Q1, Q3)</td>
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<tr>
<td>Please provide interquartile ranges for medians.</td>
<td>We believe all our continuous data are skewed, and have provided median interquartile range (Q1, Q3)</td>
<td>We have provided IQR for all the median values we have presented (table 1)</td>
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<tr>
<td>Please provide numbers at risk for Kaplan-Meier plots and ensure that plots include a measure of effect (eg, log-rank p); estimates should be reported with 95% CIs.</td>
<td>Thank you. We have provided risk tables for all Kaplan Meier plots and cumulative incidence plots in the online supplement</td>
<td>Online supplement</td>
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<tr>
<td>Please supply separate editable files (eg, EPS files, PowerPoint files, depending on software used to produce them) for all figures such as diagrams and graphs.</td>
<td>We have provided pdf files for all figures</td>
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<tr>
<td>Tables should be supplied in a separate Word file (not Excel or fdf/pdf).</td>
<td>Thank you, we have put Table 1 into a separate Word file</td>
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<tr>
<td>At the end of the manuscript please summarise the declaration of interests for each author.</td>
<td>Thank you, we have added this</td>
<td>P14</td>
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<tr>
<td>Please return all signed authorship statements (<a href="https://www.thelancet.com/pb-assets/Lancet/authors/tldh-author-signatures.pdf">https://www.thelancet.com/pb-assets/Lancet/authors/tldh-author-signatures.pdf</a>) and conflict of interest forms (forms to follow in a separate email). We also require signed statements from any named person in the acknowledgements saying that they agree to be acknowledged</td>
<td>There are many authors, so I have created a link to the dropbox where they can all be downloaded – I hope this is ok.</td>
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</tr>
<tr>
<td>All submitted research must contain a data sharing statement, to be included at the end of the manuscript. The Lancet Digital Health is a gold Open Access journal, and as such we encourage authors to share the data underlying their results, together with</td>
<td>We have included the data sharing agreement at the end of the manuscript</td>
<td>P14</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
any software used to process these results. If you are unable to share your data or source code, we encourage you to add an explanation detailing the restrictions applied.

We encourage all authors at The Lancet Digital Health to provide the software or source code used in the paper, and associated test data, parameters, and other necessary documentation, to help ensure transparency and reproducibility of our published articles.

The code used in the paper is available on GitHub [https://github.com/SurgicalInformatics/scot_covid_trajectories](https://github.com/SurgicalInformatics/scot_covid_trajectories).

Please state in the manuscript who had the final responsibility for the decision to submit the manuscript to the journal. I note on the submission system this information was included, so please move it to the manuscript.

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P14

Please include a statement on patient consent

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Cluster:
- C1 – No emergency admissions
- C2 – Minimal admissions
- C3 – Recently high
- C4 – Persistently high

Prior emergency bed-days:
- None
- 0.5 – 7
- 7.5 – 21
- 21+

Age group:
- 18–59
- 60–69
- 70–79
- 80+

Number of Charlson comorbidities:
- 0
- 1
- 2+

ICU admission:
- No
- Yes

Vaccinated:
- No
- Yes
Table 1: Baseline characteristics of patients admitted to hospital with COVID-19 in Scotland after 1\textsuperscript{st} March 2020 and discharged before 25\textsuperscript{th} October 2021, stratified by pre-admission trajectory cluster. N=33,580

<table>
<thead>
<tr>
<th>Dependent: Cluster</th>
<th>C1: No admissions N=18,772</th>
<th>C2: Minimal admissions N=12,057</th>
<th>C3: Recently high N=1,931</th>
<th>C4: Persistently high N=820</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>N (%) 18,772 (55.9)</td>
<td>12,057 (35.9)</td>
<td>1,931 (5.8)</td>
<td>820 (2.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age</td>
<td>Median (IQR) 61.0 (48.0 to 75.0)</td>
<td>74.0 (59.0 to 83.0)</td>
<td>77.0 (67.0 to 85.0)</td>
<td>75.0 (62.0 to 84.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age group</td>
<td>18-59 8626 (46.0)</td>
<td>3168 (26.3)</td>
<td>299 (15.5)</td>
<td>186 (22.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>60-69 3429 (18.3)</td>
<td>1816 (15.1)</td>
<td>284 (14.7)</td>
<td>105 (12.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>70-79 3386 (18.0)</td>
<td>2844 (23.6)</td>
<td>514 (26.6)</td>
<td>220 (26.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>80+ 3331 (17.7)</td>
<td>4229 (35.1)</td>
<td>834 (43.2)</td>
<td>309 (37.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sex</td>
<td>Female 8764 (46.7)</td>
<td>6243 (51.8)</td>
<td>991 (51.3)</td>
<td>429 (52.3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Scotland Level quintile for SIMD 2020</td>
<td>1</td>
<td>5635 (30.0)</td>
<td>3939 (32.7)</td>
<td>625 (32.4)</td>
<td>308 (37.6)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4452 (23.7)</td>
<td>2922 (24.2)</td>
<td>503 (26.0)</td>
<td>189 (23.0)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3197 (17.0)</td>
<td>2123 (17.6)</td>
<td>328 (17.0)</td>
<td>133 (16.2)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2890 (15.4)</td>
<td>1672 (13.9)</td>
<td>247 (12.8)</td>
<td>115 (14.0)</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2523 (13.4)</td>
<td>1386 (11.5)</td>
<td>225 (11.7)</td>
<td>74 (9.0)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>White 15308 (81.5)</td>
<td>11245 (93.3)</td>
<td>1855 (96.1)</td>
<td>798 (97.3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Other than white 1102 (5.9)</td>
<td>355 (2.9)</td>
<td>28 (1.5)</td>
<td>13 (1.6)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Source of COVID-19 infection</td>
<td>Community 16100 (85.8)</td>
<td>9108 (75.5)</td>
<td>1233 (63.9)</td>
<td>576 (70.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Nosocomial 1765 (9.4)</td>
<td>2317 (19.2)</td>
<td>608 (31.5)</td>
<td>203 (24.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>COVID-19 wave</td>
<td>Wave 1 3505 (18.7)</td>
<td>2445 (20.3)</td>
<td>489 (25.3)</td>
<td>257 (31.3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Wave 2 9531 (50.8)</td>
<td>6571 (54.5)</td>
<td>1133 (58.7)</td>
<td>451 (55.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Wave 3 5736 (30.6)</td>
<td>3041 (25.2)</td>
<td>309 (16.0)</td>
<td>112 (13.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Vaccinated</td>
<td>Yes 3643 (19.4)</td>
<td>2726 (22.6)</td>
<td>292 (15.1)</td>
<td>113 (13.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Number of Charlson comorbidities</td>
<td>0</td>
<td>8935 (47.6)</td>
<td>2099 (17.4)</td>
<td>145 (7.5)</td>
<td>49 (6.0)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5741 (30.6)</td>
<td>3328 (27.6)</td>
<td>429 (22.2)</td>
<td>122 (14.9)</td>
</tr>
<tr>
<td></td>
<td>2+</td>
<td>4096 (21.8)</td>
<td>6630 (55.0)</td>
<td>1357 (70.3)</td>
<td>649 (79.1)</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>Yes 1177 (6.3)</td>
<td>1931 (16.0)</td>
<td>365 (18.9)</td>
<td>190 (23.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>Yes 777 (4.1)</td>
<td>1784 (14.8)</td>
<td>455 (23.6)</td>
<td>213 (26.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>Yes 705 (3.8)</td>
<td>1250 (10.4)</td>
<td>304 (15.7)</td>
<td>144 (17.6)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>Yes 1427 (7.6)</td>
<td>2413 (20.0)</td>
<td>477 (24.7)</td>
<td>273 (33.3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Dementia</td>
<td>Yes 737 (3.9)</td>
<td>1352 (11.2)</td>
<td>260 (13.5)</td>
<td>138 (16.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>Yes 3564 (19.0)</td>
<td>4076 (33.8)</td>
<td>728 (37.7)</td>
<td>386 (47.1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Rheumatic disease</td>
<td>Yes 458 (2.4)</td>
<td>537 (4.5)</td>
<td>123 (6.4)</td>
<td>54 (6.6)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Peptic ulcer disease</td>
<td>Yes 460 (2.5)</td>
<td>671 (5.6)</td>
<td>159 (8.2)</td>
<td>66 (8.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Condition</td>
<td>Yes (%)</td>
<td>361 (3.0)</td>
<td>85 (4.4)</td>
<td>57 (7.0)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Hemiplegia or paraplegia</td>
<td>1326 (7.1)</td>
<td>2479 (20.6)</td>
<td>576 (29.8)</td>
<td>282 (34.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Renal disease</td>
<td>21 (0.1)</td>
<td>9 (0.1)</td>
<td>&lt;5 (-)</td>
<td>&lt;5 (-)</td>
<td>0.030</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>21 (0.1)</td>
<td>9 (0.1)</td>
<td>&lt;5 (-)</td>
<td>&lt;5 (-)</td>
<td>0.030</td>
</tr>
<tr>
<td>Liver disease</td>
<td>18173 (96.8)</td>
<td>11097 (92.0)</td>
<td>1695 (87.8)</td>
<td>660 (80.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mild</td>
<td>459 (2.4)</td>
<td>714 (5.9)</td>
<td>140 (7.3)</td>
<td>99 (12.1)</td>
<td></td>
</tr>
<tr>
<td>Moderate/Severe</td>
<td>140 (0.7)</td>
<td>246 (2.0)</td>
<td>96 (5.0)</td>
<td>61 (7.4)</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>15752 (83.9)</td>
<td>8959 (74.3)</td>
<td>1318 (68.3)</td>
<td>520 (63.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>None</td>
<td>2800 (14.9)</td>
<td>2598 (21.5)</td>
<td>475 (24.6)</td>
<td>217 (26.5)</td>
<td></td>
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<tr>
<td>With complications</td>
<td>220 (1.2)</td>
<td>500 (4.1)</td>
<td>138 (7.1)</td>
<td>83 (10.1)</td>
<td></td>
</tr>
<tr>
<td>Malignancy (ex. skin neoplasm)</td>
<td>16984 (90.5)</td>
<td>9730 (80.7)</td>
<td>1449 (75.0)</td>
<td>676 (82.4)</td>
<td>&lt;0.0001</td>
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<tr>
<td>None</td>
<td>1408 (7.5)</td>
<td>1632 (13.5)</td>
<td>328 (17.0)</td>
<td>116 (14.1)</td>
<td></td>
</tr>
<tr>
<td>Non-metastatic</td>
<td>380 (2.0)</td>
<td>695 (5.8)</td>
<td>154 (8.0)</td>
<td>28 (3.4)</td>
<td></td>
</tr>
<tr>
<td>Metastatic</td>
<td>0 (0 to 0)</td>
<td>6 (1 to 17)</td>
<td>31 (13 to 58)</td>
<td>100 (65 to 150)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Bed-days during emergency admissions in previous 2 years</td>
<td>Median (IQR)</td>
<td>0 (0 to 0)</td>
<td>6 (1 to 17)</td>
<td>31 (13 to 58)</td>
<td>100 (65 to 150)</td>
</tr>
</tbody>
</table>