

RESEARCH PAPER

Intensity of COVID-19 in care homes following hospital discharge in the early stages of the UK epidemic

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Abstract

Background: defining features of the COVID-19 pandemic in many countries were the tragic extent to which care home residents were affected and the difficulty in preventing the introduction and subsequent spread of infection. Management of risk in care homes requires good evidence on the most important transmission pathways. One hypothesised route at the start of the pandemic, prior to widespread testing, was the transfer of patients from hospitals that were experiencing high levels of nosocomial events.

Methods: we tested the hypothesis that hospital discharge events increased the intensity of care home cases using a national individually linked health record cohort in Wales, UK. We monitored 186,772 hospital discharge events over the period from March to July 2020, tracking individuals to 923 care homes and recording the daily case rate in the homes populated by 15,772 residents. We estimated the risk of an increase in case rates following exposure to a hospital discharge using multi-level hierarchical logistic regression and a novel stochastic Hawkes process outbreak model.

Findings: in regression analysis, after adjusting for care home size, we found no significant association between hospital discharge and subsequent increases in care home case numbers (odds ratio: 0.99, 95% CI: 0.82, 1.90). Risk factors for increased cases included care home size, care home resident density and provision of nursing care. Using our outbreak model, we found a significant effect of hospital discharge on the subsequent intensity of cases. However, the effect was small and considerably less than the effect of care home size, suggesting the highest risk of introduction came from interaction with the community. We estimated that approximately 1.8% of hospital discharged patients may have been infected.

Interpretation: there is growing evidence in the UK that the risk of transfer of COVID-19 from the high-risk hospital setting to the high-risk care home setting during the early stages of the pandemic was relatively small. Although access to testing was limited to initial symptomatic cases in each care home at this time, our results suggest that reduced numbers of discharges, selection of patients and action taken within care homes following transfer all may have contributed to the mitigation. The precise key transmission routes from the community remain to be quantified.

Keywords: care homes, hospital discharge, COVID-19, linked data, multi-level model, Hawkes process, older people

Key Points

- We monitored 186,772 hospital discharge events over the period from March to July 2020, tracking individuals to 923 care homes.

- In regression analysis, after adjusting for care home size, we found no significant association between hospital discharge.
- Using our outbreak model, we found a significant effect of hospital discharge on the subsequent intensity of cases. The precise key transmission routes from the community remain to be quantified.
- We investigated the role of nosocomial events in care homes in Wales, UK.

Introduction

Care homes are a cornerstone of adult social care, which, by definition, group clinically vulnerable people together. Residents may live in close proximity, access shared space and may be frail and experience a variety of underlying health conditions, making them more susceptible to outbreaks of infectious disease than those who live independently [1]. COVID-19 is described by Lithander et al. [2] as ‘a dynamic, specific and real threat to the health and well-being of older people’. The impact of COVID-19 on this sub-population was a defining feature of the pandemic, which was reported internationally by care providers in the media and through a growing body of research [3, 4]. Most care homes formed protective bubbles whereby visitors were restricted to essential staff and the admission of new residents. Yet, there were still many outbreaks and deaths from COVID-19, and there remains limited evidence on modifiable risk factors for increases in COVID-19 infections in care homes. Regularly, attention was drawn to links between hospital-acquired infection and discharge into the care home [5].

Care homes provide accommodation and care for those needing substantial help with personal care, but more than that, they are people’s homes [1, 6]. In 2020, there were 1,053 care homes in Wales (UK), with a maximum capacity of 25,493 places [7]. Care home markets vary across the 22 local government authorities in Wales in the supply, ownership and size of care homes [8].

Multiple interconnected challenges face the care home sector in the prevention and management of outbreaks of COVID-19. In the literature, these challenges are reported to include staff shortages, insufficient or lack of timely COVID-19 testing and poor access to personal protective equipment [6, 9]. Related clinical challenges include older adults with COVID-19 being asymptomatic or not displaying expected symptoms [2, 6, 9, 10]. Once there is an outbreak, the disease can spread quickly within a care home setting and can be difficult to contain [5, 10, 11]. A further challenge is in managing the impact of practices to shield care home residents and isolate those who are infected, for example, individuals with dementia who are walking with purpose out of their rooms. These practices can result in social isolation from families, friends and communities, with negative impacts on health and well-being [2, 6]. Set against these challenges is the caring, innovative and resilient response of care home staff and residents in managing the situations they face [12]. This confluence of events in the context of the pandemic, and impacts for residents, their families and care home staff, has been framed as a human rights issue [13]. In the UK, it is argued that underinvestment in the care home sector and

a poor interface with the health sector led to ill-informed policies. The rapid hospital discharge policies in the early period of the lockdown have been presented as examples of this [5, 14–16]. However, this was a period of considerable uncertainty, with very limited testing and rapidly increasing transmission in all communities. A quantitative estimate of the effect of this route of transmission is therefore difficult to obtain.

In Wales, guidance for discharges from hospitals to care homes was formally published on 7 April 2020. Following treatment, it was determined if there was any evidence of COVID-19 during admission and patients were transferred to a ‘step-down’ facility until they became non-infectious [17]. There was no formal guidance on testing in care homes until 27 May 2020. Guidance was to test suspected or symptomatic residents within 24 h and to test the staff within 48 h. If a test returned positive, all eligible residents and staff would be tested. Tests were to be returned within 48 h [18]. The testing strategy in Wales differed from the recommended strategies in Europe, where proactive testing was advised and infection control procedures were adapted based on the level of community prevalence [19].

The use of existing anonymised routinely collected longitudinal data can help to provide rapid access to large-scale data for studies and to provide robust evidence for commissioning decisions and policy [20]. In this study, we utilise the Secure Anonymised Information Linkage (SAIL) Databank [21–23] to investigate increases in confirmed COVID-19 cases in care homes in Wales in periods of time following a recorded exposure from a patient discharged from the hospital.

Understanding the pathways in which a virus has entered a community is key to preventing the spread of disease, particularly when the community is vulnerable. Logically, in a controlled environment like a care home, there are four routes of ingress for the virus: hospital discharge, staff, visitors and community admissions (including residents leaving a care home for social activities). This study addresses the first of these routes of ingress by assessing the impact of hospital discharge of COVID-19 patients into care homes on subsequent COVID-19 cases and whether any of the care home characteristics increased the risk.

Methods

Data sources

We performed a national, longitudinal, retrospective cohort study using the SAIL Databank, a person level anonymised

privacy protecting data linkage platform for all >3 million people who live in Wales, UK [21–23]. SAIL contains anonymised administrative and health care records. Anonymisation is performed by a trusted third party, the National Health Service (NHS) Wales Informatics Service. A unique individual anonymised person identifier (Anonymous Linking Field) links to a unique address anonymised identifier (Residential Anonymous Linking Field (RALF)) [24, 25]. Individual linking fields, nested within residential codes, are contained in the anonymised version of the Welsh Demographic Service Dataset (WDSD), replacing the identifiable names and addresses of people registered with a free-to-use (NHS) General Practitioner service.

Our Care Homes Anonymised Linking Field was created using the Care Inspectorate Wales (CIW), the national regulator of social care services in Wales, list from 2020, and by assigning a Unique Property Reference Number (UPRN; [26]). The UPRN was double encrypted into a project-level RALF and was uploaded into SAIL to create a deterministic match to the WDSD based on patient-supplied addresses. Additional characteristics of care homes were supplemented using Geographical Information Systems data. We determined if someone was a care home resident by linking their anonymised address information to the residences indexed as a care home in the WDSD. This enabled us to link the COVID-19 testing and hospital discharge data at the individual level and within individual care homes. Residents and care homes were anonymised prior to any analysis.

Our dataset consisted of 928 care homes with at least 1 current resident, successfully linked to anonymised patient data on 15,772 residents. Daily observations on case numbers of hospital transfers were made from 1 January 2020 to 31 July 2020, a dataset of 186,772 observations. We were unable to include residents who were temporarily discharged from the hospital to a care home different to their normal place of residence. We carried out two sets of analyses. (i) A multi-level logistic regression estimate of the association between exposure to hospital discharge and the risk of cases subsequently increasing in the care home. (ii) A novel stochastic outbreak model to estimate the change in intensity of cases in a care home following the date of exposure and taking into account the nature of spread within the home.

Multi-level modelling

We defined the outcome in a binary logistic regression model as the increase in COVID-19-positive cases, c , in a care home, defined daily by the difference in the sum of cases across a 2-week moving window, as follows:

$$\begin{cases} 1, & \sum_{i=1}^i c_i - \sum_{i=1}^{i-1} c_i > 1 \\ 0, & \sum_{i=1}^i c_i - \sum_{i=1}^{i-1} c_i \leq 1 \end{cases}.$$

Fourteen days is the 99th percentile of an individual's symptomatic period [28] and is the recommended quarantine period in the UK. As a marker of exposure to hospital

discharge, we included a time-dependent covariate, defined as 'yes' if a resident of the care home was discharged from the hospital in the previous 14 days. Fixed effects of type of nursing provision, mental health provision, learning disability provision, home capacity (defined by the number of available beds recorded with CIW) and resident density were included. To account for clustering, observations were nested within a month, home then local authority. We varied the periods of observation as a sensitivity analysis.

Hawkes process model

For an infectious disease in a small, closed population, there is clearly strong non-independence between observations on cases over time. We therefore developed a novel stochastic model to attempt to separate out the effects of introduction of a case from the subsequent spread within the home. An assignment of potential introduction via the hospital discharge route can then be estimated separately from both the within-home spread and a 'background' introduction rate from other outside sources (community/staff/visitors).

A random point process model for the discrete event of a confirmed case can be expanded upon using the Hawkes process [27]. The feature of this model is a self-exciting term representing a situation in which the probability of a subsequent case is increased or 'excited' by an existing case. The period of excitation represents an outbreak of, potentially, many cases within a care home. We proposed an outbreak model with two self-excitation terms: one representing the effect of a known case happening in the home (a considerable risk to future spread) and the other one representing the effect of a known hospital discharge. Since the hospital discharge may or may not carry infection, the relative magnitude of these terms informs an estimate of the risk from hospital discharge. In the extreme case, zero hospital excitation would represent a situation where no hospital discharges carried infection risk (null hypothesis), while equal excitation coefficients represent the situation where every hospital discharge was infected.

The 'intensity' of cases is the rate at which cases are expected to occur. We defined the 'intensity function' of cases at care home i on day t as follows:

$$\begin{aligned} \lambda_i(t) = & \nu(S_i) \\ & + r_c \sum_{s < t} f(t-s) n_i^c(s) + r_b \sum_{s < t} f(t-s) n_i^b(s), \end{aligned}$$

where $\nu(S_i)$ is the baseline intensity of a care home of size S_i , representing the risk of a case being introduced to the care home via normal activities (staff/community/visitors); r_c and r_b are the self-excitation and excitation by hospital parameters, representing the increased risk of an outbreak following the introduction of a case or hospital transfer, respectively; $f(t)$ is the COVID-19 serial interval distribution, which is assumed to be equal to the gamma probability density function with a mean of 6.5 and a coefficient of variation

of 0.62; and $n_i^c(s)$ and $n_i^h(s)$ are the numbers of cases in and hospital discharges to the care home i on day s . The care home size S_i is grouped into quartiles such that there are four possible values for $v(S_i)$. We assume that $n_i(t)$ has a Poisson distribution with mean $\lambda_i(t)$, hence the model can be fitted from the observed time series of hospital discharge and case time series. We used maximum likelihood and MCMC using Numpy [29, 30] for three models: with r_c and r_h both fixed to zero, with only r_h fixed to zero and with no parameters fixed. Details of the MCMC fit are given in the supplementary material along with an illustration of the effect of the self-exciting process on the intensity of cases (Supplementary Figure S1).

Results

Care home characteristics are summarised in Supplementary Table S1. There was no clear overall temporal association between the cases recorded in care homes and the numbers of hospital discharges over the period from April to June 2020 (Supplementary Figure S2). In our two care home-level analytical approaches, we found estimates of no effect and a small effect of hospital discharge on subsequent COVID-19 case rates in the care homes.

Multi-level modelling

In unadjusted univariable analyses, (Supplementary Table S2), the marker of hospital discharge was associated with an increased risk of a rise in cases in the care home (odds ratio (OR): 1.2, 95% CI: 1.0, 1.5). By far, the biggest risk factor was care home size (OR: 34.6 for the largest quintile in comparison to the smallest). As expected, there was a correlation between hospital discharge and care home size; and in the adjusted multivariable models (Table 1), there was no significant effect of hospital discharge (OR: 0.99, 95% CI: 0.82, 1.90). Care home size remained the most important factor in mutually adjusted analyses. In general, we found the provision of care for those with learning difficulties to reduce the risk, the provision of nursing care increased risk, while the provision of care for those with mental health issues had no effect. The risk was also increased as the density of residents increased. The random effects terms indicated that an increase in COVID-19 cases varied significantly by month (the largest residual) and by care home but not by local authority.

Hawkes process model

The inclusion of the case self-excitation term led to a significant improvement in the fit of the model over the care home size only model ($P < 0.001$), with the magnitude of the self-excitation effect being considerably larger than the care home size effect. We found a further significant improvement in the likelihood of the model with hospital discharge compared to the model with case excitation only ($P < 0.001$). The magnitude of change in intensity associated with hospital

discharge was comparable to the baseline intensity in a Q2 care home and was considerably smaller than the baseline effects of Q3 or Q4 homes. Furthermore, the case self-excitation coefficient was much larger. We estimated the ratio $r_h/r_c = 0.018$, suggesting that one hospital discharge had the same effect on intensity as 0.018 cases. An alternative interpretation would be that 1.8% of hospital discharges may have been infected. Estimates of the parameters from the full model are shown in Table 2. Details of the MCMC fit are given in Supplementary Figures S3 and S4.

Discussion

We used two modelling approaches, in combination with a national individually linked hospital and care home event cohort, to explore the role of hospital discharge into care homes on subsequent COVID-19 case rates. The study focused on the period during the first wave in Wales, during which this was most likely to have been a factor, before widespread testing was available. The results of both approaches suggest only a minor role for this transmission pathway, which has attracted much comment and speculation. In our multi-level regression, we found no significant effect of recent hospital discharge on the probability that case levels would subsequently increase. Care home size and provision type (specifically nursing provision) were identified as risk factors. We were also able to characterise care homes by the number of residents per metre square based on building footprint and show that high person density was a risk factor likely representing the increased opportunity for spread of directly transmitted viruses within a closed population.

Our hierarchical regression models attempted to control for effects of clustering; however, by its nature, there is a very strong likelihood of a direct link between cases of infectious disease located closely in time and space. We aimed to account for this more explicitly by modelling the process of introduction into the care home and subsequent spread by developing a simple stochastic epidemic model whereby the occurrence of a case is self-exciting and leads to an increased probability of further cases. Fitting the model with case self-excitation only resulted in a considerable improvement over the size-only model. This was a 'sense-check' result, as it was essentially a test of the hypothesis that SARS-COV-2 was highly infectious within a care home: if a case occurred, there was a highly significant increase in the risk of more cases over the following days. The magnitude of the effect was considerably larger than the care home size effect. This also highlights the importance of including the infectious dynamics in the analysis. Without it, the effect of care home size, or any other variable, may be overestimated.

When we included the impact of hospital discharge, we did indeed find a significant effect. If a care home was exposed to a discharge event, there was an estimated increase in the intensity of cases. However, the effect was relatively small. In comparison with the introduction of a known

Table 1. ORs for the multivariate multi-level logistic regression models, with the dependent variable being an increase in COVID-19-positive cases in a care home

ORs	Care home services	Space available per person	Care home capacity	Services and space available per person	Care home services and capacity
Intercept	0.004 (0.003, 0.005)	0.005 (0.003, 0.006)	0 (0, 0.001)	0.004 (0.003, 0.006)	0 (0, 0.001)
Hospital discharge					
Discharge in the previous 14 days	1.112 (0.916, 1.351)	1.206 (0.986, 1.475)	0.984 (0.817, 1.186)	1.109 (0.913, 1.346)	0.985 (0.819, 1.186)
Care home services					
Nursing	2.327 (1.716, 3.155)	–	–	2.234 (1.645, 3.034)	0.99 (0.729, 1.343)
Learning disabilities	0.324 (0.232, 0.451)	–	–	0.341 (0.244, 0.477)	0.657 (0.458, 0.944)
Mental health	1.006 (0.753, 1.343)	–	–	0.979 (0.733, 1.308)	0.931 (0.707, 1.225)
Metre square per person					
m ² (14, 18]	–	1.027 (0.69, 1.528)	–	1.077 (0.721, 1.611)	–
m ² (18, 24]	–	0.79 (0.53, 1.178)	–	0.982 (0.652, 1.479)	–
m ² (24, 33]	–	0.617 (0.402, 0.945)	–	0.881 (0.567, 1.369)	–
m ² (33, 845]	–	0.439 (0.283, 0.681)	–	0.773 (0.486, 1.232)	–
Capacity (based on CIW registration details)					
Places (5,16]	–	–	2.536 (1.227, 5.239)	–	2.319 (1.111, 4.844)
Places (16,28]	–	–	10.778 (5.58, 20.817)	–	8.218 (4.082, 16.547)
Places (28,38]	–	–	16.991 (8.857, 32.595)	–	14.028 (7.022, 28.023)
Places (38,133]	–	–	34.94 (18.388, 66.394)	–	26.334 (12.892, 53.792)
Random effects					
Month	7.422 (6.783, 8.06)	8.922 (8.245, 9.599)	5.889 (5.321, 6.458)	7.392 (6.756, 8.029)	5.796 (5.232, 6.36)
Care home	1.544 (1.14, 1.948)	1.498 (1.101, 1.896)	0.834 (0.517, 1.152)	1.491 (1.093, 1.889)	0.79 (0.478, 1.101)
Local authority	0.13 (–0.014, 0.275)	0.104 (–0.022, 0.229)	0.09 (–0.021, 0.201)	0.114 (–0.02, 0.248)	0.086 (–0.022, 0.194)
–	–	–	–	–	–
Observations	186,772				
Months (January–July)	7				
Care homes	881				
Local authorities	22				

Table 2. MCMC estimates of parameters for the full Hawkes process model

Parameter	Interpretation	Posterior mean ($\times 10^{-3}$)	95% credibility interval
ν_1	Baseline case intensity in Q1 size home	0.21	0.07, 0.35
ν_2	Baseline case intensity in Q2 size home	1.35	0.92, 1.77
ν_3	Baseline case intensity in Q3 size home	3.84	3.22, 4.43
ν_4	Baseline case intensity in Q4 size home	6.89	5.92, 7.87
r_c	Intensity excitation coefficient due to case	599.9	559.5, 640.3
r_h	Intensity excitation coefficient due to hospital transfer	11.08	2.13, 20.03

case, we estimated an approximately 50-fold lower impact. One way of interpreting the coefficients would be that an estimated 1.8% of patients discharged from hospitals into a care home may have been infected. The hospital effect was considerably less than the effect of care home size. We estimate that the change in risk posed by one hospital discharge event ‘every week’ was equivalent to the change in risk comparing a Q2-sized care home to a Q1-sized home and was much less than the difference between larger home sizes (Supplementary Figure S4).

Data linkage is a powerful tool for building comprehensive cohorts. However, while SAIL allows us to model a person’s care pathway and outbreaks at an individual care home, it is reliant on the timely updates of a person’s General Practice (GP) record. During Wave 1 of the COVID-19

pandemic, when the social care and health policy were being revised on a weekly basis, we know that temporary discharge events to care homes took place, but we are unable to differentiate these cases in our analysis. We were unable to link all care home residents to care homes in Wales due to mismatches in the GP recorded addresses and officially registered care home addresses (~10% of care homes). This may have led to some missed discharge events, but at the population level of this study, this is unlikely to have drastically influenced the resulting analysis. Further, as we progress from a pandemic to endemic phase of the disease, experience variants with different characteristics and vaccinations become widespread, and we acknowledge that the patterns of infection are likely to be different to those presented in this paper. We also note there are differences between Wales

and the other UK nations, particularly England, which may impact the observed rates of transmission. Specifically, Wales has a lower population density, large rural areas and a smaller number of hospitals than England.

Conclusions

Our results agree with other studies [3, 4] but are the first to use individual case events as the outcome. Our model is generalisable to other discrete exposure events, and subsequent disease spread, and can also be developed to include other risk variables. There has been a natural tendency to link hospitals and care homes as a transmission route for COVID-19. During the first wave, there was pressure to maximise hospital bed availability as the peak of the epidemic was approaching, and there was a lack of readily available rapid testing. However, when taken as a whole, the evidence around discharge from hospitals into care homes suggests that most care home outbreaks were related to community infection from visitors, visiting professionals or staff. Given the high prevalence in Welsh hospitals at the time, this suggests that successful mitigation was put in place through the (pretesting) decision-making regarding transfers, the substantial decline in discharge rate that was introduced prior to the first wave epidemic peak and management of patients once transferred into the care home.

List of Abbreviations

CIW	Care Inspectorate Wales
NHS	National Health Service
OR	Odds Ratio
RALF	Residential Anonymous Linking Field
SAIL	Secure Anonymised Information Linkage
UPRN	Unique Property Reference Number
WDS	Welsh Demographic Service Dataset

Supplementary Data: Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

Declaration of Conflicts of Interest: None.

Declaration of Sources of Funding: This work was supported by the Medical Research Council (MR/V028367/1); Health and Care Research Wales (Project: SCF-18-1504) and Health Data Research UK (HDR-9006), which receives its funding from the UK Medical Research Council, Engineering and Physical Sciences Research Council, Economic and Social Research Council, Department of Health and Social Care (England), Chief Scientist Office of the Scottish Government Health and Social Care Directorates, Health and Social Care Research and Development Division (Welsh Government), Public Health Agency (Northern Ireland), British Heart Foundation and the Wellcome Trust; and Administrative Data Research UK, funded by the Economic

and Social Research Council (Grant ES/S007393/1). E.B. acknowledges the support of the Supercomputing Wales programme, which is part-funded by the European Regional Development Fund via Welsh Government and the Science and Technologies Facilities Council Research Software Engineering Fellowship (EP/V052489/1).

References

1. Challis D, Mozley CG, Sutcliffe C *et al.* Dependency in older people recently admitted to care homes. *Age Ageing* 2000; 29: 255–60.
2. Lithander FE, Neumann S, Tenison E *et al.* COVID-19 in Older People: A Rapid Clinical Review. *Age Ageing* 2020; 49: 501–15.
3. Emmerson C, Adamson JP, Turner D *et al.* Risk factors for outbreaks of COVID-19 in care homes following hospital discharge: A national cohort analysis. *Influenza Other Respir Viruses* 2021; 15: 371–80.
4. Scottish Government. Hospital to Care Home discharge data published. 2020. <https://www.gov.scot/news/hospital-to-care-home-discharge-data-published/>.
5. Carter R. Covid-19: The support UK care homes need to survive. *BMJ* 2020; 369: m1858. <https://doi.org/10.1136/bmj.m1858>.
6. Gordon AL, Goodman C, Achterberg W *et al.* Commentary: COVID in Care Homes—Challenges and Dilemmas in Healthcare Delivery. *Age Ageing* 2020; 49: 701–5.
7. Care and Social Services Inspectorate Wales (CSSIW).
8. Moultrie K, Rattle N. The Care Home Market in Wales: Mapping the Sector, 2015.
9. Comas-Herrera A, Zalakain J, Lemmon E. Mortality associated with COVID-19 outbreaks in care homes: early international evidence. In: Resources to support community and institutional Long-Term Care responses to COVID-19, 2020. <https://ltccovid.org/2020/04/12/mortality-associated-with-covid-19-outbreaks-in-care-homes-early-international-evidence/>.
10. American Geriatrics Society Policy Brief. COVID -19 and Nursing Homes. *J Am Geriatr Soc* 2020; 68: 908–11.
11. The Health Foundation. Care homes have seen the biggest increase in deaths since the start of the outbreak. COVID-19 chart series, 2020.
12. My Home Life England. Covid-19: Voices from the care home frontline, 11th April 2020.
13. Peisah C, Byrnes A, Doron I(I), Dark M, Quinn G. Advocacy for the human rights of older people in the COVID pandemic and beyond: a call to mental health professionals. *Int Psychogeriatr* 2020; 32: 1199–204.
14. NHS Providers. Coronavirus Spotlight: Recent NHS Discharges into Care Homes, 2020. <https://nhsproviders.org/media/689548/spotlight-on-recent-discharges-into-care-homes-nhs-providers.pdf> (6 April 2020, date last accessed).
15. Oliver D. David Oliver: Let's not forget care homes when covid-19 is over. *BMJ* 2020; 369: m1629. <https://doi.org/10.1136/bmj.m1629>.
16. Oliver D. David Oliver: Let's be open and honest about covid-19 deaths in care homes. *BMJ* 2020; 369: m2334. <https://doi.org/10.1136/bmj.m2334>.

17. Welsh Government. Hospital discharge service requirements: COVID-19. 2020. <https://gov.wales/hospital-discharge-service-requirements-covid-19> (12 September 2021, date last accessed).
18. Welsh Government. COVID-19 Test, Trace Protect (TTP) guidelines for health and social care workers. 2020. gov.wales.
19. Blain H, Rolland Y, Schols JMGA *et al.* August 2020 Interim EuGMS guidance to prepare European Long-Term Care Facilities for COVID-19. *Eur Geriatr Med* 2020; 11: 899–913.
20. Casey JA, Schwartz BS, Stewart WF, Adler NE. Using Electronic Health Records for Population Health Research: A Review of Methods and Applications. *Annu Rev Public Health* 2016; 37: 61–81.
21. Ford DV, Jones KH, Verplancke JP *et al.* The SAIL Databank: building a national architecture for e-health research and evaluation. *BMC Health Serv Res* 2009; 9: 157. <https://doi.org/10.1186/1472-6963-9-157>.
22. Lyons RA, Jones KH, John G *et al.* The SAIL databank: linking multiple health and social care datasets. *BMC Med Inform Decis Mak* 2009; 9: 3. <https://doi.org/10.1186/1472-6947-9-3>.
23. Jones KH, Ford DV, Jones C *et al.* A case study of the Secure Anonymous Information Linkage(SAIL) gateway: a privacy-protecting remote access system for health-related research and evaluation. *J Biomed Inform* 2014; 50: 196–204.
24. Johnson RD, Griffiths LJ, Hollinghurst JP *et al.* Deriving household composition using population-scale electronic health record data—a reproducible methodology. *PLoS One* 2021; 16: e0248195. <https://doi.org/10.31235/OSF.IO/KCTNZ>.
25. Rodgers SE, Lyons RA, Dsilva R *et al.* Residential Anonymous Linking Fields (RALFs): A novel information infrastructure to study the interaction between the environment and individuals’ health. *J Public Health* 2009; 31: 582–8.
26. Ordnance Survey. Unique Property Reference Number (UPRN). OS, 2019.
27. Hawkes AG. Spectra of some self-exciting and mutually exciting point processes. *Biometrika* 1971; 58: 83–90.
28. Lauer SA, Grantz KH, Bi Q *et al.* The incubation period of corona virus disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application. *Ann Intern Med* 2020; 172: 577–82.
29. Bennett E. Bayesian Fitting of Care Home Data in SAIL. Swansea Academy of Advanced Computing, 2021; <https://github.com/sa2c/care-home-fit>.
30. Harris CR, Millman KJ, van der Walt SJ *et al.* Array programming with NumPy. *Nature* 2020; 585: 357–62.

Received 5 November 2021; editorial decision 14 January 2022