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RESEARCH PAPER

Care-home outbreaks of COVID-19 in Scotland March to May 2020: National linked data cohort analysis

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Abstract

Background: understanding care-home outbreaks of COVID-19 is a key public health priority in the ongoing pandemic to help protect vulnerable residents.
Objective: to describe all outbreaks of COVID-19 infection in Scottish care-homes for older people between 01/03/2020 and 31/03/2020, with follow-up to 30/06/2020.
Design and setting: National linked data cohort analysis of Scottish care-homes for older people.
Methods: data linkage was used to identify outbreaks of COVID-19 in care-homes. Care-home characteristics associated with the presence of an outbreak were examined using logistic regression. Size of outbreaks was modelled using negative binomial regression.
Results: 334 (41%) Scottish care-homes for older people experienced an outbreak, with heterogeneity in outbreak size (1–63 cases; median = 6) and duration (1–94 days, median = 31.5 days). Four distinct patterns of outbreak were identified: 'typical' (38% of outbreaks, mean 11.2 cases and 48 days duration), severe (11%, mean 29.7 cases and 60 days), contained (37%, mean 3.5 cases and 13 days) and late-onset (14%, mean 5.4 cases and 17 days). Risk of a COVID-19 outbreak increased with increasing care-home size (for ≥90 beds vs <20, adjusted OR = 55.4, 95% CI 15.0–251.7) and rising community prevalence (OR = 1.2 [1.0–1.4] per 100 cases/100,000 population increase). No routinely available care-home characteristic was associated with outbreak size.
Conclusions: reducing community prevalence of COVID-19 infection is essential to protect those living in care-homes. More systematic national data collection to understand care-home residents and the homes in which they live is a priority in ensuring we can respond more effectively in future.

Keywords: Coronavirus, SARS-CoV-2, care-home, outbreak, data linkage, older people

Key Points

- Two fifths of care-homes for older people in Scotland had an outbreak of COVID-19 between March and May 2020
- There was significant heterogeneity in outbreak size (1–63 cases; median 6 cases) and duration (1–94 days; median 31.5 days), with four distinct patterns of outbreak identified
- A quarter of all COVID-19 associated deaths in older people's care-homes occurred in just 26 (3%) homes
- Risk of a COVID-19 outbreak increased with increasing care-home size and rising community prevalence
- No statistically significant predictors of outbreak size could be identified from available routine linked data

Background

The COVID-19 pandemic has had a disproportionate impact on those living and working in care-home settings internationally. [1,2] Analysis in Scotland, [3] Wales [4] and England [5] has shown that cases and mortality impact have been concentrated in a small number of homes, leaving large numbers of care-homes and residents with ongoing vulnerability. Analyses identifying factors associated with risk of outbreaks have examined a range of characteristics including: care-home size; staffing ratios; occupancy rates; community incidence of infection; design standards of the home and ownership. [3,6–8] Analyses from Spain and the USA identified increased age, male sex and functional impairment as associated with elevated mortality in the care-home setting. [9,10]

One Canadian study evaluated likelihood of outbreak and size of outbreak in 623 homes in a single province. [7] This identified for-profit status was associated with the size but not the likelihood of an outbreak. [7] Determining the factors associated with outbreak (risk of introducing infection) and outbreak size (factors associated with spread once infection introduced) are important in learning how to protect care-homes from future outbreaks and manage infection.

The aim was to describe care-home outbreaks of COVID-19 infection in Scotland between 1 March and 31 May, with follow-up to 30 June 2020 using national linked datasets. Our objectives were (1) To examine timing, evolution and patterns of COVID-19 outbreaks in care-homes for older people in Scotland in terms of test confirmed cases and deaths; (2) To examine care-home characteristics associated with the presence of an outbreak, and with outbreak size.

Methods

Population, data sources and record linkage

We focused on care-home services for older people where almost all laboratory-confirmed COVID-19 outbreaks in Scotland occurred. The majority of Scotland's care-home residents live in such homes and they are a very different population from the typically younger adults living in specialist homes for learning disabilities, physical and sensory impairment or substance misuse. [11]

We identified outbreaks of SARS-CoV-2 in older people's care-home services in Scotland where the first laboratory-confirmed case while resident in the care-home was between 1 March and 31 May, with follow-up until 30 June 2020. The data sources used were:

(1) Care Inspectorate datastore [12]—publicly available data describing all adult care-home services in Scotland. Care-home characteristics: the number of registered places; sector providing care; duration of care-home service; Risk Assessment Document (RAD) Score assigned by inspectors to determine frequency of regulatory oversight; [13] and whether the home provided nursing care to residents.
(2) Electronic Communication of Surveillance in Scotland (ECOSS) dataset of all SARS-CoV-2 Polymerase Chain Reaction tests performed in Scotland before 30 June. Used to identify outbreaks based on first positive test in the home.
(3) National Records of Scotland death registration data from 1 March to 30 June 2020.
(4) Linked dataset identifying people discharged from hospital to a care-home (March to May 2020, [14]—used to categorise homes into those who did or did not receive any residents discharged from hospital during 1 March to 31 May.
(5) Scottish Government Urban/Rural Classification 2016 open data—care-home postcode was used to define location in terms of settlement size and distance from an urban centre. [15,16]
(6) Public Health Scotland Open Data Daily Case Trends by Integration Authority [17]—daily cases for each local-authority area of Scotland. The prevalence of COVID-19 in the community in the 3 months of the analysis period (for analysis of outbreak presence), and in the 2 weeks pre- and post- each homes' outbreak start (for the analysis of outbreak size) was estimated, after removing tests conducted in care-homes.

Data were linked using the CHI number, the individual identifier variable used in NHS Scotland. Address matching was used to identify samples obtained on residents in care-homes and allocate both tests and deaths to specific homes.

Outcomes

The primary outcomes were (1) Presence of an outbreak of COVID-19, defined as a positive test in a resident while in the care-home; and (2) Size of outbreak (based on number of residents testing positive, divided by number of registered places). Other outcomes examined descriptively were duration of outbreak (time between first and last positive test); presence of multiple outbreaks (defined as a period of 28 days or longer between positive tests); and COVID-19 associated and other cause mortality.

COVID-19 associated mortality was defined as the presence of ICD-10 codes U071 and U072 appearing in any location on the death certificate. [18] Mortality from other causes defined as U071/U072 NOT recorded on death certificate and underlying cause of death recorded as Cancer & Haematological (ICD-10 codes C01-C96 D32-D66); Cardiovascular (I05-I83); Dementia & Frailty (F01-F03, G30, R54); Neurological (not stroke/dementia) (F05-FO6, G10-G93, I60); Respiratory (J06-J98); Stroke/Cerebrovascular (G45, I61-I69); Other (all other ICD-10 codes).

Statistical analysis

Initial descriptive analysis examined outbreak incidence over time, and characteristics of outbreaks in terms of size, duration and mortality. Clusters analysis was undertaken to formally categorise patterns of outbreak. Clusters were identified on a summarised version of the care-home dataset including number of beds, number of cases, number of deaths, duration of outbreak and month of outbreak onset. All the data was normalised to unit mean and variance before clustering to ensure all factors were weighted evenly. K-means clustering was used to iteratively identify the closest cluster centroid for each datapoint, which defines its cluster membership, before recalculating the centroids as the mean of each cluster. We used Scikit-learn implementation of K-means clustering available for Python [19] (see also Supplementary methods are available in *Age and Ageing* online), and used the gap statistic to inform choice of number of clusters. The gap statistic had peaks at both $k = 2$ and $k = 4$. Our goal was to identify clusters that had similar outbreak timelines, thus we opted to use four clusters.

Two statistical models were fitted to separately examine (1) care-home characteristics associated with the presence of an outbreak, and (2) care-home characteristics associated with the size of the outbreak. The presence of collinearity was checked by calculating the variance inflation factor. The odds of a care-home experiencing an outbreak from 1 March to 31 May were modelled using logistic regression to examine both univariate and adjusted associations with care-home characteristics. The size of outbreaks in care-homes was modelled using negative binomial regression, with the number of positive residents as the outcome, and the number of registered places as the offset. Analysis of outbreak size was restricted to homes which had experienced an outbreak in this period, with each home followed up for a minimum of 30 days after the start of the outbreak to estimate the number of positive residents. The sensitivity of a 30-day follow-up period was explored by restricting outbreaks to those which occurred in March and April alone, therefore allowing at least 61 days follow-up to the end of June. Associations between size of outbreak and care-home and community characteristics were explored.

Data management and information governance

Identifiable individual data were analysed within secure Public Health Scotland (PHS) servers by named analysts with approval of the project and Data Protection Privacy Impact Assessment by the PHS Information Governance Lead under COVID-19 expedited processes. The project was commissioned by the Cabinet Secretary for Health and Sport in the public interest. Analysis was conducted independent from the Scottish Government.

Results

Overall summary

There were 817 older people care-home services registered in Scotland during the study period. More than half had fewer than 50 registered places, with 6.2% having 90 or more places. Most homes were privately owned (74.2%) and over two-thirds provided nursing care to residents. More than half had been operating under the current registration for more than 10 years. Most were in urban areas, with only 16.9% in remote locations (Supplementary Table S1 is available in *Age and Ageing* online).

From 1 March to 31 May, 334 (41%) older people care-homes in Scotland experienced an outbreak of COVID-19, with 3,220 individuals testing positive in the whole period examined. Fifty-three (16%) of outbreaks started in March, 233 (67%) started in April, and 48 (14%) in May. A weekly summary of new care-home outbreaks and new positive cases is presented in Figure 1A and B from March to May.

Tests and outbreaks

The number of residents within each home who tested positive ranged from 1 to 63, with a mean of 9.6 and median of 6 residents per home. The rate of positive cases per registered place ranged from 1 to 83% (average 18%). In 71 homes (21% of those with an outbreak), only a single positive test was identified.

Duration of outbreak measured by time between first and last positive case was highly varied, ranging from 1 to 94 days with a median of 31.5 days (interquartile range (IQR) 43). Only one home had an epidemiologically distinct second outbreak (i.e. a gap of 28 or more days between positive cases). However, 94 care-homes had gaps of 14–27 days between positive cases being detected, of which 16 had 2 such gaps, and 1 had 3 such gaps.

Four distinct patterns of outbreak were identified using cluster analysis methods (Figure 2, Supplementary Figures S1–S4 are available in *Age and Ageing* online). These help to illustrate the differential impact in terms of duration, size and fatality of care-home outbreaks. 'Typical' outbreaks were 38% of all outbreaks, with a mean of 11.2 cases and 6.5 deaths with mean duration 48 days. Typical outbreaks accounted for 44% of cases and deaths. Eleven percent of outbreaks were classified as 'Severe', with more cases and deaths and longer duration (mean 29.7 cases and 16.1 deaths with mean duration 60 days). Severe outbreaks accounted for 35% of cases and 33% of deaths. 'Contained' outbreaks were 37% of all outbreaks and were smaller and shorter with a mean of 3.5 cases and 2.4 deaths with mean duration 13 days. Contained outbreaks accounted for 13% of cases and 16% of deaths. 'Late-onset' outbreaks accounted for 14% of all outbreaks, all starting in May, with a mean of 5.4 cases and 2.4 deaths, with mean duration 17 days. Late-onset outbreaks accounted for 8% of cases and 6% of deaths.

Mortality

From 1 March to 30 June, 5,990 all-cause deaths were recorded in care-homes for older people in Scotland. Only 8% of homes had no recorded deaths during this period. There were 1,925 (32.1% of deaths in this period) COVID-19 associated deaths in 321 care-homes, of which 1,847 (96%) were in homes with a laboratory-confirmed outbreak

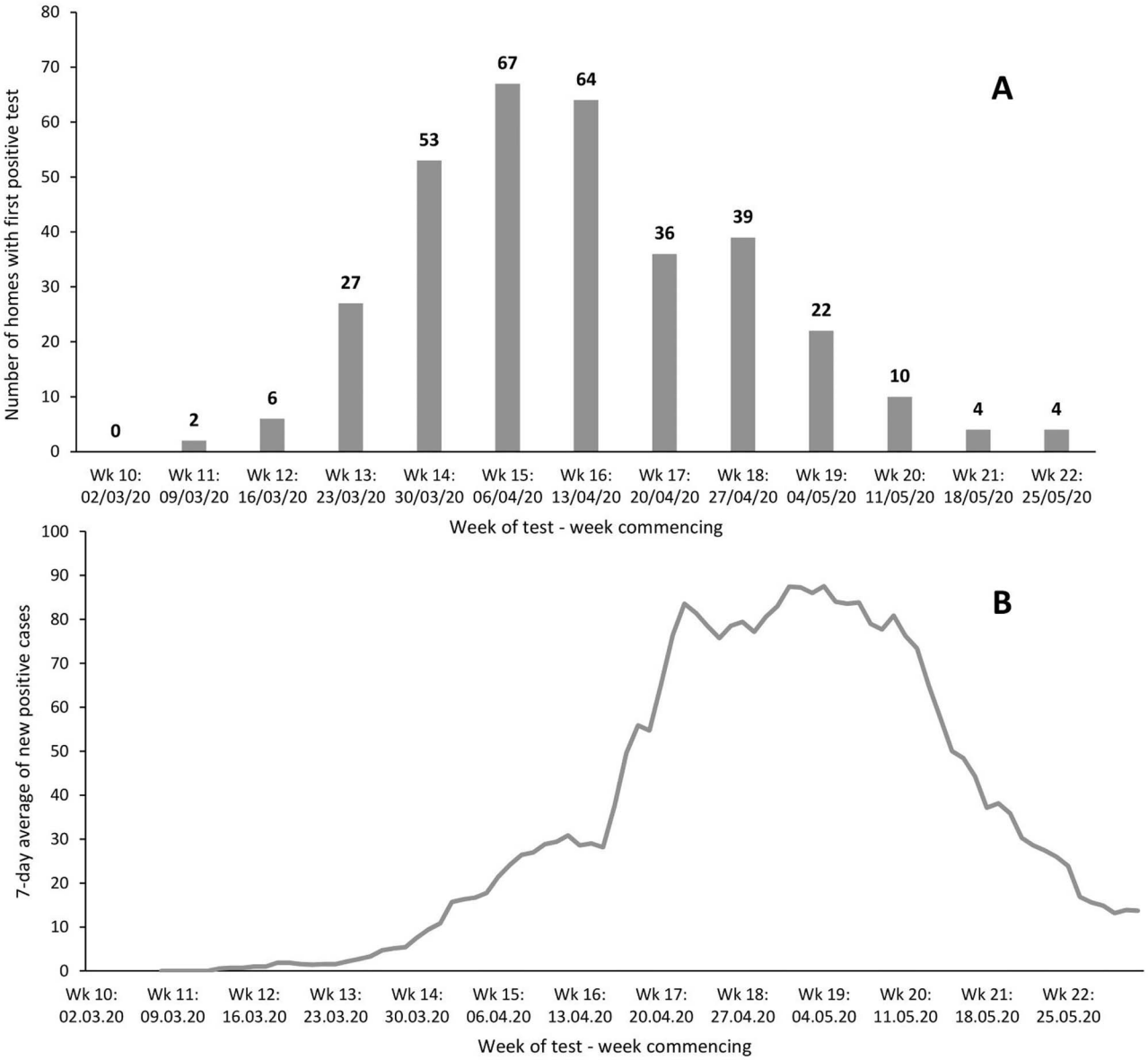

Figure 1. Number of homes with first positive test by week (A); Seven-day rolling average of new positive cases in care-homes (B).

(Figure 3). The rate of COVID-19 deaths was correlated with the rate of laboratory-confirmed cases (Pearson's R 0.561, $P = <0.001$, Supplementary Figure S1 is available in *Age and Ageing* online). In 30 of the 71 homes with only a single positive test there were between 1 and 7 COVID-19-associated deaths, with an average of two deaths per home with only a single positive laboratory confirmed test (consistent with under-ascertainment of cases due to varying testing availability in wave 1). Care-home mortality associated with COVID-19 ranged from 1 to 40% of all registered places, with median mortality of 8.2% (IQR 11.5). A quarter of all COVID-19 associated deaths occurred in just 26 homes (3% of all older people's care-homes and 8% of such homes with COVID-19 deaths).

There were 2,217 non-COVID deaths in the 334 homes with an outbreak, compared to 1,848 in the 483 homes without outbreaks (which on average are smaller). The pattern of deaths from other causes was similar in homes with and without outbreaks. Dementia and frailty accounted for 44% and 41% of non-COVID deaths in homes with and without outbreaks respectively, compared to stroke/cerebrovascular disease 10% and 13%; cardiovascular and vascular 11% in both; cancer and haematological 9% and 11%; respiratory (non-COVID) 9% and 8% and other causes 13% and 12%.

Factors associated with care-home outbreaks

Factors associated with an outbreak are shown in Table 1, for both univariate and adjusted models. The odds of a care-home experiencing an outbreak of COVID-19 increased with care-home size. Care-homes with at least 90 registered

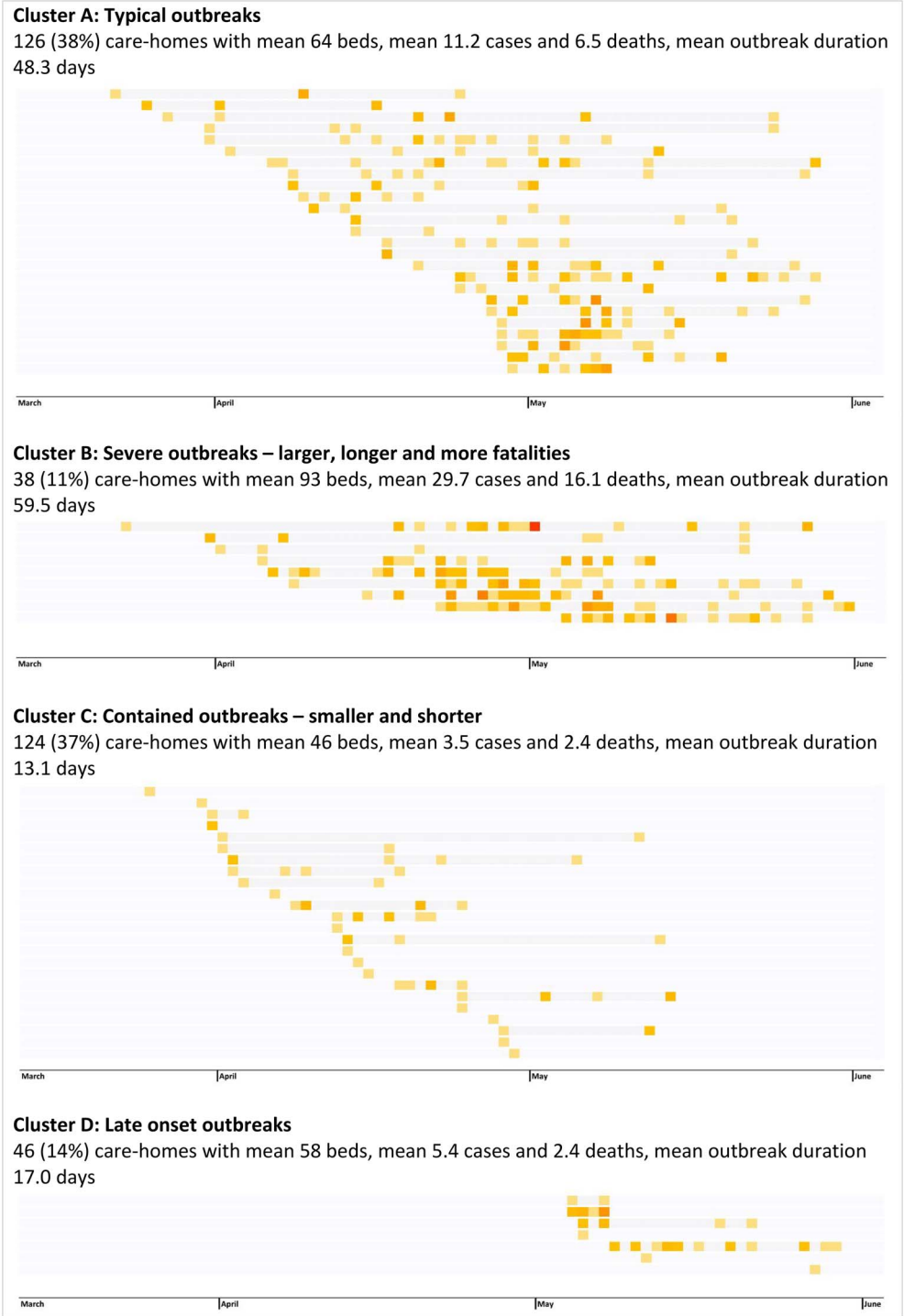

Figure 2. Cluster analysis summary characterising pattern of outbreaks*.

places had 55 times the odds of an outbreak compared to care-homes with less than 20 registered places (adjusted OR 55.5, 95% CI 15.1–252.0). Homes which had operated at least 11–14 years without change of registration had significantly lower odds of an outbreak, compared to homes which had been in service for 0–2 years (adjusted OR 0.4, 95% CI 0.2–0.9). Compared to homes situated in Large Urban Areas (Scottish Government Urban and Rural category 1), homes in Other Urban and rural areas had significantly lower odds of an outbreak, with adjusted odds ratios ranging between 0.1 and 0.5. The odds of a care-home experiencing an outbreak in March to May 2020 is 1.2 higher per 100/100,000 increase in the crude prevalence rate of COVID-19 in the community over the same time period (the observed range of prevalence is 27–635 per 100,000). In the univariate analyses, homes with at least one hospital

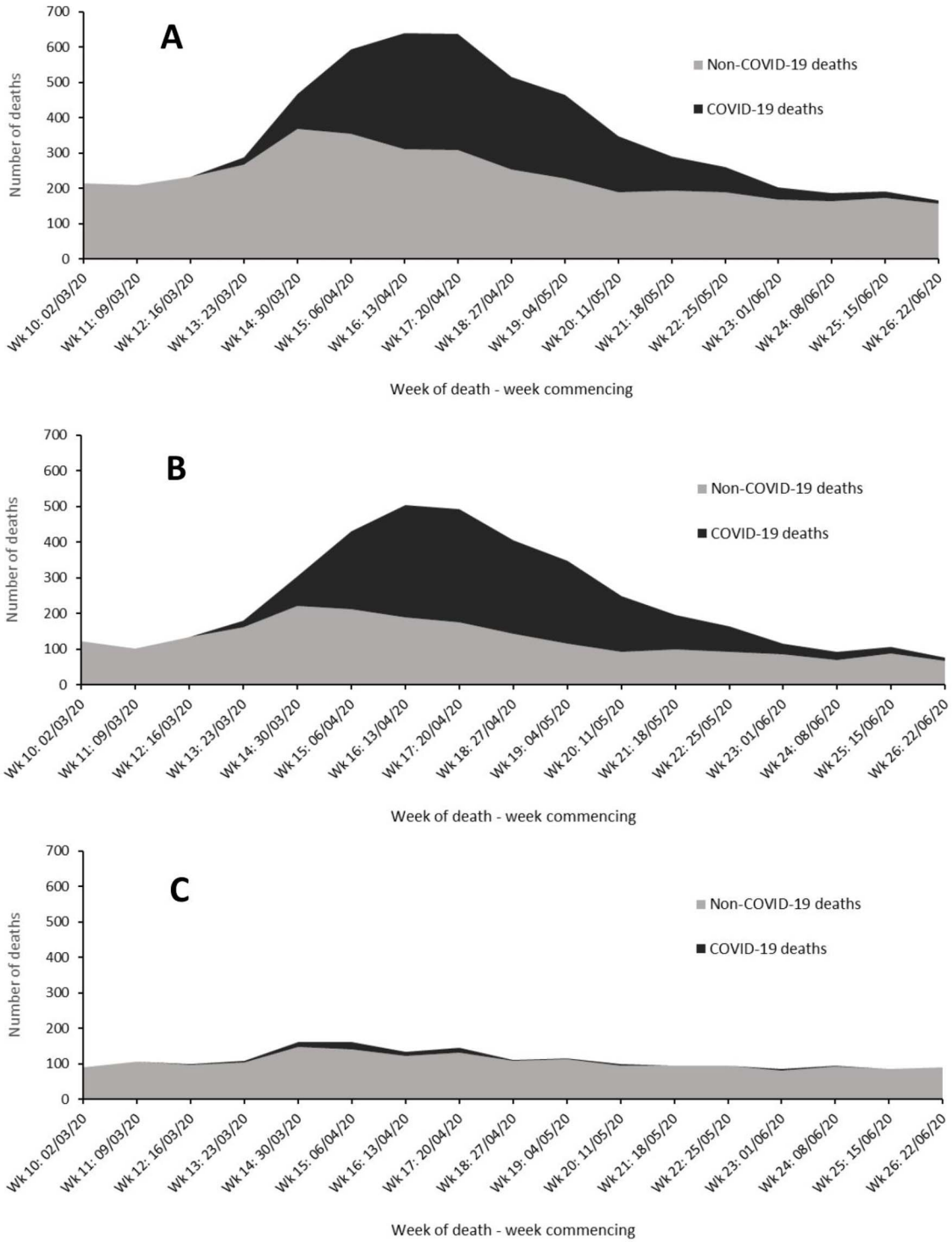

Figure 3. COVID-19 Associated Mortality and Other Mortality in Older People's Care-Homes by week of death (Panel A: all older people's care-homes; Panel B: older people's care-homes *with* an outbreak; Panel C: older people's care-homes *without* an outbreak).

discharge had higher odds of an outbreak, compared to homes which had not received a discharged patient, but after adjustment for the other predictors, the association was not statistically significant (OR 1.2, 95% CI 0.5–2.7). Local authority/NHS care-homes had increased adjusted odds of an outbreak, compared to privately run care-homes (adjusted OR 2.0 (1.1–3.7)), whilst there was no statistically significant adjusted association for not-for-profit homes.

Table 1. Care-home characteristics associated with having an outbreak of COVID-19

Care-home characteristic	Number (%) of homes with an outbreak	Univariate odds ratio 95% CI	Adjusted odds ratio 95% CI
Care-home size (no. of places)			
<20	5 (5.6)	Reference	Reference
20–29	29 (22.0)	**4.5 (1.8–13.5)**	2.7 (0.99–8.5)
30–39	44 (30.1)	**6.8 (2.8–20.4)**	**4.4 (1.7–13.6)**
40–49	58 (37.9)	**9.7 (4.0–28.7)**	**6.5 (2.5–20.5)**
50–59	34 (44.1)	**12.5 (4.9–38.6)**	**7.2 (2.5–24.0)**
60–69	67 (62.6)	**26.5 (10.8–80.2)**	**12.7 (4.6–41.6)**
70–79	28 (77.8)	**55.3 (18.1–204.0)**	**24.7 (7.2–100.0)**
80–89	23 (74.1)	**45.4 (14.6–169.2)**	**22.4 (6.4–92.3)**
≥90	46 (90.2)	**145.4 (44.3–603.8)**	**55.4 (15.0–251.7)**
Sector			
Private	267 (56.2)	Reference	Reference
Voluntary/not for profit	26 (14.1)	**0.5 (0.3–0.8)**	0.9 (0.5–1.7)
Local authority/NHS	41 (26.1)	**0.7 (0.4–0.9)**	**2.0 (1.1–3.7)**
Duration of care-home service[a]			
0–2 years	40 (54.1)	Reference	Reference
3–5 years	50 (64.1)	1.5 (0.8–1.9)	1.1 (0.5–2.3)
6–10 years	95 (43.8)	0.7 (0.4–1.1)	0.6 (0.3–1.1)
11–14 years	39 (36.8)	**0.5 (0.3–0.9)**	**0.4 (0.2–0.9)**
15–20 years	110 (32.2)	**0.4 (0.2–0.7)**	0.5 (0.3–1.0)
Risk Assessment Document Score[b]			
Low risk	178 (37.5)	Reference	Reference
Medium risk	77 (41.6)	1.2 (0.8–1.7)	0.8 (0.5–1.3)
High risk	79 (50.3)	**1.7 (1.2–2.4)**	1.2 (0.7–1.8)
Nursing care			
No nursing care	63 (24.8)	Reference	Reference
Nursing care	267 (48.2)	**2.8 (2.0–3.9)**	1.5 (0.9–2.5)
Missing	4 (44.4)	2.4 (0.6–9.4)	0.6 (0.1–3.1)
Urban rural classification[c]			
Large urban areas	147 (77.0)	Reference	Reference
Other urban areas	123 (64.4)	**0.4 (0.3–0.6)**	**0.4 (0.3–0.7)**
Accessible small towns	26 (33.8)	**0.3 (0.2–0.5)**	0.5 (0.3–1.0)
Accessible rural	23 (28.9)	**0.2 (0.1–0.4)**	**0.4 (0.2–0.7)**
Remote small towns	10 (17.2)	**0.1 (0.1–0.2)**	**0.3 (0.1–0.6)**
Remote rural	5 (6.3)	**0.04 (0.01–0.1)**	**0.1 (0.03–0.3)**
Community COVID-19 prevalence[d]			
Per 100 cases per 100,000 population increase		**1.7 (1.5–1.9)**	**1.2 (1.0–1.4)**
Hospital discharges in March–May			
No discharges	12 (3.5)	Reference	Reference
At least one hospital discharge	332 (96.5)	**2.6 (1.4–5.3)**	1.2 (0.5–2.7)

[a]Duration of care-home service is years since registration of service. [b]RAD Score based on Care Inspectorate inspections. [c]Urban Rural Classification based on Scottish Government 2016 classification incorporating population and accessibility. [d]Rate for 3 months in the Integration Authority (March–May), community tests—tests conducted in home. OR is per 100 increase in rate per 100,000; observed range of prevalence is 27–635 per 100,000. Bold text denotes statistically significant result.

Factors associated with size of care-home outbreaks

In both univariate and adjusted analysis, none of the care-home characteristics examined were associated with size of an outbreak (Table 2; only univariate associations shown). Findings were the same in sensitivity analysis restricted to the 286 homes with outbreaks starting March–April 2020 and minimum 61-day follow-up (Supplementary Table S2 is available in *Age and Ageing* online).

Discussion

Key findings

Two-fifths of older people's care-homes in Scotland experienced an outbreak of COVID-19 during March to May 2020. However, there was considerable heterogeneity in the size (1–63 residents), duration (1–93 days) and mortality impact of these outbreaks, with four clusters of outbreak pattern identified. Almost all deaths from COVID-19 (96%) occurred in homes with a laboratory-confirmed outbreak, a third of deaths were in the 5% of homes with a severe outbreak, and a quarter of deaths were in just 3% of all older people's care-homes. Equally, there was no strong evidence of large numbers of excess deaths in homes without an outbreak, consistent with mortality impact being largely mediated by the presence of an outbreak rather than wider consequences of lockdown.

Although only one home had a distinct second outbreak, the lengthy gaps between positive tests in some homes suggest either introduction of new infection or ongoing

Table 2. Care-home characteristics associated with outbreak size

Care-home characteristic	Number (%) of homes with an outbreak	Univariate incident rate ratio 95% CI
Sector		
Private	267 (79.9)	Reference
Voluntary/not for profit	26 (7.8)	1.3 (0.9–2.0)
Local authority/NHS	41 (12.3)	0.9 (0.6–1.3)
Duration of care-home service[a]		
0–2 years	40 (12.0)	Reference
3–5 years	50 (15.0)	1.0 (0.7–1.5)
6–10 years	95 (28.4)	1.0 (0.7–1.5)
11–14 years	39 (11.7)	1.1 (0.7–1.7)
15–20 years	110 (32.9)	1.2 (0.8–1.7)
Risk Assessment Document Score[b]		
Low risk	178 (53.3)	Reference
Medium risk	77 (23.1)	0.8 (0.6–1.1)
High risk	79 (23.7)	0.9 (0.7–1.1)
Nursing care		
No nursing care	63 (18.9)	Reference
Nursing care	267 (79.9)	1.0 (0.8–1.4)
Missing	4 (1.2)	0.9 (0.4–2.8)
Urban rural classification[c]		
Large urban areas	147 (44.0)	Reference
Other urban areas	123 (36.8)	0.9 (0.8–1.2)
Accessible small towns	26 (7.8)	1.1 (0.7–1.7)
Remote small towns	10 (3.0)	0.8 (0.4–1.5)
Accessible rural	23 (6.9)	0.9 (0.6–1.5)
Remote rural	5 (1.5)	1.7 (0.7–2.5)
Hospital discharges in March–May		
No discharges	12 (3.6)	Reference
At least one hospital discharge	332 (99.4)	1.0 (0.5–1.8)
Community COVID-19 prevalence at outbreak[d]		
Per 100 per 100,000 increase		1.2 (0.9–1.4)
Outbreak onset in		
March	53 (15.8)	Reference
April	233 (69.8)	1.3 (0.9–1.8)
May	48 (14.4)	0.9 (0.6–1.3)

[a]Duration of care-home service is years since registration of service. [b]RAD Score based on Care Inspectorate inspections. [c]Urban Rural Classification based on Scottish Government 2016 classification incorporating population and accessibility. [d]Rate for the 2 weeks pre- and post-outbreak in the Integration Authority, community tests – tests conducted in home. IRR is the IRR per 100 per 100,000 increase in rate.

undetected transmission (due to the absence of systematic testing in wave 1 and/or many older people not displaying classical features of infection required for wave 1 testing). [20–22]

As observed in a single region of Scotland, [3] care-home size was the most significant predictor of a home experiencing an outbreak. This study examined additional variables including urban/rural location (homes in more rural and remote areas had fewer outbreaks), community prevalence of COVID (homes in areas with higher community prevalence had more outbreaks), and hospital discharge (no statistically significant association with outbreaks, consistent with other analysis. [23,24] Care-home size is likely to be a proxy for the number of care-home staff and other professional visitors coming into the home, and the other two variables are likely associated with higher risk of any one of those people being infected. This emphasises that care-home outbreaks must be understood in the context of their wider community. [7]

However, none of the care-home characteristics examined were associated with size of outbreak (defined as the proportion of residents who have laboratory-confirmed infection). This at least partly is likely to reflect lack of data on dynamic, organisational factors such as occupancy, staffing, built environment and quality of care. For example, availability of Personal Protective Equipment and the clinical model of support care-homes could access are not systematically recorded. The VIVALDI cross-sectional survey identified reduced risk of outbreak in homes with access to sick pay, reduced use of agency staff, increased staffing ratios and cohorting. [25]

Strengths and limitations

A key strength is that analysis is for all wave 1 laboratory-confirmed COVID-19 outbreaks in Scottish care-homes for older people. [24] However, the available data in wave 1 were limited. In common with all UK regions, there is no national data available to define who is actually resident in care-homes, meaning analysis relies on using registered places as the denominator, and will not fully capture the impact of changing occupancy rates over time and short stay residents. [26]

The data sources underpinning this work include legally required information, on care services from their regulator, national death certification data and national geographic classifications based on postcode. Test data in ECOSS and the daily trend data include all COVID-19 tests performed in Scotland, irrespective of the laboratory of analysis. The linked dataset of hospital discharges was formed to undertake national analysis, with care taken in allocation of care home status. [14]

No data were available on the staffing levels of the home or whether staff worked in multiple homes, which have been associated with outbreaks. [8] Although bespoke data tools collecting more of this data are now available, [27] time-varying data on important care-home characteristics were not systematically collected during wave one. [28]

A further limitation is that test availability and test strategy varied as wave 1 evolved. Early in wave 1, test availability was generally poor and restricted to the first few residents with typical symptoms, changing in mid-April to all residents with symptoms and later to all staff and residents within the home after a positive case was identified. Staff testing was very limited until the second half of April, but wave 1 staff results cannot be reliably assigned to particular care-homes. Outbreaks are therefore likely to be under ascertained, although the finding that 96% of COVID-associated deaths occurred in homes with a laboratory-confirmed outbreak provides some assurance that the method does not miss large outbreaks. Outbreaks in this analysis were also defined based on tests done in the care-home. The exclusion of tests performed during a hospital admission will also under-ascertain outbreaks, although admissions of residents to hospital in Scotland during wave 1 was considerably lower than average, [29] indicating that such under-ascertainment is unlikely to be very large. Similarly, community prevalence rates will be under-estimated by testing being largely restricted to those requiring hospital admission, although that is still likely to be a stable estimate for comparisons between areas.

Implications—practice, policy and research

The dominant care-home characteristic associated with risk of an outbreak is care-home size, with other significant associations with community COVID-19 prevalence and urban/rural location. This is consistent with the main route of introduction of infection being from the community via staff and other professional visitors such as GPs and district nurses. [30] Across the UK a number of strategies to limit infection introduction have been introduced, including weekly testing of care-home staff, and splitting homes into smaller discrete units and operate zoning approaches where possible. [31] In Scotland, all discharges to care homes after an inpatient stay have needed to be tested since late April and residents isolated in the care home for 2 weeks after return from hospital, [32] recognising potential risks from asymptomatic and presymptomatic infection. A summary of key Scottish policy decisions are included in Supplementary Materials available in *Age and Ageing* online. These strategies are clearly not fully protective, since there have been numerous care-home outbreaks in wave 2, but there is a need to evaluate the impact on outbreak presence and size of current and future protective strategies (including more frequent testing of staff and/or residents using lateral flow devices, changing visitor policies and vaccination). In the longer run, careful consideration of the optimal design of care-homes to ensure that they provide both a homely and clinically safe built environment is required.

Improved data collection to support understanding of care-home services, staffing and residents has been recognised as a priority with a number of new data collection tools rapidly developed, including the Scottish 'safety huddle' tool and the Capacity Tracker tool in England. [27] However, more systematic data collection beyond the pandemic is needed, which will require investment and infrastructure to support understanding and data collection beneficial to residents and staff. [33] At a bare minimum, we need to know who is resident in care-homes, or users of care-at-home, both permanently and temporary short-stays.

Individual level data would help in exploring the unmeasured variation seen and accounting for differences in the population living in older people's care-homes. More detailed analysis of the role of hospital discharges and admissions from other care-homes or from the community may help to understand alternative routes of infection introduction. Genomic analysis combined with epidemiological insights would be helpful in further characterising outbreak patterns and exploring transmission in prolonged outbreaks.

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

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