Covid-19 infection and attributable mortality in UK Long Term Care Facilities: Cohort study using active surveillance and electronic records (March-June 2020)

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Abstract

Background Rates of Covid-19 infection have declined in many countries, but outbreaks persist in residents of long-term care facilities (LTCFs) who are at high risk of severe outcomes. Epidemiological data from LTCFs are scarce. We used population-level active surveillance to estimate incidence of, and risk factors for Covid-19, and attributable mortality in elderly residents of LTCFs.

Methods: Cohort study using individual-level electronic health records from 8,713 residents and daily counts of infection for 9,339 residents and 11,604 staff across 179 UK LTCFs. We modelled risk factors for infection and mortality using Cox proportional hazards and estimated attributable fractions.

Findings: 2,075/9,339 residents developed Covid-19 symptoms (22·2% [95% confidence interval: 21·4%; 23·1%]), while 951 residents (10·2% [9·6%; 10·8%]) and 585 staff (5·0% [4·7%; 5·5%]) had laboratory confirmed infections. Confirmed infection incidence in residents and staff respectively was 152·6 [143·1; 162·6] and 62·3 [57·3; 67·5] per 100,000 person-days. 121/179 (67·6%) LTCFs had at least one Covid-19 infection or death. Lower staffing ratios and higher occupancy rates were independent risk factors for infection.

1,694 all-cause deaths occurred in 8,713 (19·4% [18·6%; 20·3%]) residents. 217 deaths occurred in 607 residents with confirmed infection (case-fatality rate: 35·7% [31·9%; 39·7%]). 567/1694 (33·5%) of all-cause deaths were attributable to Covid-19, 28·0% of which occurred in residents with laboratory-confirmed infection. The remainder of excess deaths occurred in asymptomatic or symptomatic residents in the context of limited testing for infection, suggesting substantial under-ascertainment.

Interpretation: 1 in 5 residents had symptoms of infection during the pandemic, but many cases were not tested. Higher occupancy and lower staffing levels increase infection risk. Disease control measures should integrate active surveillance and testing with fundamental changes in staffing and care home occupancy to protect staff and residents from infection.

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Background

Globally the number of Covid-19 cases continues to increase, but cases in Europe have declined since April 2020,\(^1\) following the introduction of lockdown measures.\(^2\) Although the incidence of infection in the general population in England is low (0.04%),\(^3\) new infections persist, with substantially higher rates of infection reported in both long-term care facilities (LTCFs) and hospitals.\(^4\) This raises the possibility that these settings represent a reservoir for transmission of infection back to the community.

In the UK, there are an estimated 400,000 residents living in approximately 11,000 LTCFs for the elderly.\(^5\) Residents of LTCFs are particularly vulnerable to Covid-19 due to their advanced age and high prevalence of comorbidity,\(^6\) and their frequent exposure to infection through close contact with staff members, other residents and contaminated surfaces in the care facility. At the peak of the pandemic, the number of deaths in residents of LTCFs was three-fold higher than the equivalent period in 2019.\(^7\) Staff in LTCFs also have higher aged-standardised rates of Covid-19 related mortality compared to other occupations.\(^8\) National statistics suggests two-thirds of excess deaths recorded in residents of LTCFs in the last 6 months involved Covid-19,\(^2\) but this is likely to be an underestimate because many residents were not tested. Understanding the proportion of excess deaths that can be directly and indirectly attributed to Covid-19 infection is important, to fully assess the impact of the pandemic on LTCFs.

The development of public health strategies to protect the public, residents and staff from Covid-19 requires knowledge of the burden of and risk factors for infection in residents and staff in LTCFs, linked to outcomes. However, there is no syndromic surveillance for infection in LTCFs in England, and widespread one-off testing for SARS-CoV-2 using reverse transcriptase polymerase chain reaction (RT-PCR) was not established for staff and residents in LTCFs until 11 May 2020.\(^2\) Prior to this, testing was only available for residents or staff who were admitted to hospital, or as part of Public Health England’s (PHE) outbreak investigations which permitted a maximum of five tests per LTCF. Consequently national estimates of incidence and prevalence will substantially underestimate the burden of infection in residents and staff in LTCFs.
In the absence of cohort studies or active surveillance, outbreak investigations provide the most reliable estimates of the burden of infection and case-fatality. An estimated 44% of English LTCFs have had at least one outbreak, with a living systematic review reporting substantial variation in cumulative incidence of infection (0%-72%) and case fatality (0-34%) in residents of LTCFs. A major limitation of outbreak investigations is that follow-up is usually less than 30 days, and investigations are only conducted in settings in which outbreaks have been detected. Understanding the proportion of LTCFs with undetected cases is crucial for policy decisions around the frequency of and justification for regular testing in this setting.

To our knowledge, there are no studies which have employed population-level active surveillance in LTCFs throughout this pandemic to measure outcomes of both suspected and confirmed infection in residents and staff. We analysed electronic health records from the Four Seasons Health Care Group, one of the UK’s largest independent provider of residential and nursing care, with the aim of identifying strategies to protect staff and residents in LTCFs from future waves of infection. Our objectives were to estimate incidence of and risk factors for infection, and incidence of mortality in the following groups: (A) residents with no evidence of infection; (B) symptomatic residents; (C) asymptomatic residents with confirmed infection; and (D) symptomatic residents with confirmed infection. We also estimated mortality attributable to Covid-19.

Methods

Study population and setting

Staff or residents living and working in LTCFs for the elderly between 2 March and 14 June 2020, which were run by the Four Seasons Healthcare Group (FSHCG) were eligible for study inclusion. The FSHCG provides a combination of residential and nursing care (for residents with medical conditions), which is primarily state funded. Most residents are permanent, but a small proportion receive temporary (respite) care.

In 2020, there were 9,568 beds, representing 9% of all beds in England, Scotland and Northern Ireland (supplementary material 1). 90% of FSHCG LTCFs participated in the whole care home testing programme, implying that all staff and residents were tested for Covid-19 at least once between 11 May and 22 June 2020.
Data sources

Electronic record datasets collected by the FSHCG are primarily used for billing and monitoring care quality, but have also been used in research.\textsuperscript{13}

Individual-level data

FSHCG collects electronic health record data on all their residents except those occupying beds that are ‘block contracted’ to the local authority (855 beds). The dataset includes: dates of entry and exit to the LTCF, sex, date of birth, type of stay (residential/nursing) and care (general, dementia, elderly). Individual-level data on incidents including infections are also reported via ‘Datix’ which records the residents name, LTCF identifier, incident date/time, date of birth, sex, Covid-19 symptoms, tests and test results, resident current location (LTCF/hospital), and death. Information in Datix was used categorise residents’ infection status into four groups: (A) residents with no evidence of infection (not tested and/or no symptoms); (B) symptomatic residents (symptoms and not tested or tested negative); (C) asymptomatic residents with confirmed infection (no symptoms but tested positive); and (D) symptomatic residents with confirmed infection (symptoms and tested positive) (supplementary material 1). The term ‘confirmed’ denoted a positive PCR test. Datix was also used to differentiate deaths in-hospital from those in the LTCF, and to identify Covid-19 related deaths. Individual level data on residents was linked to Datix reports (supplementary material 2). 1492/1880 (79%) of Datix reports were successfully linked. Individual-level records were available between 2 March and 14 June 2020.

Aggregate data

On 24 March a new system was introduced to report Covid-19 cases and deaths. This required managers of each LTCF to report daily tallies in residents (new symptomatic cases, new confirmed infection in facility, new confirmed infection in hospital, deaths related to Covid-19) and staff (symptomatic cases, new confirmed cases). Data on staff deaths were not extracted due to the small number of cases. Covid-19 related deaths were defined as death in a resident with confirmed infection or a death attributed to Covid-19 by the coroner. The number of occupied beds in each LTCF was reported weekly.
Characteristics of each LTCF (number of beds, region, nursing versus residential care) were collected from organisational data. We therefore extracted organisational data, individual-level data for 8713 residents and aggregate data for all staff and residents (Figure 1).

Note: NI: Northern Ireland; S: Scotland; W: Wales; NE: North East; NW: North West; YTH: Yorkshire and The Humber; EM: East Midlands; WM: West Midlands; EE: East of England; L: London; SE: South East; SW: South West.

Figure 1: Study overview: location of FSHCG LTCF’s and diagram of data sources

Risk factors for infection

Risk factors for infection included individual-level variables (age, sex, general or dementia care, residential versus nursing care) and LTCF characteristics (number of beds, occupancy and bed to staff ratio). Baseline LTCF occupancy was computed by averaging weekly occupancy in January-March 2020, before the first Covid-19 case, in order to calculate a ratio of baseline occupancy to the number of bedrooms. We also estimated the ratio of bed to staff as a continuous variable. An outbreak in a LTCF was defined as at least one confirmed infection or Covid-19 related death.

Statistical analysis

Infection in staff and residents in LTCF’s
Prevalence, incidence and cumulative incidence were calculated for residents and staff using the aggregate daily tallies. These were the trusted source of information used for national reporting of cases, and encompassed all residents and staff. Infection incidence was also estimated from Datix, but was subject to under-reporting (supplementary material 2). In order to calculate infection and death incidence, we estimated the total number of residents in each LTCF by extrapolating estimates of LTCF occupancy from the individual-level dataset (because dates of entry and exit to/from the LTCF were not available for 855 beds, supplementary material 1). Daily occupancy was inferred from the weekly report of bed occupancy using linear interpolation. The total number of residents at risk of infection was unknown, so it was approximated in a multiple decrements life table (supplementary material 1). The life table allowed us to compute Kaplan-Meier product limit estimators of the cumulative incidence of symptoms, confirmed infections, and Covid-19 related deaths by day. The rate ratio for LTCF versus community infections was estimated by contrasting the cumulative incidence for confirmed cases in England with estimates from a national household survey for the period 11 May- 7 June 2020.3,15

Mortality, attributable mortality and risk factors

Individual-level data were used to estimate rates of infection, all-cause mortality and case-fatality by age and gender in residents. Aggregate data were also used to estimate the crude rate of Covid-19 related mortality. Cox proportional hazards models were used to test the association between individual and organisational-level risk factors and confirmed infection. In order to investigate the relationship between Covid-19 infection and excess mortality, we assumed that residents in non-outbreak LTCFs had not been exposed to infection, and would therefore not experience excess Covid-19 related mortality. We therefore compared all-cause mortality in residents with no evidence of infection (group A) in LTCFs with and without outbreaks.

A Cox proportional hazards regression model tested the effect of individual and LTCF-level risk factors on all-cause mortality, alongside the effect of the time-variant infection status (groups A-D) and LTCF outbreak status. We estimated the attributable fraction of deaths for each infection category in LTCF’s with and without outbreaks, taking the reference category as individuals with no direct evidence of infection (group A) in non-outbreak LTCFs. This fraction was obtained by using the model to predict the counterfactual mortality, then computing the
attributable fraction within study. Ninety-five percent confidence intervals for proportions and rates were computed from the exact Poisson and binomial limits. Data were analysed in R3·5·0 using the epitool and survival libraries. All computer syntax is available on an online repository.

Research ethics
This study was approved by the University College London Research Ethics Committee (project reference 13355/002).

Role of the funding source
The funders of the study had no role in study design, data collection, data analysis, data interpretation or writing of the report. LS and PDM had full access to all the data in the study and LS had final responsibility for the decision to submit for publication.

Findings
Cases of infection in residents and staff
The study included 9,339 residents across England, Scotland and Northern Ireland and 11,604 staff. 121/179 (67.6%) LTCFs, totalling 7,102 residents, recorded at least one Covid-19 outbreak (including unconfirmed outbreaks) in either the individual-level or aggregate datasets. The mean duration of follow-up for residents and staff was 71 days and 82 days respectively in the aggregate dataset. Mean and median duration of resident follow-up was 86 and 105 days respectively in the individual-level dataset.

Symptoms of infection were recorded in 2,075 residents based on the aggregate dataset, contributing to an overall cumulative incidence of 22.2% [21.4%; 23.1%] or an incidence rate of 368.0 per 100,000 resident-days [352.3; 384.2] (Table 1). An additional 951 residents had a confirmed infection, of whom 199 were diagnosed in hospital. The cumulative incidence of confirmed infection was 10.2% [9.6%; 10.8%], with an incidence rate of 152.6 per 100,000 [143.1; 162.6]. Kaplan-Meier estimates of the temporal trend in symptomatic and confirmed cases are shown in Figure 2.
In England, 179 infections were confirmed of a total 194,023 residents-days between 11 May 2020 and 7 June 2020. In comparison, the survey of English community households found a total of 35 confirmed cases out of 483,259 person-days during the same period. This implies a confirmed infection rate ratio comparing LTCFs to the community of 12·7 [8·9; 18·3].

Table 1: Cumulative incidence and rate of SARS-CoV-2 infections in residents according to FSHCG aggregate dataset (2 Mar 2020-14 Jun 2020)

| Residents | All LTCFs | Outbreak LTCFs only |
|-----------|-----------|---------------------|
|           | Symptomatic | Confirmed | COVID-19 related deaths | Symptomatic | Confirmed | COVID-19 related deaths |
| Cases     | 2,075 | 951 | 526 | 1,807 | 951 | 526 |
| N exposed | 9,339 | 9,339 | 9,339 | 7,102 | 7,102 | 7,102 |
| Total exposure (days) | 563,901 | 623,161 | 659,843 | 383,536 | 430,133 | 466,813 |
| Cumulative incidence (%) | [21·4; 23·1] | [9·6; 10·8] | [5·2; 6·1] | [24·4; 26·5] | [12·6; 14·2] | [6·8; 8·0] |
| Incidence rate (per 100,000 person-days) | [352·3; 384·2] | [143·1; 162·6] | [73·0; 86·8] | [449·7; 493·4] | [207·3; 235·6] | [103·3; 122·7] |

Note: underlying data available on request from authors.

Figure 2: Kaplan-Meier estimates of the cumulative incidence of symptomatic cases, confirmed infections and COVID-related deaths in (A) residents (n=9,339) and (B) staff (n=11,604) according to FSHCG aggregate data (Mar 2020-Jun 2020)

1,892/11,604 staff (16·3% [15·6%; 17·0%]) reported symptoms of infection during the study period, and 585 (5·0% [4·7%; 5·5%]) had a confirmed infection (Table 2, Figure 2).
Table 2: Cumulative incidence and rate of SARS-CoV-2 infections among staff according to FSHCG manager counts (2 Mar 2020-14 Jun 2020)

| Staff                        | Symptomatic | Confirmed |
|------------------------------|-------------|-----------|
| Cases                        | 1,892       | 585       |
| N exposed                    | 11,604      | 11,604    |
| Total exposure (days)        | 856,323     | 939,312   |
| Cumulative incidence (%)     | 16.3 [15.6; 17.0] | 5.0 [4.7; 5.5] |
| Incidence rate (per 100,000 person-days) | 220.9 [211.1; 231.1] | 62.3 [57.3; 67.5] |

Estimates of incidence for private residents derived from Datix are reported in supplementary material 2.

Mortality in residents

526 Covid-related resident deaths were reported in the aggregate dataset, equivalent to a crude incidence of 5.6% [5.2; 6.1] or 79.7 [73.0; 86.8] per 100,000 resident-days. 24.7% of these deaths took place in hospital (Table 1).

Individual-level data were available for 8,713 (93.3%) residents. 68.7% of residents received nursing care, and 39.2% received dementia care (Table 3). 1,694 all-cause deaths occurred in residents of LTCF’s, equivalent to a crude cumulative incidence of 19.4% [18.6%; 20.3%]. The proportion of resident deaths was two-fold higher in LTCFs with outbreaks compared to those without outbreaks (22.6% versus 11.2%).

217 deaths occurred in residents with confirmed infection, equivalent to an all-cause case-fatality rate in infected residents (Groups C and D) of 35.7% [31.9%; 39.7%] (Table 4). The case-fatality rate increased with age and was higher in men compared to women.
Table 3: Characteristics of FSHCG residents by type of LTCF, sex, age, region and status on study exit (Mar 2020- Jun 2020)

|                      | Outbreak LTCFs (N=6328) | Other LTCFs (N=2385) | Total (N=8713) |
|----------------------|--------------------------|----------------------|----------------|
| **Sex**              |                          |                      |                |
| Female               | 4051 (64-0%)             | 1616 (67-8%)         | 5667 (65-0%)   |
| Male                 | 2277 (36-0%)             | 769 (32-2%)          | 3046 (35-0%)   |
| **Age**              |                          |                      |                |
| <75 years            | 1069 (16-9%)             | 355 (14-9%)          | 1424 (16-3%)   |
| 75–84 years          | 2113 (33-4%)             | 752 (31-5%)          | 2865 (32-9%)   |
| 85–94 years          | 2577 (40-7%)             | 1052 (44-1%)         | 3629 (41-7%)   |
| 95+ years            | 569 (9-0%)               | 226 (9-5%)           | 795 (9-1%)     |
| **Resident type**    |                          |                      |                |
| General/elderly      | 3799 (60-0%)             | 1495 (62-7%)         | 5294 (60-8%)   |
| Dementia             | 2529 (40-0%)             | 890 (37-3%)          | 3419 (39-2%)   |
| **Admission type**   |                          |                      |                |
| Continuing care/     |                          |                      |                |
| independent living   | 293 (4-6%)               | 58 (2-4%)            | 351 (4-0%)     |
| Permanent            | 5375 (84-9%)             | 2065 (86-6%)         | 7440 (85-4%)   |
| Respite              | 660 (10-4%)              | 262 (11-0%)          | 922 (10-6%)    |
| **Funding type**     |                          |                      |                |
| Residential          | 1992 (31-5%)             | 742 (31-1%)          | 2734 (31-4%)   |
| Nursing              | 4336 (68-5%)             | 1643 (68-9%)         | 5979 (68-6%)   |
| **Infection status by 14 June** |                    |                      |                |
| A: No evidence of infection | 5268 (83-2%)            | 2274 (95-3%)         | 7542 (86-6%)   |
| B: Symptomatic not confirmed | 453 (7-2%)              | 111 (4-7%)           | 564 (6-5%)     |
| C: Asymptomatic confirmed | 133 (2-1%)              | 0 (0-0%)             | 133 (1-5%)     |
| D: Symptomatic confirmed | 474 (7-5%)              | 0 (0-0%)             | 474 (5-4%)     |
| **Status as of 14 June** |                        |                      |                |
| Deceased             | 1428 (22-6%)             | 266 (11-2%)          | 1694 (19-4%)   |
| In LTCF              | 4558 (72-0%)             | 2011 (84-3%)         | 6569 (75-4%)   |
| Permanently Discharged | 215 (3-4%)              | 69 (2-9%)            | 284 (3-3%)     |
| Temporary Discharged | 127 (2-0%)               | 39 (1-6%)            | 166 (1-9%)     |
| **Region/nation**    |                          |                      |                |
| East Midlands        | 333 (5-3%)               | 285 (11-9%)          | 618 (7-1%)     |
| East of England      | 338 (5-3%)               | 274 (11-5%)          | 612 (7-0%)     |
| London               | 619 (9-8%)               | 0 (0-0%)             | 619 (7-1%)     |
| North East           | 821 (13-0%)              | 197 (8-3%)           | 1018 (11-7%)   |
| North West           | 965 (15-2%)              | 120 (5-0%)           | 1085 (12-5%)   |
| Northern Ireland     | 1054 (16-7%)             | 770 (32-3%)          | 1824 (20-9%)   |
| Scotland             | 785 (12-4%)              | 449 (18-8%)          | 1234 (14-2%)   |
| South East           | 567 (9-0%)               | 26 (1-1%)            | 593 (6-8%)     |
| South West           | 171 (2-7%)               | 71 (3-0%)            | 242 (2-8%)     |
| West Midlands        | 105 (1-7%)               | 127 (5-3%)           | 232 (2-7%)     |
| Yorkshire and The Humber | 570 (9-0%)            | 66 (2-8%)            | 636 (7-3%)     |

Table 4: All-cause case-fatality rates by age and sex among residents (n=8,713; Mar 2020–Jun 2020)

| Age       | Sex   | N   | Confirmed infections | Total deaths | Deaths in confirmed infections | Case-fatality rate (%) |
|-----------|-------|-----|----------------------|--------------|-------------------------------|------------------------|
| <75 years | Female| 712 | 48                   | 87           | 9                             | 18.8 [8.9; 32.6]       |
| 75–84 years | Female| 1,687 | 114               | 254          | 31                            | 27.2 [19.3; 36.3]      |
| 85–94 years | Female| 2,617 | 173               | 484          | 58                            | 33.5 [26.5; 41.1]      |
| 95+ years | Female| 651 | 42                   | 171          | 18                            | 42.9 [27.7; 59.0]      |
| <75 years | Male  | 712 | 37                   | 114          | 12                            | 17.5 [10.0; 28.4]      |
| 75–84 years | Male | 1,178 | 96               | 266          | 41                            | 42.7 [32.7; 53.2]      |
| 85–94 years | Male | 1,012 | 86               | 277          | 44                            | 45.2 [36.4; 55.0]      |
| 95+ years | Male  | 144 | 11                   | 41           | 4                             | 28.6 [14.5; 47.4]      |
| All       |       | 8,713 | 607               | 1,694        | 217                           | 35.7 [31.9; 39.7]      |
Factors associated with confirmed infections in residents

Using individual-level resident data, factors affecting the rate of confirmed cases were investigated in a Cox Proportional Hazard model. Male sex, age ≥85 years, and residence in a nursing LTCF (adjusted HR=1·5 [1·2; 1·8]) were all independently associated with increased risk of confirmed Covid-19 infection (Table 5). Large LTCFs had greater rates of infection (adjusted HR=1.8 [1·4; 2·4] for LTCFs with ≥70 beds versus <35 beds). LTCF baseline occupancy and staffing ratios had the greatest effect on residents’ risk of infection. For example, the adjusted hazard ratio for confirmed infection was 2.5 times [1·9; 3·3] greater in LTCFs with 0·85- 1 resident per room versus LTCFs with 0·7-0·85 resident per room.

Higher staff to resident ratios were associated with lower risk of infection: a ten percentage point increase in the bed to staff ratio was associated with a 23% increase in infection (adjusted HR=1·23 [1·17; 1·31]).

Table 5: Risk factors for confirmed infection in residents: hazard ratios (HR) from a Cox proportional hazards model (n=8,713)

| Table 5: Risk factors for confirmed infection in residents: hazard ratios (HR) from a Cox proportional hazards model (n=8,713) |
|-------------------------------------------------|
| **Gender**                                      |
| Female                                         | 377 (6·7%) | 5667 | 1.00 (reference) | 1.00 (reference) |
| Male                                           | 230 (7·6%) | 3046 | 1.24 (1·06-1·47) | 1.32 (1·11-1·56) |
| **Age**                                        |
| <75 years                                      | 85 (6·0%)  | 1424 | 1.00 (reference) | 1.00 (reference) |
| 75–84 years                                    | 210 (7·3%) | 2865 | 1.26 (0·98-1·62) | 1.32 (1·03-1·71) |
| 85–94 years                                    | 259 (7·1%) | 3629 | 1.24 (0·97-1·59) | 1.42 (1·10-1·82) |
| 95+ years                                      | 53 (6·7%)  | 795  | 1.22 (0·86-1·72) | 1.43 (1·01-2·03) |
| **Bed type**                                   |
| Residential                                    | 154 (5·6%) | 2734 | 1.00 (reference) | 1.00 (reference) |
| Nursing                                        | 453 (7·6%) | 5979 | 1.38 (1·15-1·66) | 1.40 (1·15-1·70) |
| **Care type**                                  |
| General/elderly                                | 374 (7·1%) | 5294 | 1.00 (reference) | 1.00 (reference) |
| Dementia                                       | 233 (6·8%) | 3419 | 0·95 (0·80-1·12) | 0·90 (0·76-1·06) |
| **Total beds**                                 |
| 20–34 beds                                     | 106 (5·0%) | 2129 | 1.00 (reference) | 1.00 (reference) |
| 45–59 beds                                     | 341 (7·5%) | 4544 | 1·51 (1·21-1·88) | 1·59 (1·27-1·99) |
| 70–84 beds                                     | 160 (7·8%) | 2040 | 1·63 (1·28-2·09) | 1·87 (1·44-2·43) |
| **Bed:staff ratio**                            |
| Mean (SD)                                      | 0·9 (0·2)  | 1·65 (1·09-2·48) | 8·22 (4·62-14·63) |
| **Occupants:**                                 |
| bed:rooms ratio                                | (0·7-0·85] | 62 (4·0%) | 1549 | 1.00 (reference) | 1.00 (reference) |
| (0·25-0·4]                                    | 5 (7·1%)   | 70   | 1·94 (0·78-4·82) | 0·69 (0·26-1·82) |
| (0·4-0·55]                                    | 9 (3·1%)   | 286  | 0·75 (0·37-1·51) | 0·44 (0·22-0·90) |
| (0·55-0·7]                                    | 29 (8·1%)  | 356  | 2·01 (1·29-3·13) | 2·04 (1·29-3·21) |
| (0·85-1]                                      | 438 (7·1%) | 6139 | 1·72 (1·32-2·25) | 2·48 (1·84-3·33) |
| (1·1-15]                                      | 64 (20·4%) | 313  | 4·83 (3·41-6·85) | 9·28 (6·20-13·90) |
Factors associated with all-cause mortality

The time-dependent Cox proportional hazard models in Table 6 examine the relationship between infection status (groups A-D) and mortality. After controlling for other risk factors, increased mortality was associated with older age, male gender (adjusted HR=1.4 [1.3; 1.6]), and receiving nursing care (adjusted HR=1.4 [1.2; 1.5]).

We estimated excess mortality in outbreak and non-outbreak LTCFs, taking individuals with no evidence of infection (group A) in non-outbreak LTCFs as the reference group. Risk of all-cause mortality was almost two-fold higher in residents in Group A (no direct evidence of infection) in outbreak versus non-outbreak LTCFs (adjusted HR=2.0 [1.7; 2.2]). Risk of death was also higher in group B (residents with symptoms but unconfirmed infection) in outbreak versus non-outbreak LTCFs relative to the baseline group (adjusted HR=4.3 [3.0; 6.2] versus 9.4 [7.6; 12]). All-cause mortality was strongly associated with group C - asymptomatic confirmed infection (adjusted HR=3.3 [2.0; 5.7]) and group D - symptomatic confirmed infection (adjusted HR=13 [11; 16]), compared to baseline.

It is important to note these hazard ratio estimates do not give a comprehensive measure of effect: hazards were not proportional across these categories (Figure 3).
Table 6: Risk factors for all-cause mortality in residents of LTCFs with and without Covid-19 outbreaks: hazard ratios (HR) from a Cox proportional hazards model (n=8,713, Mar 2020–Jun 2020)

| Variable                | Deaths | N   | HR (univariate) | HR (multivariate) |
|-------------------------|--------|-----|-----------------|-------------------|
| **Gender**              |        |     |                 |                   |
| Female                  | 996 (17.6%) | 5667 | 1.00 (reference) | 1.00 (reference)  |
| Male                    | 698 (22.9%) | 3046 | 1.40 (1.27-1.54) | 1.44 (1.30-1.59)  |
| **Age**                 |        |     |                 |                   |
| <75 years               | 201 (14.1%) | 1424 | 1.00 (reference) | 1.00 (reference)  |
| 75–84 years             | 520 (18.2%) | 2865 | 1.30 (1.11-1.53) | 1.36 (1.14-1.61)  |
| 85–94 years             | 761 (21.0%) | 3629 | 1.50 (1.28-1.75) | 1.75 (1.49-2.06)  |
| 95+ years               | 212 (26.7%) | 795  | 1.93 (1.59-2.35) | 2.32 (1.88-2.85)  |
| **Bed type**            |        |     |                 |                   |
| Residential             | 420 (15.4%) | 2734 | 1.00 (reference) | 1.00 (reference)  |
| Nursing                 | 1274 (21.3%) | 5979 | 1.38 (1.24-1.54) | 1.36 (1.21-1.54)  |
| **Care type**           |        |     |                 |                   |
| General/elderly         | 1015 (19.2%) | 5294 | 1.00 (reference) | 1.00 (reference)  |
| Dementia                | 679 (19.9%) | 3419 | 1.02 (0.92-1.12) | 1.00 (0.90-1.11)  |
| **Total beds**          |        |     |                 |                   |
| 20–34 beds              | 373 (17.5%) | 2129 | 1.00 (reference) | 1.00 (reference)  |
| 45–59 beds              | 872 (19.2%) | 4544 | 1.08 (0.96-1.22) | 0.91 (0.80-1.03)  |
| 70–84 beds              | 449 (22.0%) | 2040 | 1.26 (1.09-1.44) | 0.96 (0.82-1.13)  |
| **Bed:staff ratio**     |        |     |                 |                   |
| Mean (SD)               | 0.9 (0.2) |     | 1.31 (1.02-1.70) | 1.23 (0.88-1.73)  |
| **Occupants: bedrooms ratio** |      |     |                 |                   |
| (0.7-0.85)              | 303 (19.6%) | 1549 | 1.00 (reference) | 1.00 (reference)  |
| (0.25,0.4]              | 14 (20.0%) | 70   | 1.08 (0.63-1.84) | 0.87 (0.51-1.48)  |
| (0.4-0.55]              | 53 (18.5%) | 286  | 0.91 (0.68-1.22) | 0.82 (0.61-1.11)  |
| (0.55,0.7]              | 73 (20.5%) | 356  | 1.02 (0.79-1.31) | 0.67 (0.51-0.88)  |
| (0.85,1]                | 1197 (19.5%) | 6139 | 0.95 (0.84-1.08) | 0.79 (0.69-0.91)  |
| (1,1.15]                | 54 (17.3%) | 313  | 0.80 (0.60-1.06) | 0.43 (0.32-0.59)  |
| **Infection/outbreak status** |      |     |                 |                   |
| **Non-outbreak LTCFs**  |        |     |                 |                   |
| A Uninfected (other LTCF) | 252 (11.1%) | 2274 | 1.00 (reference) | 1.00 (reference)  |
| B Symptomatic not confirmed | 14 (12.6%) | 111  | 4.44 (3.18-6.21) | 4.34 (3.02-6.22)  |
| **Outbreak LTCFs**      |        |     |                 |                   |
| A Uninfected            | 1030 (19.6%) | 5268 | 1.93 (1.70-2.20) | 1.95 (1.70-2.23)  |
| B Symptomatic not confirmed | 181 (40.0%) | 453  | 8.82 (7.31-10.65) | 9.44 (7.57-11.77) |
| C Confirmed asymptomatic | 15 (11.3%) | 133  | 3.25 (1.93-5.46) | 3.34 (1.97-5.66)  |
| D Confirmed symptomatic  | 202 (42.6%) | 474  | 12.21 (10.27-14.51) | 12.76 (10.50-15.50) |
Figure 3: Kaplan-Meier estimates of resident (n=8,713) survival by SARS-COV-2 case type

Attributable mortality

Model-based estimates of attributable mortality were derived from the individual-level data. Overall, 567/1,694 (33%) deaths were attributed to Covid-19. In LTCFs with outbreaks only 28% (159 residents) of the mortality attributable to COVID-19 occurred in people with confirmed infection (Groups C and D), (Table 7). Exclusion of the early pandemic period in sensitivity analysis increased attributable mortality to 560/1,343 (41.7%). Model-based estimates of deaths based on individual-level were slightly higher (8%) than counts from the aggregate data.
# Table 7: Model-based estimates of attributable death in residents of LTCFs with and without Covid-19 outbreaks (n=8,713, Mar 2020- Jun 2020)

| Infection/outbreak status | Adjusted HR | Resident-days | Total deaths | Deaths attributable to Covid-19 (% all-cause deaths)* |
|---------------------------|-------------|---------------|--------------|-----------------------------------------------|
| **Non-outbreak LTCFs**    |             |               |              |                                               |
| A Uninfected              | 1·00 [ 1·00; 1·00] | 470,234       | 733          | 0 ( 0·00)                                    |
| B Symptomatic not confirmed | 4·36 [ 3·03; 6·25] | 6,680         | 37           | 26 (4·59)                                   |
| **Outbreak LTCFs**        |             |               |              |                                               |
| A Uninfected              | 1·93 [ 1·69; 2·20] | 234,480       | 549          | 261 (46·03)                                  |
| B Symptomatic not confirmed | 9·33 [ 7·48; 11·64] | 15,944        | 158          | 120 (21·16)                                  |
| C Confirmed asymptomatic  | 3·28 [ 1·93; 5·55] | 5,316         | 15           | 11 (1·94)                                   |
| D Confirmed symptomatic   | 12·47 [10·26; 15·17] | 15,033       | 202          | 148 (26·10)                                  |
| **TOTAL**                 |             |               | 747,687      | 1,694                                        |

* column percent; *row percent

## Interpretation

### Main findings

This population-level study demonstrates the major impact of Covid-19 on LTCFs, with 22% of residents and 16% of staff experiencing symptoms and overall case-fatality of 35·7%. Residents with no direct evidence of infection in LTCFs with outbreaks had twice the mortality of the equivalent group in LTCFs without outbreaks, implying substantial case under-ascertainment.

Less than one-third of deaths attributable to COVID-19 in outbreak LTCFs were confirmed which is likely due to poor availability of testing until late in the pandemic. In addition to the need for active surveillance linked to increased testing capacity, higher staff to resident ratios and reduced LTCF occupancy are critically important to reducing the spread of infection.

Our estimates of the prevalence of confirmed Covid-19 infections and deaths in residents are comparable to a large survey of managers of LTCFs in England. However, both studies are likely to have underestimated the proportion of residents who became infected due to limited testing, asymptomatic infection and moderate sensitivity of PCR testing. Our estimate of 35·7% case-fatality in residents with confirmed infection over a mean of 71 days is higher than previous literature, but is based on longer follow-up, a larger number of residents, and our study population had higher overall mortality. For example, an outbreak investigation in 4 LTCFs in London, UK measured a case-fatality rate of 17% among 126 residents over a period of 62 days, while Stall et al. measured a rate of 28% in over a period of 53 days in a Canadian study.
Whereas two-thirds of LTCFs in our study reported at least one case of infection or death, just
44% of LTCFs have notified an outbreak to PHE. This suggests that nationally, local health
protection teams may be unaware of Covid-19 infections in up to 1 in 5 LTCFs. Integration of
data systems, so that test results can be accessed and acted upon by local public health teams
is fundamental to the pandemic response.

In common with a Canadian cohort study, we found strong associations between infections
and LTCF occupancy. We also identified lower staff to resident ratios as a risk factor for
infection. These organisational factors, linked to chronic underfunding of the care sector, are
likely to facilitate the implementation of infection control procedures such as isolating or
cohorting infected residents, staff training, and regular environmental deep cleaning. When
staff care for fewer residents they also have reduced likelihood of spreading infection between
residents. Higher staff to resident ratios may also decrease reliance on agency staff who may
spread infection between LTCFs, and indicate better resourced LTCFs.

**Strengths and limitations**
The unique surveillance system we established in partnership with FSHCG allowed us to track
infections throughout the entire pandemic period across a large number of LTCFs, and identify
symptomatic as well as confirmed and asymptomatic cases. To our knowledge, this is the most
complete reporting system for Covid-19 infections in LTCFs published to date. It is possible
that LTCFs that paid less attention to active surveillance to support control will have had higher
levels of uncontrolled outbreaks compared to those seen in this study.

A limitation is lack of access to information on comorbidity and ethnicity, both of which have
been shown to be important risk factors for adverse outcomes in Covid-19. However, we were
able to identify individuals with dementia, and adjust for receipt of nursing care which will
partially capture comorbidity. We also lacked information on the overall rate of testing in each
LTCF.

**Clinical, research and policy implications**
In the UK the number of infected residents and staff has been underestimated, due to limited
availability of testing until late in the pandemic. High levels of asymptomatic infection will also
lead to under-ascertainment. It is important to note however, that mortality rates were also
increased in those recorded as asymptomatic infections suggesting that in an elderly cohort
residents may have atypical presentations that do not conform to standard case definitions. Although our findings support increased use of testing to improve case ascertainment, frequent testing in residents of LTCFs may not always be desirable if the risk of infection is low, because the testing procedure (nasopharyngeal swabs) is invasive and may distress vulnerable residents. Since the incubation period and serial interval of COVID-19 is short, the interval between successive screens required to interrupt transmission may also need to be short. Rapid early diagnosis of symptomatic cases in residents and staff and expansion of more widespread testing after a case is identified may also be effective strategies to prevent transmission. Such approaches depend on strengthened surveillance in LTCFs and would be greatly facilitated by the availability of near patient testing platforms, which may be achievable in larger LTCFs.

Our findings of excess deaths in those with no direct evidence of infection may be due to under-ascertainment, direct effects of Covid-19 control measures on delivery of care, and/or indirect effects due to additional disruption caused by the outbreak. Studies from other healthcare settings have highlighted the ways in which Covid-19 has impacted delivery of care associated with excess mortality in individuals who are uninfected. Detailed analysis of cause of death and reasons for hospital admission in residents of LTCFs will be important to understand how the pandemic has affected the quality of care in LTCFs. Our analysis provides a method that could be widely applied to estimate excess mortality, provided LTCF’s with outbreaks can be reliably identified.

Globally, there is an opportunity to mitigate the impact of future waves of infection on staff and residents in LTCF’s. Our findings suggest that countries can achieve this most effectively by adopting a holistic approach, which integrates surveillance and focused testing for Covid-19 with increased investment to reduce LTCF occupancy and increase staffing.

Contributors

LS conceived the research question. LS and PDM designed the study, with advice from GR and AJ. PDM undertook the statistical analysis. HW extracted the dataset and undertook the data linkage. LS obtained the research funding. LS and PDM wrote the first draft of the manuscript. All authors interpreted the data and edited and revised the final manuscript.
Declaration of interests

FL, GR, LS are supported by research funding from the ESRC. LS is a member of the Care Home working group, a subgroup of the Scientific Advisory Group for Emergencies. AH is a member of the New and Emerging Respiratory Virus Threats Advisory Group (NERVTAG). All other authors declare no competing interests.

Data sharing

All computer syntax used in the analysis is available through an online repository. The data that support the findings of this study are available from the Four Seasons Healthcare Group but restrictions apply to the availability of these data, which were used under a data sharing agreement for the current study and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Four Seasons Healthcare Group.

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Figures

Figure 1: Study overview: location of FSHCG LTCF’s and diagram of data sources

Figure 2: Kaplan-Meier estimates of the cumulative incidence of symptomatic cases, confirmed infections and COVID-related deaths in (A) residents (n=9,339) and (B) staff (n=11,604) according to FSHCG aggregate data (Mar 2020-Jun 2020)

Figure 3: Kaplan-Meier estimates of resident (n=8,713) survival by SARS-COV-2 case type

Supplementary material

Supplementary material 1: Quality and methodology report
Supplementary material 2: Incidence of confirmed and symptomatic in residents based on Datix incident reports
Supplementary material 3: Kaplan-Meier estimators data (available on request)