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Factors associated with SARS-CoV-2 infection and outbreaks in long-term care facilities in England: a national cross-sectional survey

Laura Shallcross, Danielle Burke, Owen Abbott, Alasdair Donaldson, Gemma Hallatt, Andrew Hayward, Susan Hopkins, Maria Krutikov, Katie Sharp, Leone Wardman, Sapphira Thorne

Summary

Background Outbreaks of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection have occurred in long-term care facilities (LTCFs) worldwide, but the reasons why some facilities are particularly vulnerable to outbreaks are poorly understood. We aimed to identify factors associated with SARS-CoV-2 infection and outbreaks among staff and residents in LTCFs.

Methods We did a national cross-sectional survey of all LTCFs providing dementia care or care to adults aged 65 years or older in England between May 26 and June 19, 2020. The survey collected data from managers of eligible LTCFs on LTCF characteristics, staffing factors, the use of disease control measures, and the number of confirmed cases of infection among staff and residents in each LTCF. Survey responses were linked to individual-level SARS-CoV-2 RT-PCR test results obtained through the national testing programme in England between April 30 and June 13, 2020. The primary outcome was the weighted period prevalence of confirmed SARS-CoV-2 infections in residents and staff reported via the survey. Multivariable logistic regression models were fitted to identify factors associated with infection in staff and residents, an outbreak (defined as at least one case of SARS-CoV-2 infection in a resident or staff member), and a large outbreak (defined as LTCFs with more than a third of the total number of residents and staff combined testing positive, or with >20 residents and staff combined testing positive) using data from the survey and from the linked survey–test dataset.

Findings 9081 eligible wLTCFs were identified, of which 5126 (56·4%) participated in the survey, providing data on 160 033 residents and 248 594 staff members. The weighted period prevalence of infection was 10·5% (95% CI 9·9–11·1) in residents and 3·8% (3·4–4·2) in staff members. 2724 (53·1%) LTCFs reported outbreaks, and 469 (9·1%) LTCFs reported large outbreaks. The odds of SARS-CoV-2 infection in residents (adjusted odds ratio [aOR] 0·80 [95% CI 0·75–0·86], p<0·0001) and staff (0·70 [0·65–0·77], p<0·0001), and of large outbreaks (0·59 [0·38–0·93], p=0·024) were significantly lower in LTCFs that paid staff statutory sick pay compared with those that did not. Each one unit increase in the staff-to-bed ratio was associated with a reduced odds of infection in residents (0·82 [0·78–0·87], p<0·0001) and staff (0·63 [0·59–0·68], p<0·0001. The odds of infection in residents (1·30 [1·23–1·37], p<0·0001) and staff (1·20 [1·13–1·29], p<0·0001), and of outbreaks (2·56 [1·94–3·49], p<0·0001) were significantly higher in LTCFs in which staff often or always cared for both infected or uninfected residents compared with those that cohorted staff with either infected or uninfected residents. Significantly increased odds of infection in residents (1·01 [1·01–1·01], p<0·0001) and staff (1·00 [1·00–1·01], p=0·0005), and of outbreaks (1·08 [1·05–1·10], p<0·0001) were associated with each one unit increase in the number of new admissions to the LTCF relative to baseline (March 1, 2020). The odds of infection in residents (1·19 [1·12–1·26], p<0·0001) and staff (1·19 [1·10–1·29], p<0·0001), and of large outbreaks (1·65 [1·07–2·54], p=0·024) were significantly higher in LTCFs that were for profit versus those that were not for profit. Frequent employment of agency nurses or carers was associated with a significantly increased odds of infection in residents (aOR 1·65 [1·56–1·74], p<0·0001) and staff (1·85 [1·72–1·98], p<0·0001), and of outbreaks (2·33 [1·72–3·16], p<0·0001) and large outbreaks (2·42 [1·67–3·51], p<0·0001) compared with no employment of agency nurses or carers. Compared with LTCFs that did not report difficulties in isolating residents, those that did had significantly higher odds of infection in residents (1·33 [1·28–1·38], p<0·0001) and staff (1·48 [1·41–1·56], p<0·0001), and of outbreaks (1·84 [1·48–2·30], p<0·0001) and large outbreaks (1·62 [1·24–2·11], p=0·0004).

Interpretation Half of LTCFs had no cases of SARS-CoV-2 infection in the first wave of the pandemic. Reduced transmission from staff is associated with adequate sick pay, minimal use of agency staff, an increased staff-to-bed ratio, and staff cohorting with either infected or uninfected residents. Increased transmission from residents is associated with an increased number of new admissions to the facility and poor compliance with isolation procedures.

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Introduction

The global burden of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is increasing, with many countries that successfully curtailed the first wave of the pandemic reporting new infections following the relaxation of lockdown measures.[1]

Long-term care facilities (LTCFs), which provide care to older adults and people with disabilities, have encountered among the highest rates of SARS-CoV-2 infection among both staff and residents, and account for 30–50% of all COVID-19-related deaths in countries including the USA,[2] England,[3] Scotland,[4] France, Spain, and Sweden.[5] Residents of LTCFs who become infected with SARS-CoV-2 are at an increased risk of severe outcomes compared with the general population because of their age and the high prevalence of comorbidity,[6] but they are also highly exposed to infection through frequent close contact with other residents and staff in the care setting.[7] Undetected infection, due to presymptomatic and asymptomatic infections, and low testing rates at the start of the pandemic, are likely to have played a key role in the rapid transmission of SARS-CoV-2 in LTCFs.[8,9] In England, widespread one-off testing for SARS-CoV-2 using RT-PCR tests was not implemented for staff and residents in LTCFs until May 11, 2020. Before this date, SARS-CoV-2 testing was only available for residents or staff who were admitted to hospital or as part of outbreak investigations by Public Health England (PHE), which permitted a maximum of five tests per LTCF.[10]

In the UK, there are an estimated 400 000 residents living in approximately 11 000 LTCFs that provide care for older adults,[11] but there is poor-quality demographic, infection prevention, or administrative data available for residents and staff in these facilities. Studies based on administrative data from Canada, the USA, and Europe have identified risk factors for SARS-CoV-2 infection

Research in context

Evidence before this study

Outbreaks of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) have occurred worldwide in long-term care facilities (LTCFs), which provide care to older and susceptible residents, and are associated with high mortality. The reasons why some LTCFs are particularly vulnerable to SARS-CoV-2 outbreaks are poorly understood. Most studies of risk factors for SARS-CoV-2 infections in LTCFs done to date have been limited by scale and poor quality administrative, demographic, and infection control data.

For the **WHO COVID-19 database** see https://search.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/

We did a systematic search of MEDLINE (Ovid), the WHO COVID-19 database, and medRxiv on July 27, 2020, using the search terms "COVID-19", "SARS-CoV-2", "coronavirus" AND "care home", "nursing home", OR "long term care facility". We searched for articles reporting risk factors for SARS-CoV-2 infection or outbreaks in LTCFs, with no date or language restrictions. Studies that did not investigate LTCF-level risk factors were excluded. 14 studies, comprising 11 cross-sectional studies and three surveys, met our inclusion criteria. Risk of bias was high across all studies, and the results could not be pooled because of heterogeneity between the studies. The main risk factors for infection, outbreaks, or both, in an LTCF included the size of the facility, low staff-to-resident ratios, an urban location, high LTCF occupancy, and high community prevalence of SARS-CoV-2 infection. Only one study collected data on the use of disease control measures during the pandemic, and no studies provided data on risk factors, such as the use of temporary staff or the effect of staff working across multiple locations.

Added value of this study

We did a national telephone survey with managers of LTCFs in England to collect data on the number of staff and residents who had been infected with SARS-CoV-2 in the first wave of the pandemic, and to investigate associations between LTCF characteristics and practices and the odds of SARS-CoV-2 infections and outbreaks. The survey, which was completed by more than half of eligible LTCFs, highlighted the major impact of the pandemic on LTCFs, with more than half of LTCFs reporting at least one case. The survey also provided new insights into strategies that might reduce the risk of transmission of SARS-CoV-2 infection in LTCFs by capturing detailed information about the use of disease control measures and staffing practices during the pandemic. Overall, the results highlighted the key role of staff in the transmission of infection, but there was also an association between the number of new admissions to the LTCF and the odds of infections and outbreaks, highlighting the different routes by which SARS-CoV-2 can enter the facility.

Implications of all the available evidence

Almost half of LTCFs surveyed in this study did not report any cases of SARS-CoV-2 infection in the first wave of the pandemic. These facilities are likely to be most vulnerable to current and future waves of infection, highlighting the need for effective control measures. Strategies that might reduce transmission from staff include adequate sick pay, minimising the use of temporary staff, improving the staff-to-bed ratio, and cohorting staff with either infected or uninfected residents. However, it is challenging to implement these measures in the context of a limited workforce. Transmission of SARS-CoV-2 by residents is associated with the number of admissions to the facility and poor compliance with disease control measures (eg, isolation of residents), underscoring the need to test or isolate residents when they are admitted to the facility to prevent importation of infection. Future research should attempt to quantify the relative importance of the different routes by which infection can be imported to the LTCF to inform the development of targeted infection prevention and control activities.

and outbreaks in LTCFs, including lower staff-to-resident ratios,[12] increased facility size,[13] lower care quality ratings,[12] a higher proportion of residents from minority ethnic groups,[14] and LTCFs that are for profit rather than state-funded.[15] However, as many of these studies are small and have relied on administrative data rather than surveys, they may have been unable to capture the wide range of potential factors that might influence infection risk.

To inform the SARS-CoV-2 pandemic response, we invited all managers of LTCFs in England to participate in a survey to collect information on the number of confirmed SARS-CoV-2 infections in staff and residents, staffing practices (eg, employment of temporary agency staff and sick pay policies), the use of disease control measures (eg, cleaning frequency, staff cohorting [ie, a staff member who cares for cohorts of either infected or uninfected residents and does not move between cohorts]), and isolation of residents), and the number of staff and residents at the facility. Responses were linked to results from the national SARS-CoV-2 testing programme. Our objective was to identify factors associated with SARS-CoV-2 infection and outbreaks in residents and staff. We also estimated the prevalence of laboratory-confirmed infections in residents and staff, and the proportion of LTCFs with outbreaks.

Methods

Study design and participants

We did a national cross-sectional survey of LTCFs providing dementia care or care to adults aged 65 years or older in England between May 26 and June 19, 2020. Eligible LTCFs were identified from a directory maintained by LaingBuisson.[11] Survey responses were linked to individual-level SARS-CoV-2 RT-PCR test results obtained between April 30 and June 13, 2020, through the national testing programme, which aimed to test all residents and staff of LTCFs in England.

Ethical approval for the study was obtained from PHE's Research Ethics and Governance Group (NR0210). Information sheets were sent to participants in advance. The telephone interviewer went through the consent form at the start of the survey and the completed consent form was then emailed to each care home manager after the interview.

Procedures

The survey collected data on LTCF characteristics, the use of disease control measures, and the number of confirmed cases of infection in staff and residents in each LTCF. Candidate risk factors for infection were identified from the published literature and from previous knowledge of disease control measures.[16] Experts from the UK Office for National Statistics designed and piloted the survey using cognitive interview methods to test comprehension, accuracy, and question acceptability.[17] In the weeks before the survey began, managers of eligible LTCFs were sent an invitation letter by PHE explaining that they would shortly receive a telephone call from Ipsos MORI. The letter outlined the purpose of the survey, listed the information that would be requested (so that it could be collated in advance of the interview), and explained that the survey should be completed by care home managers. Incentives for managers to participate in the survey were not provided. Subject to obtaining informed consent from managers, the finalised 30-min survey was delivered by telephone (appendix pp 2–8). Survey responses were recorded electronically and transferred securely to the National Health Service (NHS) COVID-19 data store reference library, which is powered by Palantir Foundry.

See **Online** for appendix

For more on the **NHS COVID-19 data store reference library** see https://data.england.nhs.uk/covid-19/

Data on LTCF characteristics included the degree of social deprivation, measured by the postcode-based Index of Multiple Deprivation (IMD), which is a summary measure of relative deprivation between small areas of England based on a weighted average of deprivation across seven domains: income, employment, education, health, crime, housing, and the living environment; region ; size; the membership of a care home group; type of funding (for profit *vs* not for profit); the staff-to-bed ratio (total number of staff divided by the number of beds); and the Care Quality Commission's (CQC) rating of the quality of leadership of the LTCF. In England, the CQC assesses the quality of an LTCF across five domains. We chose the leadership domain of the assessment (ie, the "well-led" question), in view of its relevance to the management of the pandemic.

Data on disease control measures included the use of barrier nursing (gloves, facemasks, and aprons); whether there were difficulties in isolating residents due to non-compliance (eg, because of dementia); the cohorting of staff with either infected or uninfected residents; cleaning frequency; sick pay for staff; employment of temporary agency staff; use of personal protective equipment; and how often staff worked at other locations. These factors were selected on the basis of theoretical assumptions about risk factors for transmission of SARS-CoV-2 and national guidance.[18]

Managers were also asked to provide the number of new admissions to the LTCF and the number of weeks of closure to visitors since baseline (March 1, 2020). The survey also requested the number of confirmed cases of SARS-CoV-2 infection in staff (including cleaners, catering staff, and administrative staff) and residents, as well as the number of residents who had died since contracting COVID-19. In addition, individual-level data on age and sex, and whether they had symptoms on the date they had a nasopharyngeal swab taken, were available for care home staff and residents who underwent PCR testing via the national testing programme. This information could be linked to specific care homes using their CQC unique identification number.

A national community testing programme, which involved the testing of all staff and residents of LTCFs

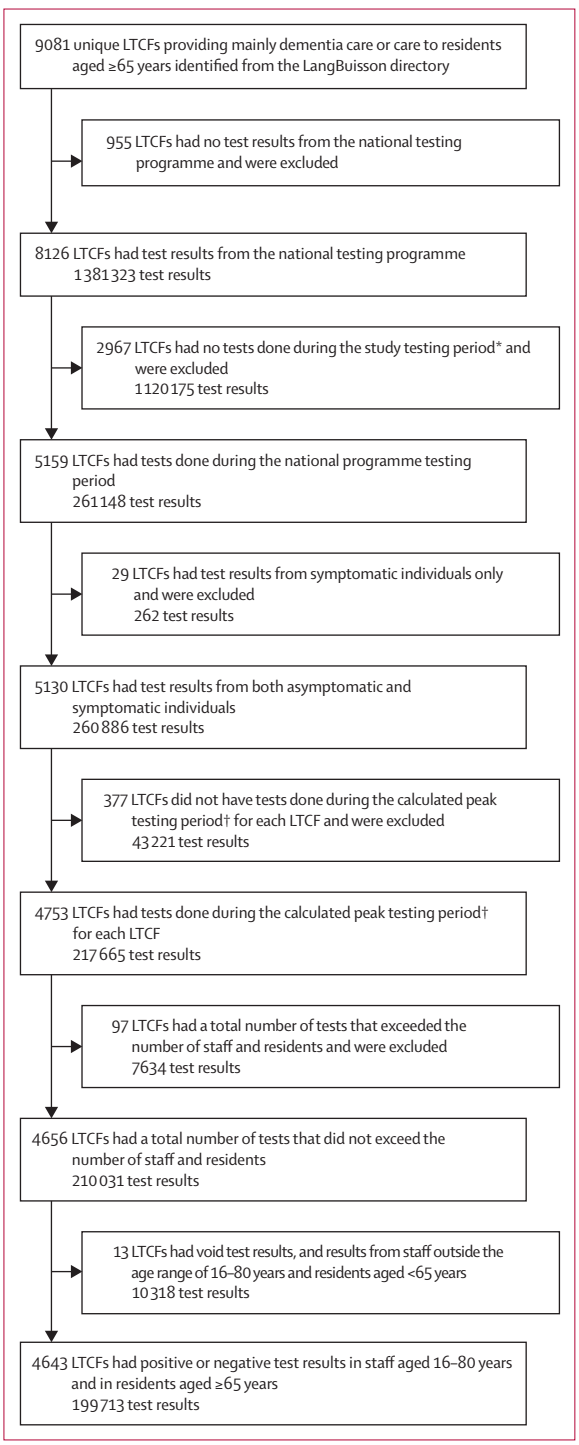

Figure 1: **Study flow chart**
The chart illustrates the process for identifying LTCFs with severe acute respiratory syndrome coronavirus 2 test results for staff and residents, derived from the national testing programme. LTCF=long-term care facility. *The study testing period was between April 30 and June 13, 2020. †The peak period of testing was identified because this was likely to represent when each LTCF had participated in the national testing programme (see appendix p 9).

in England, was officially launched on on May 11, 2020. PCR testing of clinical isolates from nasopharyngeal swabs was done by the National Bioresource Centre using an Applied Biosystems 7500 Fast RT-PCR system (Thermo Fisher Scientific, Waltham, MA, USA) with the Applied Biosystems TaqPath 1-Step Multiplex Master Mix (catalogue number A28523) and the TaqPath COVID-19-ASY-KIT 1000 (catalogue number A47817). Primer sequence details are not currently available.

For linkage of individual-level SARS-CoV-2 test results from the national testing programme to survey responses, an LTCF identifier was used to link individual test results to specific LTCFs, and to link test results with survey responses (figure 1, appendix p 9).

Outcomes

The primary outcome was the weighted period prevalence of confirmed SARS-CoV-2 infections in residents and staff reported via the survey. A survey-based outcome was preferred for the primary outcome because it was not possible to reliably attribute national programme test results to LTCFs using routine data before May, 2020. Additionally, the national testing programme measured infection at a point in time rather than over the course of the first wave of the pandemic. The three secondary outcomes were (1) the weighted point prevalence of SARS-CoV-2 in residents and staff between April 30 and June 13, 2020, measured using test results from the national testing programme; (2) the proportion of care homes with an outbreak (defined as one or more cases of infection); and (3) the proportion of LTCFs that had a large outbreak (defined as LTCFs with more than a third of the total number of residents and staff combined testing positive, or with >20 residents and staff combined testing positive).

Statistical analysis

Estimates of period prevalence of confirmed SARS-CoV-2 infections derived from the survey and point prevalence of confirmed infections derived from the national programme test data were weighted to provide nationally relevant estimates that take into account non-response by post-stratification, considering the LTCF size, IMD score, and the total number of LTCFs run by the provider.[19] LTCFs were grouped into post-strata on the basis of combinations of the number of beds, IMD score, and the total number of LTCFs run by the provider. This resulted in 30 post-strata, which were collapsed into 21 post-strata to achieve a minimum of 50 responding LTCFs in each stratum, with each having a separate non-response weight adjustment contributing to the overall estimates (appendix p 9).

We investigated potential risk factors for ingress and spread of infection. We fitted multivariable logistic regression models to identify factors associated with infection in staff and residents using data from the survey and from the linked survey–national testing

programme dataset. The outcomes of interest were binomial counts of infected residents and staff by LTCF (survey data) and the presence or absence of infection (linked dataset). A multilevel model was fitted in the linked dataset to estimate the individual-level and LTCF-level factors associated with infection, using random effects to account for clustering by LTCF. Using survey data, multivariable logistic regression models were also fitted to identify factors associated with outbreaks (ie, by comparing LTCFs with outbreaks with those that had no cases), and factors associated with large versus small outbreaks (ie, by comparing LTCFs in which a third of staff and residents combined were infected, or in which there were >20 cases of infection in staff and residents combined, with those that did not meet this definition, but had one or more cases).

All predefined risk factors and potential confounding factors were included in the models unless there was strong evidence of collinearity, assessed by variance inflation factors, or variables were uninformative (eg, staff training, as almost all managers reported staff being trained). Risk factors with a variance inflation factor of more than 10 were excluded from the analysis. Weighting factors from the estimation of period prevalence were included in all models as adjustment factors to adjust for survey non-response.

Results were presented as proportions, adjusted odds ratios (aORs; adjusted for all other variables in the model) with 95% CIs, or both. All reported model p values were considered significant if p<0·008 (α=0·05), using the conservative Bonferroni adjustment for multiple hypothesis testing done for the six dependent variables (ie, odds of infection in residents [survey data], odds of infection in staff [survey data], odds of an outbreak [at least one case *vs* none; survey data], odds of a large outbreak *vs* an outbreak [survey data], odds of infection in residents [national programme testing data], and odds of infection in staff [national programme testing data]). A heatmap was used to visualise the strength of the association for each risk factor across all outcomes.

Sensitivity analyses were done to compare complete case data (primary analysis), with models fitted to imputed data. The proportion of variables with missing data is reported in the appendix (p 24).

All analyses were done with RStudio 3.5 in the secure NHS COVID-19 data store.

Role of the funding source

The funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

We identified 9081 eligible LTCFs in England, 5126 (56·4%) of which participated in the survey between May 26 and June 19, 2020, providing data on 160 033 residents and 248 594 staff. Researchers from Ipsos MORI attempted to contact 8634 (95·1%) of 9081 eligible LTCFs at least once and 6164 (67·8%) of LTCFs were telephoned three or more times. Three LTCFs that participated in the survey but subsequently withdrew were excluded from analyses. Participating LTCFs were similar to those that did not participate in terms of the number of beds per LTCF, type of funding, region, and degree of deprivation, with survey weights varying from 1·5 to 2·2. The mean number of residents per LTCF was 32·2 (SD 17·3) and the mean number of staff was 48·5 (31·2), and most (4289 [83·7%] of 5126) LTCFs were for-profit (table 1). 2573 (50·2%) LTCFs were single institutions, and 1102 (21·5%) primarily provided dementia care. The uptake of disease control measures by each LTCF have been reported previously.[19]

A confirmed SARS-CoV-2 infection was reported in the survey for 19 571 residents and 10 630 staff, equivalent to a weighted period prevalence of 10·5% (95% CI 9·9–11·1) in residents and 3·8% (3·4–4·2) in staff. Of 5126 LTCFs, 2724 (53·1%) reported at least one case of SARS-CoV-2 during the survey period, and 469 (9·1%) reported a large outbreak. RT-PCR test results from the national testing programme were identified for 108 289 residents and 91 424 staff from 4643 LTCFs between April 30 and June 13, 2020. Based on these data, the weighted prevalence of infection was 2·8% (2·4–3·1) in residents and 0·6% (0·5–0·8) in staff. 608 (95·9%) of 634 staff and 2657 (74·4%) of 3573 residents with a positive test were recorded as asymptomatic at the time of testing (appendix p 10).

For-profit status was associated with a significantly higher odds of infection in residents (aOR 1·19 [95% CI 1·12–1·26], p<0·0001) and staff (1·19 [1·10–1·29], p<0·0001) compared with LTCFs that were not for profit (table 2), with moderate evidence of an association with large outbreaks (1·65 [1·07–2·54], p=0·024; table 3). Compared with LTCFs with fewer than 25 beds, larger LTCFs (ie, those with >50 beds) were significantly more likely to have one or more cases of infection (2·76 [1·97–3·88], p<0·0001), but were not more likely to have large outbreaks (table 3), and the odds of infection in residents (0·87 [0·79–0·96], p=0·006) and staff (0·79 [0·70–0·90], p=0·0003) were significantly lower (table 2). There was substantial regional variation in the odds of infection and outbreaks in residents and staff (tables 2, 3). Residents in LTCFs with the highest degree of social deprivation (quintile [Q] 1) had significantly increased odds of infection compared with all other degrees of social deprivation (Q1 *vs* Q2–Q5, 1·08 [1·03–1·14], p=0·0012) (table 2), but the highest degree of social deprivation was not associated with significantly higher odds of outbreaks, or large outbreaks, compared with other degrees of social deprivation (table 3).

Compared with no employment of agency nurses or carers, frequent (ie, on most days or every day) employment of agency nurses or carers was associated with a significantly increased odds of infection in residents

	LTCFs (n=5126)
Social deprivation	
Q1 (most deprived)	871/5125 (17·0%)
Q2–Q5	4254/5125 (83·0%)
Provider type	
For profit	4289 (83·7%)
Not for profit	837 (16·3%)
Provider size	
One LTCF	2573/5125 (50·2%)
2–9 LTCFs	1471/5125 (28·7%)
≥10 LTCFs	1081/5125 (21·1%)
Number of beds	
<25	1096 (21·4%)
25–50	2497 (48·7%)
>50	1533 (29·9%)
Number of residents	32·2 (17·3)
Number of staff	48·5 (31·2)
Number of nurses or carers	33·7 (23·4)
Number of cleaning, maintenance, or catering staff	10·4 (7·1)
Number of office or other staff	4·5 (5·0)
Region	
East Midlands	488/5124 (9·5%)
East of England	556/5124 (10·9%)
London	282/5124 (5·5%)
North East	273/5124 (5·3%)
North West	715/5124 (14·0%)
South East	1006/5124 (19·6%)
South West	719/5124 (14·0%)
West Midlands	562/5124 (11·0%)
Yorkshire and the Humber	523/5124 (10·2%)
Care Quality Commission rating of leadership at the LTCF	
Outstanding or good	3724 (72·6%)
Requires improvement or is inadequate	1323 (25·8%)
Not rated or inspected	79 (1·5%)
Main type of care provided	
For residents with dementia	1102 (21·5%)
For residents aged ≥65 years	4024 (78·5%)

Data are n/N (%), n (%), or mean (SD). LTCF=long-term care facility. Q=quintile.

Table 1: **Baseline characteristics**

(aOR 1·65 [95% CI 1·56–1·74], p<0·0001) and staff (1·85 [1·72–1·98], p<0·0001; table 2, figure 2), and an increased odds of outbreaks (2·33 [1·72–3·16], p<0·0001) and large outbreaks (2·42 [1·67–3·51], p<0·0001; table 3, figure 2). The odds of infection in staff were also significantly higher when staff regularly worked at other sites (a few times per week) versus never (1·26 [1·13–1·41], p<0·0001; table 2). Compared with LTCFs that always cohorted staff with either infected or uninfected residents, those facilities in which staff often or always cared for both infected and uninfected residents had significantly higher odds of infection in residents (1·30 [1·23–1·37], p<0·0001) and staff (1·20 [1·13–1·29], p<0·0001), and were significantly more likely to have outbreaks (2·60 [1·94–3·49], p<0·0001), but not large outbreaks.

Protective factors included statutory sick pay to staff, which significantly reduced the odds of infection in residents (aOR 0·80 [95% CI 0·75–0·86], p<0·0001) and staff (0·70 [0·65–0·77], p<0·0001) compared with no staff sick pay (table 2). Statutory sick pay also reduced the odds of large outbreaks compared with no payment, but this difference was not significant (0·59 [0·38–0·93], p=0·024; table 3). Each one unit increase in the staff-to-bed ratio was associated with a reduced odds of infection in residents (0·82 [0·78–0·87], p<0·0001) and staff (0·63 [0·59–0·68], p<0·0001; table 2).

Compared with the ability to isolate residents, being unable to isolate residents due to non-compliance (eg, due to dementia) was associated with an increased odds of infection in residents (aOR 1·33 [95% CI 1·28–1·38], p<0·0001) and staff (1·48 [1·41–1·56], p<0·0001), and an increased odds of outbreaks (1·84 [1·48–2·30], p<0·0001) and large outbreaks (1·62 [1·24–2·11], p=0·0004; figure 2). Compared with LTCFs that reported cleaning communal areas at least twice per day, those that reported cleaning these areas once per day had higher odds of infection in staff (1·10 [1·03–1·17], p=0·003), with some evidence of increased odds in residents (1·05 [1·00–1·11], p=0·039; table 2). Cleaning frequency in other areas, and frequency of personal protective equipment use did not affect the odds of infection or outbreaks in both staff or residents (tables 2, 3). Unexpectedly, the use of barrier nursing for both infected residents and all residents was associated with significantly higher odds of infection in both staff and residents and significantly higher odds of an outbreak compared with no barrier nursing (tables 2, 3), and there was moderate evidence that providing barrier nursing for all residents was associated with a higher odds of large outbreaks compared with no barrier nursing (1·44 [1·08–1·91], p=0·013; table 3). Each one unit increase in the number of new admissions to the LTCF relative to baseline was associated with increased odds of infection in residents (1·01 [1·01 –1·014], p<0·0001) and staff (1·00 [1·00–1·01], p=0·0005; table 2), and an increased odds of an outbreak (1·08 [1·05–1·10], p<0·0001; table 3). There was moderate evidence that later closure to visitors was a risk factor for infection in residents (1·02 (1·00–1·04); p=0·012; table 2).

Analysis of risk factors for infection using the linked dataset found an association between increasing age (per year) and the odds of infection in residents (aOR 1·01 [95% CI 1·01–1·03], p=0·0007; appendix p 11) but not in staff. Similar risk factors for infection were identified when the analysis was repeated using national programme test results as the outcome (appendix pp 11–13), and using multiple imputation to account for missing survey data in the sensitivity analysis (appendix pp 14–22).

Discussion

This cross-sectional study shows the widespread but variable impact of COVID-19 on LTCFs in England. Almost half of LTCFs did not report any cases of SARS-CoV-2 infection in the first wave of the pandemic, and remain vulnerable to current and future waves of infection, thus emphasizing the need for effective infection prevention and control strategies. Our findings

	Residents*			Staff†		
	Proportion with SARS-CoV-2 infection (%)	Adjusted OR (95% CI)	p value	Proportion with SARS-CoV-2 infection (%)	Adjusted OR (95% CI)	p value
Social deprivation						
Q2–Q5	9941/91 048 (10·9%)	1 (ref)	NA	5582/132 334 (4·2%)	1 (ref)	NA
Q1	3054/22 112 (13·8%)	1·08 (1·03–1·14)	0·0012	1469/31 497 (4·7%)	0·85 (0·80–0·91)	<0·0001
Provider type						
Not for profit	2043/18 860 (10·8%)	1 (ref)	NA	1164/31 544 (3·7%)	1 (ref)	NA
For profit	10 952/94 300 (11·6%)	1·19 (1·12–1·26)	<0·0001	5887/132 287 (4·5%)	1·19 (1·10–1·29)	<0·0001
Provider size						
1 LTCF	4939/47 282 (10·4%)	1 (ref)	NA	2660/67 667 (3·9%)	1 (ref)	NA
2–9 LTCFs	3881/32 992 (11·8%)	0·98 (0·94–1·03)	0·48	2216/49 096 (4·5%)	0·99 (0·93–1·05)	0·62
≥10 LTCFs	4175/32 886 (12·7%)	1·04 (0·99–1·09)	0·14	2175/47 068 (4·6%)	0·99 (0·92–1·05)	0·67
Staff-to-bed ratio						
Baseline‡	NA	1 (ref)	NA	NA	1 (ref)	NA
One unit increase in the staff-to-bed ratio‡	12 995/113 160 (11·5%)	0·82 (0·78–0·87)	<0·0001	7051/163 831 (4·3%)	0·63 (0·59–0·68)	<0·0001
Region						
London	783/6368 (12·3%)	1 (ref)	NA	307/10 013 (3·1%)	1 (ref)	NA
East Midlands	1027/10 255 (10·0%)	1·02 (0·92–1·13)	0·69	620/14 270 (4·3%)	1·68 (1·46–1·94)	<0·0001
East of England	1320/13 524 (9·8%)	1·05 (0·95–1·16)	0·32	675/18 019 (3·7%)	1·47 (1·28–1·69)	<0·0001
North East	1259/7851 (16·0%)	1·42 (1·28–1·57)	<0·0001	867/10 556 (8·2%)	3·04 (2·64–3·50)	<0·0001
North West	1918/15 432 (12·4%)	1·07 (0·97–1·17)	0·17	1006/21 740 (4·6%)	1·60 (1·40–1·83)	<0·0001
South East	1923/19 023 (10·1%)	0·98 (0·90–1·08)	0·69	1181/28 408 (4·2%)	1·50 (1·32–1·71)	<0·0001
South West	1110/14 424 (7·7%)	0·96 (0·87–1·07)	0·47	571/21 573 (2·6%)	1·24 (1·08–1·44)	0·0030
West Midlands	2205/14 283 (15·4%)	1·39 (1·27–1·52)	<0·0001	823/22 046 (3·7%)	1·40 (1·22–1·60)	<0·0001
Yorkshire and the Humber	1450/12 000 (12·1%)	1·10 (0·99–1·21)	0·066	1001/17 206 (5·8%)	2·17 (1·89–2·48)	<0·0001
Number of beds in LTCF						
<25	580/8895 (6·5%)	1 (ref)	NA	295/11 727 (2·5%)	1 (ref)	NA
25–50	5385/51 225 (10·5%)	0·95 (0·86–1·04)	0·27	2975/71 708 (4·1%)	0·92 (0·81–1·04)	0·20
>50	7030/53 040 (13·3%)	0·87 (0·79–0·96)	0·0056	3781/80 396 (4·7%)	0·79 (0·70–0·90)	0·0003
Care Quality Commission rating of leadership at the LTCF						
Outstanding or good	9267/83 987 (11·0%)	1 (ref)	NA	5256/120 856 (4·3%)	1 (ref)	NA
Requires improvement or is inadequate	3587/27 880 (12·9%)	1·00 (0·96–1·05)	0·89	1689/40 383 (4·2%)	0·82 (0·78–0·87)	<0·0001
Not rated or inspected	141/1293 (10·9%)	1·03 (0·86–1·24)	0·75	106/2592 (4·1%)	1·07 (0·88–1·31)	0·50
Main type of care provided						
For residents aged ≥65 years	9384/83 998 (11·2%)	1 (ref)	NA	4962/121 140 (4·1%)	1 (ref)	NA
For residents with dementia	3611/29 162 (12·4%)	0·96 (0·92–1·01)	0·11	2089/42 691 (4·9%)	1·03 (0·97–1·08	0·35
Staff sick pay						
None	1073/8647 (12·4%)	1 (ref)	NA	681/13 007 (5·2%)	1 (ref)	NA
Statutory	9786/86 123 (11·4%)	0·80 (0·75–0·86)	<0·0001	5112/120 169 (4·3%)	0·70 (0·65–0·77)	<0·0001
Full or more than statutory	2136/18 390 (11·6%)	0·78 (0·72–0·85)	<0·0001	1258/30 655 (4·1%)	0·68 (0·61–0·75)	<0·0001
Employment of agency nurses or carers						
None employed	3333/46 217 (7·2%)	1 (ref)	NA	1657/62 133 (2·7%)	1 (ref)	NA
A few times per month	2947/23 299 (12·6%)	1·57 (1·48–1·66)	<0·0001	1357/27 569 (4·9%)	1·51 (1·39–1·63)	<0·0001
A few times per week	2509/18 082 (13·9%)	1·34 (1·27–1·42)	<0·0001	1575/35 103 (4·5%)	1·28 (1·19–1·38)	<0·0001
Most days or every day	4206/25 562 (16·5%)	1·65 (1·56–1·74)	<0·0001	2462/39 026 (6·3%)	1·85 (1·72–1·98)	<0·0001

(Table 2 continues on next page)

	Residents*			Staff†		
	Proportion with SARS-CoV-2 infection (%)	Adjusted OR (95% CI)	p value	Proportion with SARS-CoV-2 infection (%)	Adjusted OR (95% CI)	p value
(Continued from previous page)						
Employment of other bank or agency staff						
None employed	9129/87 490 (10·4%)	1 (ref)	NA	4798/124 394 (3·9%)	1 (ref)	NA
A few times per month	1468/8892 (16·5%)	1·28 (1·20–1·37)	<0·0001	802/13 553 (5·9%)	1·31 (1·20–1·42)	<0·0001
A few times per week	1198/9093 (13·2%)	1·08 (1·01–1·16)	0·022	788/13 865 (5·7%)	1·34 (1·23–1·45)	<0·0001
Most days or every day	1200/7685 (15·6%)	1·08 (1·00–1·16)	0·044	663/12 019 (5·5%)	1·04 (0·95–1·13)	0·42
How often staff work at other sites						
Not at all	11 325/100 485 (11·3%)	1 (ref)	NA	5983/143 533 (4·2%)	1 (ref)	NA
A few times per month	1086/7647 (14·2%)	1·12 (1·04–1·20)	0·0024	591/12 292 (4·8%)	1·03 (0·94–1·13)	0·53
A few times per week	537/4656 (11·5%)	0·97 (0·88–1·07)	0·54	397/7311 (5·4%)	1·26 (1·13–1·41)	<0·0001
Most days or every day	47/372 (12·6%)	1·27 (0·93–1·75)	0·14	80/695 (11·5%)	3·04 (2·38–3·88)	<0·0001
Cohorting of staff with either infected or uninfected residents						
Often or always	3112/30 330 (10·3%)	1 (ref)	NA	1653/43 123 (3·8%)	1 (ref)	NA
Rarely or sometimes	5008/34 797 (14·4%)	1·11 (1·06–1·17)	<0·0001	2758/53 253 (5·2%)	1·08 (1·02–1·16)	0·02
Not at all	4458/25 950 (17·2%)	1·30 (1·23–1·37)	<0·0001	2471/38 870 (6·4%)	1·20 (1·13–1·29)	<0·0001
NA	417/22 083 (1·9%)	0·31 (0·28–0·34)	<0·0001	169/28 585 (0·6%)	0·25 (0·21–0·29)	<0·0001
Cleaning frequency of communal areas						
At least twice per day	9487/83 396 (11·4%)	1 (ref)	NA	5035/119 764 (4·2%)	1 (ref)	NA
Once per day	3193/26 511 (12·0%)	1·05 (1·00–1·11)	0·039	1802/39 301 (4·6%)	1·10 (1·03–1·17)	0·0027
Other	315/3253 (9·7%)	0·7 (0·60–0·81)	<0·0001	214/4766 (4·5%)	1·21 (1·02–1·45)	0·030
Cleaning frequency of communal touchpoints						
At least twice per day	11 472/98 778 (11·6%)	1 (ref)	NA	6180/144 102 (4·3%)	1 (ref)	NA
Once per day	930/9648 (9·6%)	0·85 (0·79–0·92)	<0·0001	539/12 907 (4·2%)	0·99 (0·90–1·09)	0·84
Other	593/4734 (12·5%)	1·15 (1·03–1·28)	0·017	332/6822 (4·9%)	1·03 (0·90–1·19)	0·66
Cleaning frequency of staff rooms						
At least twice per day	6186/56 532 (10·9%)	1 (ref)	NA	3522/81 868 (4·3%)	1 (ref)	NA
Once per day	5733/48 225 (11·9%)	1·02 (0·98–1·07)	0·36	3012/69 493 (4·3%)	0·91 (0·86–0·96)	0·0005
Other	1076/8403 (12·8%)	1·24 (1·14–1·34)	<0·0001	517/12 470 (4·1%)	0·85 (0·77–0·95)	0·0024
Staff use of personal protective equipment						
All of the time	9696/79 786 (12·2%)	1 (ref)	NA	5286/115 831 (4·6%)	1 (ref)	NA
For any contact with all residents	1132/12 556 (9·0%)	0·86 (0·81–0·91)	<0·0001	544/18 129 (3·0%)	0·92 (0·86–0·99)	0·03
For any contact with infected or shielding residents	124/1803 (6·9%)	1·20 (1·05–1·37)	0·009	50/2481 (2·0%)	0·89 (0·73–1·08)	0·24
For delivering direct care to all residents	1765/16 985 (10·4%)	0·91 (0·85–0·97)	0·007	1064/24 526 (4·3%)	0·82 (0·752–0·90)	<0·0001
For delivering direct care to infected or shielding residents	278/2030 (13·7%)	0·58 (0·48–0·70)	<0·0001	107/2864 (3·7%)	0·51 (0·39–0·68)	<0·0001
Barrier nursing for infected residents						
No	873/34 565 (2·5%)	1 (ref)	NA	521/44 708 (1·2%)	1 (ref)	NA
Yes	12122/78 595 (15·4%)	3·60 (3·34–3·88)	<0·0001	6530/119 123 (5·5%)	2·60 (2·36–2·86)	<0·0001
Barrier nursing for all residents						
No	4039/49 269 (8·2%)	1 (ref)	NA	2129/69 668 (3·1%)	1 (ref)	NA
Yes	8956/63 891 (14·0%)	1·42 (1·37–1·48)	<0·0001	4922/94 163 (5·2%)	1·39 (1·31–1·46)	<0·0001
Inability to isolate residents§						
No	5993/69 344 (8·6%)	1 (ref)	NA	2999/98 839 (3·0%)	1 (ref)	NA
Yes	7002/43 816 (16·0%)	1·33 (1·28–1·38)	<0·0001	4052/64 992 (6·2%)	1·48 (1·41–1·56)	<0·0001

(Table 2 continues on next page)

	Residents*			Staff†		
	Proportion with SARS-CoV-2 infection (%)	Adjusted OR (95% CI)	p value	Proportion with SARS-CoV-2 infection (%)	Adjusted OR (95% CI)	p value
(Continued from previous page)						
Number of new admissions to the LTCF						
Baseline‡	NA	1 (ref)	NA	NA	1 (ref)	NA
Each one unit increase in admissions relative to baseline‡	12 995/113 160 (11·5%)	1·01 (1·01–1·01)	<0·0001	7051/163 831 (4·3%)	1·00 (1·00–1·01)	0·0005
Number of weeks of closure to visitors						
Baseline‡	NA	1 (ref)	NA	NA	1 (ref)	NA
Each additional week relative to baseline‡	12 995/113 160 (11·5%)	1·02 (1·00–1·04)	0·012	7051/163 831 (4·3%)	1·02 (1·0–1·03)	0·14

Data are n/N (%), unless otherwise specified. ORs were adjusted for all other variables in the model. SARS-CoV-2=severe acute respiratory syndrome coronavirus 2. LTCF=long-term care facility. OR=odds ratio. Q=quintile. NA=not applicable. *The resident model includes 3311 LTCFs (R^2=0·27). †The staff model includes 3138 LTCFs (R^2=0·26).‡Refers to the value at the start of the pandemic (March 1, 2020). §Caused by residents being unable to comply with control measures (eg, because they had dementia).

Table 2: **Risk factors for SARS-CoV-2 infection in residents and staff of LTCFs based on survey data**

	Proportion of LTCFs with an outbreak of SARS-CoV-2 infection*	Adjusted OR (95% CI)	p value	Proportion of LTCFs with a large outbreak of SARS-CoV-2 infections†‡	Adjusted OR (95% CI)	p value
Social deprivation						
Q2–Q5	1510/2558 (59·0%)	1 (ref)	NA	231/1510 (15·3%)	1 (ref)	NA
Q1	371/571 (65·0%)	0·98 (0·75–1·29)	0·90	79/371 (21·3%)	1·32 (0·95–1·84)	0·097
Provider type						
Not for profit	324/499 (64·9%)	1 (ref)	NA	42/324 (13·0%)	1 (ref)	NA
For profit	1557/2630 (59·2%)	1·38 (0·99–1·91)	0·057	268/1557 (17·2%)	1·65 (1·07–2·54)	0·024
Provider size						
1 LTCF	790/1453 (54·4%)	1 (ref)	NA	120/790 (15·2%)	1 (ref)	NA
2–9 LTCFs	563/922 (61·1%)	0·93 (0·74–1·17)	0·52	91/563 (16·2%)	0·89 (0·65–1·22)	0·47
≥10 LTCFs	528/754 (70·0%)	1·14 (0·86–1·51)	0·37	99/528 (18·8%)	1·18 (0·84–1·65)	0·34
Staff-to-bed ratio						
Baseline§	NA	1 (ref)	NA	NA	1 (ref)	NA
Each one unit increase in staff-to-bed ratio§	1881/3129 (60·1%)	1·06 (0·88–1·27)	0·56	310/1881 (16·5%)	1·02 (0·80–1·30)	0·86
Region						
London	136/165 (82·4%)	1 (ref)	NA	8/136 (5·9%)	1 (ref)	NA
East Midlands	174/297 (58·6%)	0·28 (0·15–0·51)	<0·0001	22/174 (12·6%)	2·55 (1·07–6·06)	0·034
East of England	195/346 (56·4%)	0·28 (0·15–0·49)	<0·0001	32/195 (16·4%)	3·29 (1·43–7·57)	0·0051
North East	139/198 (70·2%)	0·36 (0·19–0·69)	0·0022	38/139 (27·3%)	5·65 (2·42–13·22)	0·0001
North West	282/430 (65·6%)	0·39 (0·22–0·70)	0·0015	43/282 (15·2%)	2·79 (1·23–6·32)	0·014
South East	323/554 (58·3%)	0·29 (0·17–0·50)	<0·0001	50/323 (15·5%)	3·09 (1·39–6·86)	0·0055
South West	156/428 (36·4%)	0·11 (0·06–0·19)	<0·0001	30/156 (19·2%)	4·28 (1·85–9·95)	0·0007
West Midlands	261/371 (70·4%)	0·34 (0·19–0·61)	0·0003	50/261 (19·2%)	3·89 (1·74–8·69)	0·0009
Yorkshire and the Humber	215/340 (63·2%)	0·33 (0·18–0·60)	0·0003	37/215 (17·2%)	3·32 (1·45–7·58)	0·0045
Number of beds in LTCF						
<25	159/503 (31·6%)	1 (ref)	NA	21/159 (13·2%)	1 (ref)	NA
25–50	959/1653 (58·0%)	1·73 (1·30–2·31)	0·0002	125/959 (13·0%)	0·70 (0·41–1·19)	0·18
>50	763/973 (78·4%)	2·76 (1·97–3·88)	<0·0001	164/763 (21·5%)	1·13 (0·66–1·96)	0·65

(Table 3 continues on next page)

	Proportion of LTCFs with a small outbreak of SARS-CoV-2 infection*	Adjusted OR (95% CI)	p value	Proportion of LTCFs with a large outbreak of SARS-CoV-2 infections†‡	Adjusted OR (95% CI)	p value
(Continued from previous page)						
Care Quality Commission rating of leadership at the LTCF						
Outstanding or good	1339/2292 (58·4%)	1 (ref)	NA	225/1339 (16·8%)	1 (ref)	NA
Requires improvement or is inadequate	515/793 (64·9%)	1·17 (0·93–1·48)	0·19	82/515 (15·9%)	0·83 (0·61–1·11)	0·21
Not rated or inspected	27/44 (61·4%)	0·79 (0·34–1·82)	0·58	3/27 (11·1%)	0·57 (0·16–1·98)	0·38
Main type of care provided						
For residents aged ≥65 years	1405/2406 (58·4%)	1 (ref)	NA	221/1405 (15·7%)	1 (ref)	NA
For residents with dementia	476/723 (65·8%)	1·00 (0·79–1·28)	0·94	89/476 (18·7%)	0·99 (0·74–1·33)	0·97
Staff sick pay						
None	134/224 (59·8%)	1 (ref)	NA	31/134 (23·1%)	1 (ref)	NA
Statutory	1415/2421 (58·4%)	1·0 (0·68–1·45)	0·99	232/1415 (16·4%)	0·59 (0·38–0·93)	0·024
Full or more than statutory	332/484 (68·6%)	1·17 (0·74–1·86)	0·50	47/332 (14·2%)	0·55 (0·31–0·97)	0·040
Employment of agency nurses or carers						
None employed	612/1372 (44·6%)	1 (ref)	NA	63/612 (10·3%)	1 (ref)	NA
A few times per month	428/620 (69·0%)	1·61 (1·21–2·15)	0·0013	64/341 (18·8%)	1·85 (1·23–2·77)	0·0030
A few times per week	341/516 (66·1%)	1·62 (1·23–2·13)	0·0005	69/428 (16·1%)	1·51 (1·02–2·24)	0·038
Most days or every day	500/621 (80·5%)	2·33 (1·72–3·16)	<0·0001	114/500 (22·8%)	2·42 (1·67–3·51)	<0·0001
Employment of other bank or agency staff						
None employed	1373/2459 (55·8%)	1 (ref)	NA	212/1373 (15·4%)	1 (ref)	NA
A few times per month	182/243 (74·9%)	1·50 (0·99–2·26)	0·055	38/182 (20·9%)	1·31 (0·86–2·00)	0·20
A few times per week	163/236 (69·1%)	1·13 (0·77–1·67)	0·52	35/163 (21·5%)	1·39 (0·90–2·16)	0·14
Most days or every day	163/191 (85·3%)	1·97 (1·17–3·30)	0·011	25/163 (15·3%)	0·73 (0·45–1·19)	0·21
How often LTCF staff work at other sites						
Not at all	1640/2775 (59·1%)	1 (ref)	NA	268/1640 (16·3%)	1 (ref)	NA
A few times per month	140/205 (68·3%)	0·96 (0·64–1·46)	0·85	26/140 (18·6%)	1·04 (0·65–1·69)	0·86
A few times per week	93/137 (67·9%)	1·15 (0·69–1·89)	0·60	14/93 (15·1%)	1·04 (0·56–1·93)	0·89
Most days or every day	8/12 (66·7%)	0·80 (0·20–3·30)	0·76	2/8 (25·0%)	1·77 (0·31–10·11)	0·52
Cohorting of staff with either infected or uninfected residents						
Often or always	470/829 (56·7%)	1 (ref)	NA	74/470 (15·7%)	1 (ref)	NA
Rarely or sometimes	693/901 (76·9%)	1·53 (1·19–1·97)	0·0010	122/693 (17·6%)	0·98 (0·70–1·38)	0·92
Not at all	580/692 (83·8%)	2·60 (1·94–3·49)	<0·0001	104/580 (17·9%)	0·98 (0·69–1·39)	0·90
NA	138/707 (19·5%)	0·37 (0·28–0·49)	<0·0001	10/138 (7·2%)	0·52 (0·25–1·08)	0·079
Cleaning frequency of communal areas						
At least twice per day	1384/2331 (59·4%)	1 (ref)	NA	225/1384 (16·3%)	1 (ref)	NA
Once per day	441/717 (61·5%)	1·05 (0·80–1·37)	0·73	78/441 (17·7%)	1·10 (0·79–1·53)	0·56
Other	56/81 (69·1%)	0·87 (0·40–1·93)	0·74	7/56 (12·5%)	0·81 (0·30–2·17)	0·67
Cleaning frequency of communal touchpoints						
At least twice per day	1643/2741 (59·9%)	1 (ref)	NA	277/1643 (16·9%)	1 (ref)	NA
Once per day	153/273 (56·0%)	0·89 (0·61–1·30)	0·56	20/153 (13·1%)	0·74 (0·43–1·28)	0·28
Other	85/115 (73·9%)	2·25 (1·11–4·56)	0·025	13/85 (15·3%)	0·96 (0·45–2·06)	0·92
Cleaning frequency of staff rooms						
At least twice per day	922/1573 (58·6%)	1 (ref)	NA	147/922 (15·9%)	1 (ref)	NA
Once per day	802/1275 (62·9%)	0·98 (0·78–1·23)	0·87	138/802 (17·2%)	1·00 (0·75–1·35)	0·95
Other	157/281 (55·9%)	1·11 (0·76–1·62)	0·60	25/157 (15·9%)	0·98 (0·59–1·64)	0·94

(Table 3 continues on next page)

highlight the key role of staff, compliance with disease control measures, and new admissions to the LTCF in the transmission of infection, and are consistent with the long recognised drivers of infection in LTCFs, such as overcrowding, contact frequency, and staffing ratios.[20–23] We identify specific strategies that could be deployed immediately to reduce the risk of COVID-19 in LTCFs, including provision of financial support to staff so they are incentivised to test and self-isolate when unwell, a reduction in the use of agency staff, an

	Proportion of LTCFs with a small outbreak of SARS-CoV-2 infection*	Adjusted OR (95% CI)	p value	Proportion of LTCFs with a large outbreak of SARS-CoV-2 infections†‡	Adjusted OR (95% CI)	p value
(Continued from previous page)						
Staff use of personal protective equipment						
All the time	1366/2197 (62·2%)	1 (ref)	NA	228/1366 (16·7%)	1 (ref)	NA
For delivering direct care to all residents	191/375 (50·9%)	0·96 (0·71–1·30)	0·80	29/191 (15·2%)	1·03 (0·66–1·61)	0·90
For delivering direct care to infected or shielding residents	25/47 (53·2%)	0·68 (0·34–1·36)	0·28	2/25 (8·0%)	0·48 (0·11–2·15)	0·34
For any contact with all residents	269/462 (58·2%)	0·85 (0·65–1·13)	0·26	45/269 (16·7%)	0·90 (0·62–1·31)	0·59
For any contact with infected or shielding residents	30/48 (62·5%)	0·72 (0·35–1·52)	0·39	6/30 (20·0%)	1·32 (0·50–3·43)	0·58
Barrier nursing for infected residents						
No	256/1083 (23·6%)	1 (ref)	NA	25/256 (9·8%)	1 (ref)	NA
Yes	1625/2046 (79·4%)	5·33 (4·30–6·60)	<0·0001	285/1625 (17·5%)	1·29 (0·79–2·09)	0·31
Barrier nursing for all residents						
No	685/1387 (49·4%)	1 (ref)	NA	89/685 (13·0%)	1 (ref)	NA
Yes	1196/1742 (68·7%)	1·68 (1·38–2·05)	<0·0001	221/1196 (18·5%)	1·44 (1·08–1·91)	0·013
Inability to isolate residents¶						
No	1035/2052 (50·4%)	1 (ref)	NA	128/1035 (12·4%)	1 (ref)	NA
Yes	846/1077 (78·6%)	1·84 (1·48–2·30)	<0·0001	182/846 (21·5%)	1·62 (1·24–2·11)	0·0004
Number of new admissions to the LTCF						
Baseline§	NA	1 (ref)	NA	NA	1 (ref)	NA
Each one unit increase in new admissions relative to baseline§	1881/3129 (60·1%)	1·08 (1·05–1·10)	<0·0001	310/1881 (16·5%)	1·00 (0·99–1·02)	0·29
Number of weeks of closure to visitors						
Baseline§	NA	1 (ref)	NA	NA	1 (ref)	NA
Each additional week relative to baseline§	1881/3129 (60·1%)	0·99 (0·92–1·07)	0·85	310/1881 (16·5%)	1·06 (0·96–1·17)	0·26

Data are n/N (%), unless otherwise specified. ORs were adjusted for all other variables in the model. SARS-CoV-2=severe acute respiratory syndrome coronavirus 2. LTCF=long-term care facility. OR=odds ratio. Q=quintile. NA=not applicable. *The number of LTCFs with cases versus the number of LTCFs with no cases is based on 3129 LTCFs, of which 1881 (60·1%) had cases (R^2=0·39). †A large outbreak was considered as an LTCF with more than a third of the total number of residents and staff combined testing positive, or with >20 residents and staff combined testing positive. ‡The large outbreak versus small outbreak model is based on 1881 LTCFs, of which 310 (16·5%) LTCFs were considered to have had a large outbreak (R^2=0·09). §Refers to the value at the start of the pandemic (March 1, 2020). ¶Caused by residents being unable to comply with control measures (eg, because they had dementia).

Table 3: **Risk factors for outbreaks and large outbreaks of SARS-CoV-2 infection in staff and residents combined**

improvement in staff-to-bed ratios, and widespread adoption of disease control measures, such as staff cohorting and isolation.

The likelihood of infection and outbreaks was reduced in LTCFs that often or always cohorted staff with either infected or uninfected residents compared with those that did not, consistent with a survey of 132 LTCFs in southwest France published in July, 2020.[24] LTCFs that provided staff sick pay had significantly fewer cases of infection among both residents and staff compared with those that did not, and LTCFs that did not employ agency staff also had significantly fewer cases of infection compared with those that did. The odds of infection in staff were also higher in LTCFs in which staff frequently worked at other sites than in those in which staff did not work at other sites. This finding is consistent with another study done in England, which found that the odds of infection in care home staff was three times higher in those staff members who worked across multiple locations than those who worked at one site.[25] Taken together, these results strongly suggest that staff play a key role in transmitting infection to each other and to residents, although it is difficult to discern a causal association between employment of agency staff and initiation of outbreaks without actual dates of employment and infection. The likelihood of infection in staff and residents was also associated with the number of new admissions to the LTCFs, highlighting the potential risks of importation of infection by new or returning residents.

Almost half of LTCFs in this study did not report any cases of SARS-CoV-2 infection, and similar findings from regional studies in North America and Europe suggest that many staff and residents were still susceptible to

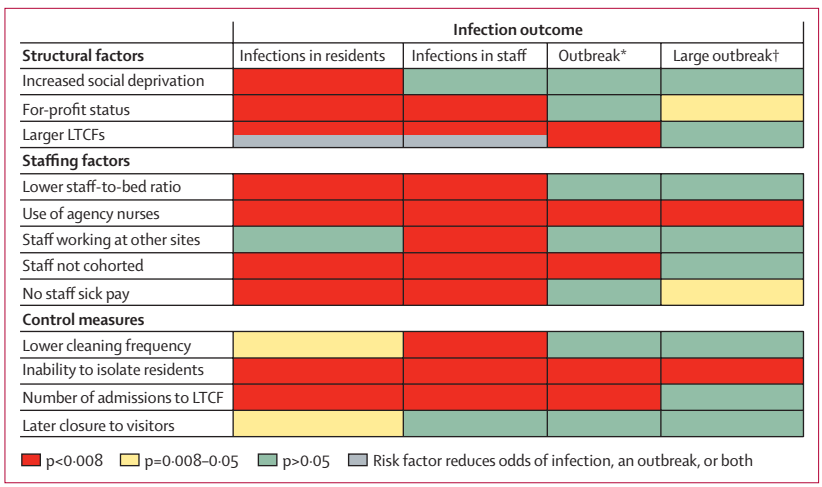

***Figure 2*: Heat map illustrating the main risk factors for SARS-CoV-2 infection and outbreaks in LTCFs**
The figure illustrates which risk factors are most strongly associated with SARS-CoV-2 infection in LTCF residents and staff, outbreaks, and large outbreaks. Red denotes strong evidence of an association with the specified risk factor, yellow denotes some evidence of an association, and green denotes no evidence of an association. Each column represents findings from each of the four risk factor analyses. SARS-CoV-2=severe acute respiratory syndrome coronavirus 2. LTCF=long-term care facility. *Defined as at least one case of SARS-CoV-2 per LTCF. †Defined as LTCFs with more than a third of the total number of residents and staff combined testing positive, or with more than 20 residents and staff combined testing positive.

infection after the first wave of the pandemic.[12,24,26,27] Strategies that might prevent future infections include coordinated investment to recompense staff who are required to shield or self-isolate so that they do not take on multiple jobs, and investment to minimise reliance on agency staff and reduce the number of individuals who work across multiple locations. In June, 2020, the UK Government established the Infection Control Fund, which provides regions with financial support to cover the costs of implementing these measures.[28] Given the likely importance of staff in transmission of infection, our finding that the prevalence of asymptomatic infection in this group is high[29] emphasises the need for regular staff testing to facilitate early detection of infection and prevent outbreaks. Strategies are also required to improve the implementation of disease control measures, such as isolation. The association between new admissions and the increased odds of infection shows the importance of testing and isolating residents on admission to the LTCF.

Consistent with all cross-sectional studies, our findings could be subject to confounding and reverse causality, which are particularly problematic for measures that might be initiated in response to infection, such as barrier nursing or employment of agency staff. This is the most probable explanation for the unexpected association between use of barrier nursing and the risk of infections and outbreaks. Variability in access to testing capacity and earlier onset of the pandemic in London and the West Midlands compared with the rest of England are probable explanations for the regional differences in prevalence of infection observed in staff and residents in our study. The survey response rate of 56·4% partly reflects the fact that the survey was done rapidly (ie, within 5 weeks), because our aim was to generate rapid evidence to inform the pandemic response. As a result, 2470 (27·2%) of 9081 LTCFs were only telephoned once or twice, which might have reduced survey participation. LTCFs were also experiencing an intense workload at the time of the survey, which might have also influenced participation. Survey respondents and non-respondents were similar in terms of LTCF characteristics, such as size, membership of a care home group, postcode-based deprivation, and region. There was also substantial variation in the prevalence of SARS-CoV-2 infection between LTCFs, which provides some evidence that the number of infections did not strongly influence survey participation. However, we cannot exclude the possibility that other factors that were not captured by our sampling frame might have influenced the decision of managers to participate, thus introducing selection bias due to survey non-response. Managers of LTCFs were asked to report on behalf of their staff and residents, introducing the possibility of recall bias, and social desirability bias might have also affected survey responses. In addition, survey responses could potentially be biased by pressure on managers to report or not report details of LTCF operations. Finally, the survey lasted approximately 30 min, and although managers were given advance notice of the questions, interview fatigue might have reduced the quality of information that was obtained towards the end of the survey. Although we asked managers of LTCFs to report the number of residents who had died since contracting COVID-19, we did not include mortality as an outcome in our analysis because of concerns about the quality of this information and its interpretation. We did not include a definition for death in the questionnaire and, in the context of the limited testing capacity for COVID-19, it is difficult to reliably differentiate deaths caused by COVID-19 from deaths due to other causes.

Confidence in our results is increased by the evaluation of potential risk factors for SARS-CoV-2 infection among residents and staff, and risk factors for outbreaks and large outbreaks, that allowed us to investigate factors associated with both ingress and spread of infection, and by the fact that similar results were obtained in sensitivity analyses. The national scale of our study, and similarity of survey responders and non-responders in terms of LTCF characteristics and region, suggest that our findings could be generalisable to all LTCFs in England.

In conclusion, this study documented the substantial burden of SARS-CoV-2 across LTCFs in England during the first wave of the pandemic, and identified that staff and residents in half of LTCFs without outbreaks remain at a high risk of infection. Strategies that could be implemented immediately and might reduce the impact of COVID-19 in LTCFs include provision of financial support to LTCF staff to incentivise testing and

self-isolation when sick, investment to reduce reliance on agency staff, and a focus on the implementation of disease control measures, such as staff cohorting and isolation of residents. The widespread and rapid adoption of these measures could support efforts to protect this susceptible sector of society from future waves of SARS-CoV-2 infection.

Contributors

LS, AH, and SH designed the survey. OA and LW designed and piloted the questionnaire. OA, ST, DB, and LS designed the statistical analysis plan. DB, ST, and KS had full access to all the data in the study and statistically analysed the data. ST and DB accessed and verified the data. AD managed the project. GH extracted the dataset and did the data linkage under instructions from the research team. MK reviewed the literature. LS wrote the first draft of the manuscript. All authors revised and edited the manuscript. The corresponding author had final responsibility to submit for publication.

Declaration of interests

LS reports grants from the Department of Health and Social Care during the conduct of the study, and is a member of the Social Care Working Group, which reports to the Scientific Advisory Group for Emergencies. AH is a member of the New and Emerging Respiratory Virus Threats Advisory Group at the Department of Health. GH is an employee of Palantir Technologies UK, which has a paid contract with the Department of Health and Social Care to provide the data platform that was used for this study. All other authors declare no competing interests.

Data sharing

Deidentified, LTCF-level data collected from the survey and the associated questionnaire will be deposited in the Office for National Statistics, Secure Research Service (SRS) at the time of publication in a peer reviewed journal, or shortly afterwards, for use by accredited researchers. The study protocol is also available on the University College London website. Accredited researchers can access the survey via the SRS following submission of a project proposal that explains the intended use of the dataset and the value of the project. Further details about applying to use the SRS are available from the Office for National Statistics website.

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References

1 European Centre for Disease Prevention and Control. Resurgence of reported cases of COVID 19 in the EU/EEA, the UK and EU candidate and potential candidate countries. Stockholm: European Centre for Disease Prevention and Control, 2020.

2 Kaiser Family Foundation. State COVID-19 data and policy actions. 2021. https://www.kff.org/coronavirus-covid-19/issue-brief/state-covid-19-data-and-policy-actions/ (accessed Jan 28, 2021).

3 Office for National Statistics. Deaths involving COVID-19 in the care sector, England and Wales: deaths occurring up to 12 June 2020 and registered up to 20 June 2020 (provisional). 2020. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/deathsinvolvingcovid19inthecaresectorengland andwales/deathsoccurringupto12june2020 andregisteredupto20june2020provisional (accessed Sept 16, 2020).

4 National Records of Scotland. Deaths involving coronavirus (Covid-19) in Scotland: week 29 (13 to 19 July 2020). 2020. https://www.nrscotland.gov.uk/files//statistics/covid19/covid-deaths-report-week-29.pdf (accessed Sept 16, 2020).

5 European Centre for Disease Prevention and Control. Surveillance of COVID-19 at long-term care facilities in the EU/EEA. Stockholm: European Centre for Disease Prevention and Control, 2020.

6 Williamson EJ, Walker AJ, Bhaskaran K, et al. Factors associated with COVID-19-related death using OpenSAFELY. *Nature* 2020; **584:** 430–36.

7 Pineles L, Perencevich EN, Roghmann M-C, et al. Frequency of nursing home resident contact with staff, other residents, and the environment outside resident rooms. *Infect Control Hosp Epidemiol* 2019; **40:** 815–16.

8 Salcher-Konrad M, Jhass A, Naci H, Tan M, El-Tawil Y, Comas-Herreras A. COVID-19 related mortality and spread of disease in long-term care: a living systematic review of emerging evidence. *medRxiv* 2020; published online Aug 1. https://doi.org/10.1101/2020.06.09.20125237 (preprint).

9 Arons MM, Hatfield KM, Reddy SC, et al. Presymptomatic SARS-CoV-2 infections and transmission in a skilled nursing facility. *N Engl J Med* 2020; **382:** 2081–90.

10 Department of Health and Social Care. Government launches new portal for care homes to arrange coronavirus testing. 2020. https://www.gov.uk/government/news/government-launches-new-portal-for-care-homes-to-arrange-coronavirus-testing (accessed Oct 27, 2020).

11 LaingBuisson. Care of older people UK market report 30th edition 2019. London: LaingBuisson, 2020.

12 Li Y, Temkin-Greener H, Shan G, Cai X. COVID-19 infections and deaths among Connecticut nursing home residents: facility correlates. *J Am Geriatr Soc* 2020; **68:** 1899–906.

13 Abrams HR, Loomer L, Gandhi A, Grabowski DC. Characteristics of U.S. nursing homes with COVID-19 cases. *J Am Geriatr Soc* 2020; **68:** 1653–56.

14 He M, Li Y, Fang F. Is there a link between nursing home reported quality and COVID-19 cases? Evidence from California skilled nursing facilities. *J Am Med Dir Assoc* 2020; **21:** 905–08.

15 Stall NM, Jones A, Brown KA, Rochon PA, Costa AP. For-profit long-term care homes and the risk of COVID-19 outbreaks and resident deaths. *CMAJ* 2020; **192:** e946–45.

16 Department of Health, Health Protection Agency. Prevention and control of infection in care homes – an information resource. 2013. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/214929/Care-home-resource-18-February-2013.pdf (accessed Sept 16, 2020).

17 Beatty PC, Willis GB. Research synthesis: the practice of cognitive interviewing. *Public Opin Q* 2007; **71:** 287–311.

18 Department of Health and Social Care, Public Health England. Coronavirus (COVID-19): adult social care guidance. 2020. https://www.gov.uk/government/collections/coronavirus-covid-19-social-care-guidance (accessed Sept 16, 2020).

19 Office for National Statistics. Impact of coronavirus in care homes in England: 26 May to 19 June 2020. 2020. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/articles/impactofcoronavirusincarehomesinenglandvivaldi/26mayto19june2020 (accessed Sept 16, 2020).

20 Brown KA, Jones A, Daneman N, et al. Association between nursing home crowding and COVID-19 infection and mortality in Ontario, Canada. *medRxiv* 2020; published online June 23. https://doi.org/10.1101/2020.06.23.20137729 (preprint).

21 Smith D, Duval A, Pouwels K, et al. Optimizing COVID-19 surveillance in long-term care facilities: a modelling study. *BMC Med* 2020; **18:** 386.

22 Dutey-Magni PF, Williams H, Jhass A, et al. Covid-19 infection and attributable mortality in UK long term care facilities: cohort study using active surveillance and electronic records (March–June 2020). *medRxiv* 2020; published online July 15. https://doi.org/10.1101/2020.07.14.20152629 (preprint).

23 Zimmerman S, Gruber-Baldini A, Hebel JR, Sloane PD, Magaziner J. Nursing home facility risk factors for infection and hospitalization: importance of registered nurse turnover, administration, and social factors. *J Am Geriatr Soc* 2002; **50:** 1987–95.

24 Rolland Y, Lacoste M-H, De Mauleon A, et al. Guidance for the prevention of the COVID-19 epidemic in long-term care facilities: a short-term prospective study. *J Nutr Health Aging* 2020; published online July 13. https://doi.org/10.1007/s12603-020-1440-2.

For the **study protocol** see https://doi.org/10.5522/04/12993506.v1

For more on **accessing SRS data** see https://www.ons.gov.uk/aboutus/whatwedo/statistics/requestingstatistics/approvedresearcherscheme

25 Ladhani SN, Chow JY, Janarthanan R, et al. Increased risk of SARS-CoV-2 infection in staff working across different care homes: enhanced CoVID-19 outbreak investigations in London care homes. *J Infect* 2020; **84:** 621–24.

26 Fisman DN, Bogoch I, Lapointe-Shaw L, McCready J, Tuite AR. Risk factors associated with mortality among residents with coronavirus disease 2019 (COVID-19) in long-term care facilities in Ontario, Canada. *JAMA Netw Open* 2020; **3:** e2015957.

27 Burton J, Bayne G, Evans C, et al. Evolution and impact of COVID-19 outbreaks in care homes: population analysis in 189 care homes in one geographic region. *Lancet Healthy Longev* 2020; **1:** E21–31.

28 Department of Health and Social Care. Coronavirus (COVID-19): care home support package. 2020. https://www.gov.uk/government/publications/coronavirus-covid-19-support-for-care-homes/coronavirus-covid-19-care-home-support-package (accessed Sept 16, 2020).

29 Goldberg SA, Lennerz J, Klompas M, et al. Presymptomatic transmission of SARS-CoV-2 amongst residents and staff at a skilled nursing facility: results of real-time PCR and serologic testing. *Clin Infect Dis* 2020; published online July 15. https://doi.org/10.1093/cid/ciaa991.