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Major Article

Impact of visitation and cohorting policies to shield residents from covid-19 spread in care homes: an agent-based model

Le Khanh Ngan Nguyen MPH [a,*], Susan Howick PhD [a], Dennis McLafferty MSc [b], Gillian Hopkins Anderson BA [a], Sahaya Josephine Pravinkumar MPH [c], Robert Van Der Meer PhD [a], Itamar Megiddo PhD [a]

[a] Department of Management Science, Strathclyde Business School, University of Strathclyde, Glasgow, United Kingdom
[b] Adult Services, Health & Social Care North Lanarkshire, Motherwell, United Kingdom
[c] Department of Public Health, National Health Services Lanarkshire, Kirklands Hospital, Bothwell, United Kingdom

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A B S T R A C T

Background: This study examines the impact of visitation and cohorting policies as well as the care home population size upon the spread of COVID-19 and the risk of outbreak occurrence in this setting.
Methods: Agent-based modelling
Results: The likelihood of the presence of an outbreak in a care home is associated with the care home population size. Cohorting of residents and staff into smaller, self-contained units reduces the spread of COVID-19. Restricting the number of visitors to the care home to shield its residents does not significantly impact the cumulative number of infected residents and risk of outbreak occurrence in most scenarios. Only when the community prevalence where staff live is considerably lower than the prevalence where visitors live (the former prevalence is less than or equal to 30% of the latter), relaxing visitation increases predicted infections much more significantly than it does in other scenarios. Maintaining a low infection probability per resident-visitor contact helps reduce the effect of allowing more visitors into care homes.
Conclusions: Our model predictions suggest that cohorting is effective in controlling the spread of COVID-19 in care homes. However, according to predictions shielding residents in care homes is not as effective as predicted in a number of studies that have modelled shielding of vulnerable population in the wider communities.

INTRODUCTION

Many care homes across the globe implemented strict "no visitor" and/or cohorting policies and curtailed group activities as part of their infection prevention and control strategies. Although there have been several modelling studies of the impacts of non-pharmaceutical interventions on COVID-19 epidemics, few have examined shielding.[1-5] These studies have modelled shielding strategies targeting vulnerable groups in the general population and provided different views on how such strategies could be ended. None of them have explicitly considered shielding care home residents to our knowledge.

Although visitation restrictions to shield residents have been suggested as an intervention to partially prevent the introduction of COVID-19 into care homes, experts and advocates are increasingly

* Address correspondence to Le Khanh Ngan Nguyen, MPH, PGR Suite, Department of Management Science, Strathclyde Business School, University of Strathclyde, 199 Cathedral Street, Glasgow, G4 0QU, United Kingdom
E-mail address: nguyen-le-khanh-ngan@strath.ac.uk (L.K.N. Nguyen).
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Contributors: LN, IM, and SH designed the model and planned the inference framework. LN programmed the model, performed data analysis, interpreted the study findings with help from IM and SH. LN wrote the first manuscript, and IM and SH contributed to commenting on and editing the subsequent versions of the manuscript. DM and SP provided relevant data on COVID-19 spread and infection control policies in care homes in Lanarkshire and contributed to designing the examined interventions and verifying the model design. DM, SP, RV, and GA facilitated the communication between LN and other care home stakeholders for data collection. All authors contributed to scoping the problems and approving the work and final version of the manuscript for publication.

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concerned that such practice may cause substantial unintended harms to the health and wellbeing of residents.[6] A recent survey conducted in English care homes reported that the deprivation of visitation from and physical contact with loved ones have predominantly contributed to lowering residents' mood, exacerbating irritability, agitation, and anxiety among residents and the symptoms of their dermentia, and reducing oral intake.[7] A more sustainable and balanced approach that both allows needed contact with family visitors, but also prevents the introduction and spread of COVID-19 in care homes may be needed. Understanding to what extent these visiting policy interventions protect residents is important to inform decisions about how to balance the risk of COVID-19 and care home residents' well-being.

Cohorting is considered a common and effective infection control measure in acute care settings such as hospitals and some studies showed the association between the presence of an outbreak and the care home resident population.[8-10] However, the impact of this intervention in care home has not been well studied. As healthcare systems are likely to bear additional costs for staffing, equipment, and support to implement cohorting in care homes, evaluating the effectiveness of this intervention is important.

To address these issues, we developed an agent-based model to investigate the impacts of visitation and cohorting policies as well as care home population size upon the transmission dynamics of COVID-19 in care homes. The model simulates the transmission dynamics of COVID-19 via contacts between individuals, including residents, staff members, and visitors.

METHODS

Model

We develop an agent-based model, building on and adapting our previous work[11]. The model simulates the transmission dynamics of COVID-19 via contacts between individual agents, including residents, staff members, and visitors within a care home (See the 'ODD' (Overview, Design concepts, and Details) protocol in the Appendix S1 for the detailed model structure). Agent-based modelling provides more flexibility to reflect variations in size, structure, and operation across care homes and is more suitable to capture the complexity and heterogeneity of individuals and their interactions in the small care home setting.

Three sources of importing COVID-19 into a care home include infected residents upon admission (from hospitals and the community) and staff and visitors who acquired the infection elsewhere.[11] Care homes that we worked with in Lanarkshire reported that staff often live in local areas near the care homes where they work while visitors are from different areas across Scotland. We simulated experiments to test how relaxing the visitation policy affects the occurrence of outbreaks in a care home when the local transmission differs from the regional/national transmission. The relative-prevalence parameter describes the ratio of the infection prevalence in the communities where staff come from to the prevalence where visitors are from (i.e. relative infection prevalence). In base case simulations, the ratio of relative prevalence was set to one.

We assumed that recovered individuals are immune to re-infection throughout the simulated time (i.e. 6 months). We assumed that all staff and residents are susceptible at the beginning of the simulation.

Data collection and parameters

Data collection through literature review, discussions, and semi-structured interviews with stakeholders from the Health and Social Care Partnerships (HSCPL), Public Health, and care homes in Lanarkshire is described in our previous paper.[11] Key model input parameters used for the base case simulation are presented in Table 1.

Interventions

We examined the impacts of visiting policy, care home population size, and structure under two incremental intervention scenarios: a reference intervention and one which also includes weekly staff testing. The reference intervention included isolation of symptomatic cases and testing of new admissions (two tests), social distancing and restricted visiting policy which reduces the average number of visitors per resident per day and contact rate between staff and visitors by 75% (unless stated otherwise in visiting policy scenarios). Interventions such as hand hygiene and using Personal Protective Equipment (PPE) change the infection probability per contact, representing the reduction in transmission risk. Residents and staff members who are symptomatic or tested positive are isolated and excluded from work respectively the day after being tested. We assume that all staff members comply with weekly COVID-19 testing. Analysis that relaxes this assumption is available in our previous paper.[11] These interventions were chosen based on discussion with local care home stakeholders in Lanarkshire and in line with the guidance for controlling COVID-19 by the Scottish government.[22] We used the daily data of Scotland adjusted for undetected cases for the infection prevalence in the community.[13,15] The interventions were described in detail in Appendix S1.

Experiment designs

Exploring the effect of visiting policy. We investigated the impact of the number of visitors per resident per day for different infection probabilities per contact which reflect the adherence to measures such as hand hygiene and using PPE in the care home. We also examined a scenario in which the transmission risk between visitors and residents is different from the risk between other types of contacts in the facility. We varied the infection probability of visitor-resident contacts and used a fixed infection probability for other types of contacts.

Additionally, we investigated the effect of visiting policy when the prevalence of COVID-19 in the communities where staff and visitors come from are different. We used the base case value of community infection prevalence to determine then probability at which visitors can introduce COVID-19 into the care home and then applied the relative-prevalence to determine the probability at which a staff member can introduce the infection into the facility.

Exploring the effect of care home population size and structure. When examining the effect of care home population size, we scaled the staffing levels based on the resident:staff ratio used in the base case simulation. In cohorting interventions, we assumed that residents and staff are split evenly into smaller, self-contained units within a care home and examined two scenarios: individuals including staff and residents across units do not interact and interactions across units occur at the probability of 20%. The care home was divided into: (i) one cohort with 80 residents and 72 staff members; (ii) two cohorts each with 40 residents and 36 staff members; (iii) four cohorts each with 20 residents and 18 staff members; and (iv) eight cohorts each with ten residents and 9 staff members.

Outcomes

We reported outcomes in our base case for a care home with a capacity of 80 residents. We ran 1,000 simulations for each scenario. The outcomes we collected include the cumulative number of infected residents, the time elapsed until the first resident is infected by other people in the care home (distributions, means, and CIs) and

Table 1
Key model parameters characterizing the introduction of COVID-19 into the care home and its transmissions (See Table S1-6 in Appendix S1 for the complete list of parameters)

Parameter Name	Meaning and Rationale	Base-case Value	Sensitivity Analysis	Source
Infection Prevalence Hospital	Infection prevalence in the hospital	0.02	Triangular distribution (min = 0, max = 0.5, mode = 0.2)	[12-14](estimated)
Infection Prevalence Community	Infection prevalence in the community	Time-series of data from Scotland adjusted for undetected cases	Triangular distribution for multiplier on the same curve of prevalence over time (min = 1, max = 3, mode = 5)	[13,15] (The undetected cases represent 50 – 80% of the total cases in the community. We adopted the worse situation (80% cases undetected) for the base case scenario)
Relative-prevalence	Ratio of infection prevalence in the community where staff live to the prevalence where visitors come from	1.0	Triangular distribution (min = 0, max = 0.5, mode = 1.0)	Discussions with representatives from Health and Social Care Partnership and Public Health Lanarkshire
Contact Rate RR	The number of contacts that a resident has with other residents per day	Drawn for each individual resident from a Poisson distribution with a mean of 3.9 contacts per resident per day	Mean of the Poisson distribution is drawn from a triangular distribution (min = 1, max = 5, mode = 3.9)	[16,17]
Contact Rate SS	The number of contacts that a staff has with other staff per day	Drawn for each individual staff member from a Poisson distribution with a mean of 7.3 contacts per staff member per day	Mean of the Poisson distribution is drawn from a triangular distribution (min = 1, max = 10, mode = 7.3)	[16]
Contact Rate SR	The number of contacts that a staff has with residents per day	Drawn for each individual staff member from a Poisson distribution with a mean of 16.2 contacts per staff per day	Mean of the Poisson distribution is drawn from a triangular distribution (min = 10, max = 20, mode = 16.2)	[16,17]
Contact Rate SV	The number of contacts that a staff has with visitors per day	5.0 contacts per staff member per day	Triangular distribution (min = 0, max = 10, mode = 5.0)	Discussions with the manager and staff of a Scottish care home for older people
Contact Across Units	The probability that a resident comes into contact with another resident in the other unit	20%	Triangular distribution (min=0, max = 0.5, mode =0.2)	Discussions with the manager and staff of a Scottish care home for older people
Visitors Per Day	The average number of people visiting a resident per day	1.0 visitor per resident per day	Triangular distribution (min = 0, max = 2.0, mode = 1.0	[16,18]
Infection Probability	The probability that an individual (resident or staff) is infected after coming into contact with another infectious individual (resident, staff or visitor)	0.02	Triangular distribution (min = 0.001, max = 0.1, mode = 0.02)	[19-21]
Infection Probability RV	The infection probability per contact between residents and visitors	0.02	Triangular distribution (min = 0.001, max = 0.1, mode = 0.02)	[19-21]

the probability of outbreak occurrence (i.e., presence of at least two infected residents).

Verification and validation

Our simulation model is built in Anylogic PLE 8.7.2. For verification, we performed tracing of randomly chosen agents of each type via simulation output and using the debugger, bottom-up testing, stress testing, and regression testing. We built confidence in our model using 3 approaches: face validation, cross-validation to observed data in care homes in Lanarkshire and published literature, and sensitivity analysis. In face validation, the model was developed in conjunction with care home stakeholders including representatives from HSCPL, Public Health Lanarkshire, care home managers, and the Scottish Government Data Analysis Research Group. This helped ensure that the model sufficiently represents the investigated system while making the appropriate assumptions to develop such a model. In cross-validation, we ran the scenario in one of the care homes in Lanarkshire and compared the time series prevalence of COVID-19 in residents to observed data provided by that care home. The period for comparison was between March and May 2020 when the care home experienced an outbreak. The care home implemented the reference intervention and was closed to admission of new residents and visitors 10 days after the first resident developed COVID-19 symptoms. We also compared the risk of outbreak occurrence in care homes varied in population size with Scottish data and the analysis of care homes in Lothian.

*Sensitivity and Uncertainty Analyses***:** We carried out global probabilistic sensitivity analyses for parameter uncertainty. Table 1 summarizes the probability distributions of the model parameters. We simulated the model for 100,000 sets of samples, generated by using the Latin Hypercube Sampling (LHS) method. The calculated Partial Rank Correlation Coefficient (PRCC) determined the strength of the relationship between each LHS parameter and each outcome measure. We also examined the robustness of the findings on the visiting policy to the care home's population size and structure (Table S2-1 in Appendix 2).

RESULTS

Impact of visiting policy

Different risks of transmission per contact

In the first experiment, we assumed that all infectious-susceptible contacts between individuals in the care home, including residents, staff, and visitors, have the same infection probability and that the community prevalence of COVID-19 where staff live and where residents live is equal.

Relaxing the visiting policy did not significantly impact the cumulative number of infected residents (Fig. S3-1). The difference in the mean cumulative number of infected residents between no visiting and normal visiting policy (one visitor/resident/day) after 90 days was one to two (95% CI) infections among residents for the infection probability per contact of 0•02 in the base case scenario. There was no difference in this outcome when the infection probability was below 0.02 while the mean difference was 2 to 5 (95%CI) for the value of 0.1 (Fig. S3-1-A). The mean difference in the cumulative number of

COVID-19 deaths among residents after 90 days were zero to two (95%CI) across the values of infection probability per contact. The mean elapsed time until the first resident is infected prolonged by 1 to 6 days (95%CI) when visiting was banned across the values of infection probability per contact (Fig. S3-1-B). The distributions of outputs for each of these outcomes in both visitation scenarios were almost identical when the transmission risk per contact was very low. When this parameter was higher, they still had similar unimodal, relatively symmetrical shape and spread but slightly shifted. The impact of the size of infection probability per contact was much more significant than the visiting policy. In addition, the visiting policy had little impact on the probability of an outbreak in the care home within the first 90 days of the epidemic. Unless the risk of transmission per contact was very low (<0.02) and weekly testing of staff was implemented, an outbreak occurred in 97%-100% of simulations after 90 days.

Lower community infection prevalence where staff live compared to prevalence where visitors come from

In this section, we report the modelling results when relaxing the assumption about equal community infection prevalence where staff and visitors live. As the relative infection prevalence in communities where staff live reduces compared to the infection prevalence in communities where visitors live, the number of infected residents also reduced (Fig. 1-A).

Restricting visiting was more effective when the infection prevalence in the staff community was comparatively low. When the staff community infection prevalence was significantly lower than the prevalence among visitors' community (i.e., the former equalled 0%-30% of the latter), relaxing the visiting policy increased the cumulative number of infected residents and the risk of outbreak occurrence in the care home. In particular, the mean difference in the cumulative numbers of infected residents after 90 days between no visiting and normal visiting policy was 2 to 3 (95%CI, the same relative infection prevalence less than 30%) in the weekly staff testing intervention. Halting visitation delayed the time until the first infection occurred among residents by 9-16 days (95%CI) (Fig. 1-B). Additionally, when the community infection prevalence where staff live was extremely low (i.e., between zero and 10% of the infection prevalence where visitors come from), resuming the normal visitation policy doubled the risk of an outbreak within the first 90 days of the epidemic (Fig. 1-C). The impact of modifying the visiting policy on the model outcomes was much smaller when the infection prevalence in communities where staff live was above 30% of the prevalence in communities where visitors live.

Different risks of transmission per resident-visitor contact

The impact of relaxing visitation increased as the risk of transmission for contacts between residents and visitors increased (Fig. 2). The mean difference in the cumulative number of infected residents between the no visiting and normal visiting policies in the weekly staff testing intervention after 90 days rose from one (95%CI: 1-2) when the transmission probability was very low (0.005) to 3 infections (95%CI: 3-4) when it was very high (0.1) (Fig. 2-A). The elapsed time until the first resident is infected was prolonged by 26-41 days (95%CI) (Fig. 2-B). Likewise, the risk of outbreak occurrence increased when allowing visitors into the care home (Fig. 2-C).

impact of care home population size

Figure 3 shows that the larger the care home's size, the more quickly a resident acquires COVID-19 on average. As a result, the risk of an outbreak in a large care home was higher than in a smaller one (Table S3-2 in Appendix S3). There was a statistically significant association between the presence of an outbreak and the size of a care home (mean OR per 20-bed increase 2.57, range: 1.15 – 5.74 for different infection probabilities in both the reference and weekly staff testing scenarios). The modelling results on the risk of outbreak occurrence in care homes with different size were in line with the reported data in Scottish care homes.[14] The prediction on the association between the care home size and the risk of experiencing an outbreak showed a good approximation of observed data in Lothian Health Board (OR per 20-bed increase 3.5, 95%CI: 2.06 – 5.94).[9] Additionally, both intervention strategies were more impactful for the smallest care homes (i.e. size of 10 residents).

Although smaller care homes were less likely to have an outbreak, the size of care homes did not affect the attack rate. There was no statistically significant association between the proportion of infections among residents and care home population size under the same intervention strategy once the infection was already in the care homes. The addition of weekly staff testing and/or a decline in the

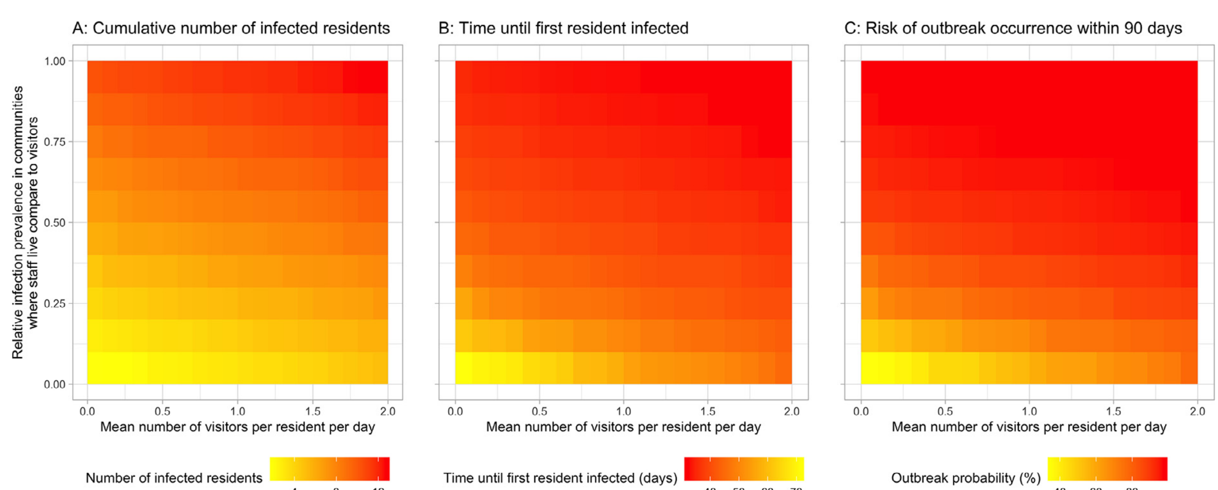

Fig. 1. The impact of visiting policy and relative community infection prevalence on the spread of COVID-19
Heatmap plot for the impact of different number of visitors allowed in the weekly testing of staff strategy upon
A: The cumulative number of infected residents 90 days after the simulation starts
B: The elapsed time until the first resident is infected
C: The probability of an outbreak occurrence within the first 90 days
Other parameters take the base case values. All infectious-susceptible contacts have the same infection probability of 0.02.

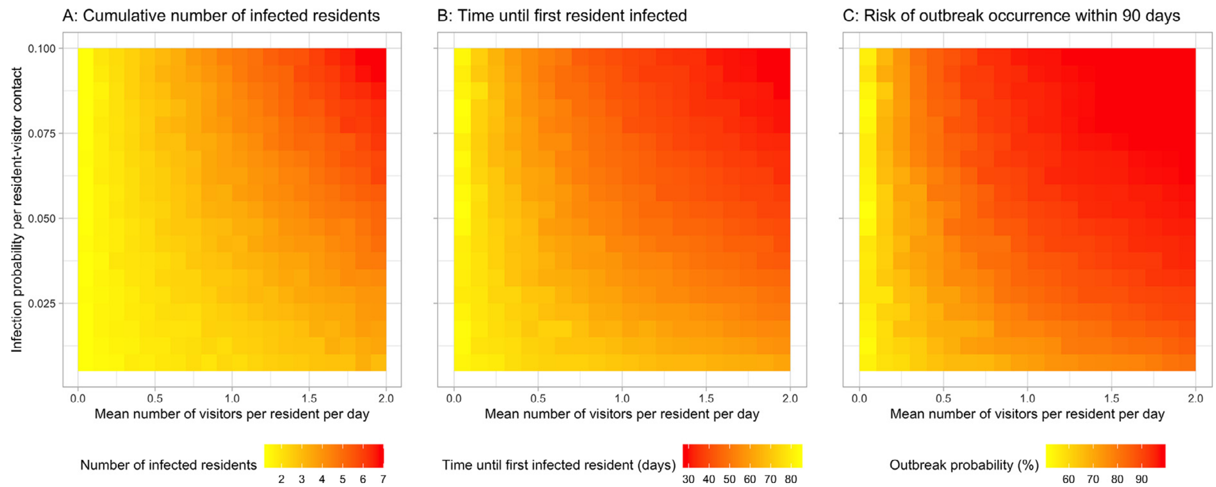

Fig. 2. Impact of visiting policy and risk of transmission between visitors and residents on the spread of COVID-19
Heatmap plot for the impact of different numbers of visitors allowed in the testing of staff strategy upon
A: The cumulative number of infected residents 90 days after the simulation starts
B: The elapsed time until the first resident is infected
C: The probability of an outbreak occurrence within the first 90 days
The community infection prevalence among staff is one tenth of the prevalence among visitors. Other parameters take the base case values. The infection probability per contact for other types of contacts is 0.02.

infection probability per contact significantly improved the outcomes irrespective of size.

Impact of cohorting

When the infection probability per contact was set to a very low value (< 0.02), dividing the care home into smaller units had little effect on the cumulative number of infected residents after 90 days (Fig. 4A). However, when the risk of transmission per contact was increased, the effectiveness of cohorting was noticeable. The impact of cohorting was most significant when the size of a unit was reduced from 20 to 10 residents. Our model predictions remained robust when we relaxed the assumption of no interactions across units (Fig. S3-2 in Appendix S3). By contrast, splitting a care home into smaller units did not show any impact upon the elapsed time until the first resident acquired the infection or the probability of outbreak occurrence (Fig. S3-3 and S3-4). Regardless of the cohort size, the weekly staff testing strategy was more effective in controlling the spread of COVID-19 than the reference intervention alone (Fig. 4B).

Validation results

*Cross-Validation***:** The model-generated time series prevalence of COVID-19 among residents matched closely to the observed data in a care home in Lanarkshire (Figure S2-1 in Appendix S2). The risk of outbreak occurrence in care homes which varied in population size agreed with Scottish data and the analysis of care homes in Lothian as we described in the results.

Sensitivity and Uncertainty Analyses: Outputs from the PRCC analyses summarized in Table S2-2 in the Supplementary Materials. The PRCC values determined the associations between each of the parameters and the modelling outcomes. The cumulative number of infections among residents were sensitive to the infection probability per contact and the infection prevalence in the community. The probability of an outbreak occurring within 90 days was not sensitive to any parameter. Furthermore, the findings about the scenarios in which the impact of relaxing visitation was statistically insignificant, small, or significant were robust to modifying the population size and structures (unit size, residents-per-staff ratio) of the care home.

DISCUSSIONS

This study proposes an agent-based model to study halting or restricting visitation and cohorting in care homes in response to COVID-19, interventions included in the UK national guidance and implemented in numerous care homes across the world. These intensive interventions have led to growing concerns about their negative impacts upon the well-being of residents and burdens to healthcare systems. However, the effectiveness of these intervention strategies has not been well investigated. Our modelling study helped address this gap of understanding the effectiveness of visitation and cohorting policies in controlling the ingress of COVID-19 into, and its spread in, this setting.

When the community infection prevalence where staff live is above approximately one-third of the prevalence where visitors come from, reducing the number of visitors allowed had little impact on the ingress of COVID-19 into, and its spread in, the care home. Residents can still acquire the infection from staff members who interact with several other individuals in the care home and are likely to spread the virus, which affects the likelihood and size of an outbreak more than the effect of the visiting policy. Current evidence from care homes in England has highlighted that staff, particularly bank and agency staff, have been an unwitting source of infection.[23,24] If indeed staff live near the care home and provided local transmission is not very low compared to the rest of the population, the finding suggests that care homes can relax their visitation policy to a level for which they are able to ensure that all visitors strictly adhere to infection control measures. An early warning system that estimates the relative community prevalence of COVID-19 in a local area and the whole region/country could help care homes decide when they should halt visitation to protect their residents and staff.

Our findings suggest that shielding residents in care homes will not be as effective as reported in a number of studies, which have considered shielding vulnerable populations more broadly.[1-5] These studies used age-stratified compartmental meta-population models that assume homogeneous mixing within a compartment. Although such models incorporated different transmission rates between compartments representing age-specific populations or shielders/non-shielders, they did not account for contact patterns at an individual

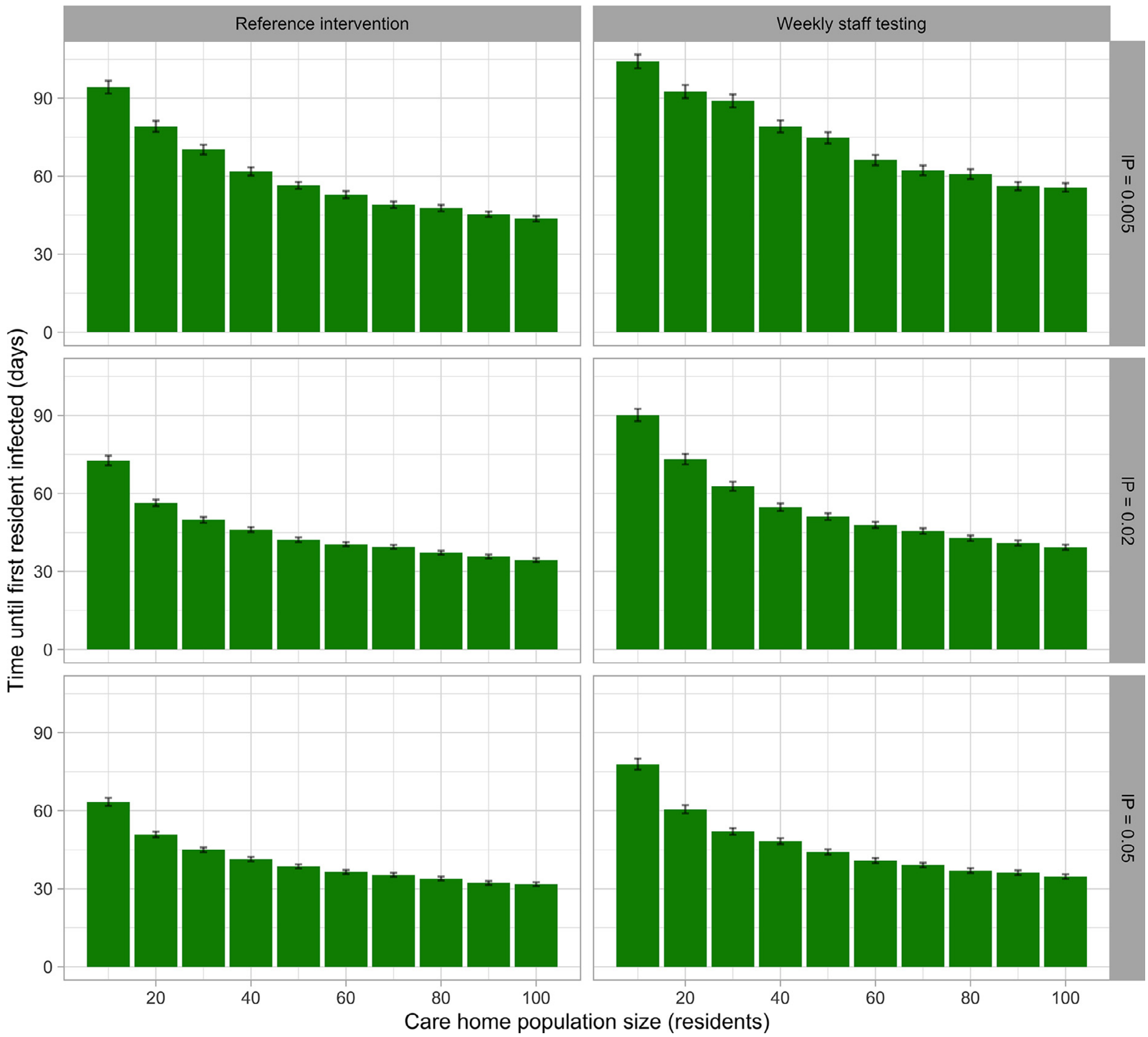

Fig. 3. Impact of care home population size on the elapsed time until the first resident becomes infected

The results are presented for the weekly staff testing scenario at across low-high values of infection probability (i.e. IP = 0.005, 0.02, and 0.05) in the reference and weekly staff testing scenarios. The simulations in which no resident is infected are excluded. Base case values are used for other parameters. Columns denote the mean values of 1,000 simulations and error bars denote 95% CI of the means.

level that we accounted for in our model. In particular, if staff and visitors could introduce COVID-19 into a care home in equal probabilities (i.e., equal prevalence in the communities where staff and visitors live and the same probability of infection per contact), staff are more likely to spread the virus than visitors. Staff come into contact with several residents and other staff members. Therefore, they can acquire the infection from an individual in the care home and transmit it to another, further spreading the virus. By contrast, visitors are less likely to mediate transmissions between residents as they only interact with a very limited number of staff and residents (e.g., a resident whom they come to visit and staff members looking after this resident). Thus, shielding by stopping visiting is not very effective in most circumstances as long as staff and their close contacts outside the care home are not also shielded from the community, which seems unlikely. We did not investigate the effect of shielding care home residents from visitors on the spread of COVID-19 in the community while other models examined the effects of shielding interventions on the overall population. There may be a risk that visitors can acquire COVID-19 from staff and residents in care homes and spread it to others in the community. Furthermore, while vulnerable groups in other models were shielded from the rest of the population, our model only considered shielding residents from visitors.

The modelling results on the risk of outbreak occurrence in care homes with different population sizes aligned with the reported data in Scottish care homes. US data also indicated significant associations between the presence of an outbreak and care home size.[10] As the number of staff members and visitors are generally proportional to the number of residents in a care home, the likelihood that COVID-19 is introduced into the facility by these individuals increases as its size increases. Moreover, in care homes with different capacities but similar structures (i.e., same number of units, staff pooling systems, and residents-to-staff ratio), an individual can come into contact with a greater number of other different individuals, leading to a higher probability of interacting with an infected individual and, therefore, acquiring the infection.

Although cohorting of residents and staff did not affect either the elapsed time until the first resident is infected or the risk of outbreak occurrence, this intervention reduced the impact of an outbreak once it occurs. This is because the number of staff members and visitors

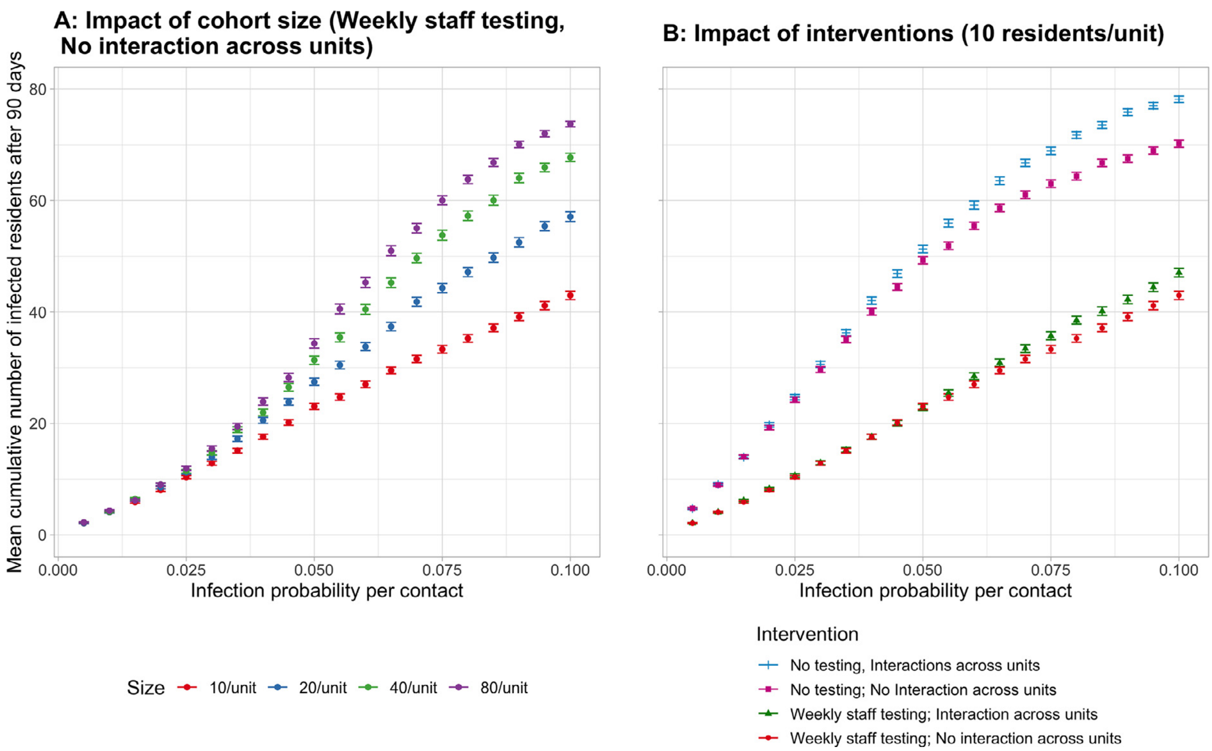

Fig. 4. Impact of cohort size and interventions in the smallest examined cohort on the spread of COVID-19

The care home with capacity of 80 residents are split into one, two, four, and eight units with 80, 40, 20, and 10 residents per unit Interactions of residents and staff across units of the care home occur at zero and 20% of total contacts for the "no interaction across units" and "interaction across units" scenarios respectively. The reference intervention is implemented across all plotted scenarios. Points represent the mean values of 1,000 simulations; error bars represent 95% CIs of the means.

who can introduce the virus into the facility was the same for all cohorting scenarios. Cohorting reduced the probability of having an outbreak in each unit but the overall probability for the entire facility did not decline (i.e., when an outbreak occurs in at least one of its cohorts). Nevertheless, cohorting disrupted the spread of COVID-19 and reduced the extent of an outbreak as infected individuals came into contact with fewer other individuals, and mostly ones from within their cohort.

Although care home size cannot be altered without losing places for existing and potential residents, cohorting residents and staff into smaller, discrete units could potentially alleviate the extent of an outbreak once it occurs. The cohorting intervention is more impactful in circumstances when the risk of transmission per contact is high, such as when PPE provision is inadequate, compliance to hand hygiene and wearing PPE is low, and/or maintaining social distancing is difficult. Reshaping the structure of care homes, however, requires the care home's efforts to recruit and train additional staff as well as outside support to accommodate sufficient levels of staff within each unit to maintain safe care. Staff illness and absence during COVID-19 outbreaks could further complicate the cohorting situation.

The study is subject to a number of limitations. We have not incorporated changes in individuals' behaviours as a result of implementing the shielding and/or cohorting interventions into the model. Therefore, we have not captured how such changes would affect the outcomes. As the changes in behaviour in the presence of interventions and the relationships between behavioural changes and risks of transmission are difficult to predict,[25] it is essential to continue to closely monitor outbreaks in care homes. Furthermore, as our model has assumed that visitors only come into contact with the resident whom they visit and do not interact with other residents, the effect of loosening visiting policy may be underestimated. However, relaxing this assumption will lead to the same impact as increasing the number of visitors allowed. Also, interactions between visitors and residents other than the one whom they visit are unlikely to happen amidst the ongoing pandemic.

CONCLUSIONS

In conclusion, cohorting residents and staff into smaller, discrete units could help reduce the spread of COVID-19 in a care home. This intervention is especially effective when the risk of transmission per contact is high due to factors such as low compliance to hand hygiene, insufficient supplies of PPE, and difficulty in practicing social distancing. By contrast, the model predictions suggest that shielding residents in care homes will not be as effective as reported in a number of studies that have investigated shielding of vulnerable population in wider communities. Therefore, in specific circumstances, care homes could consider relaxing of visitation to the extent which they can ensure that visitors strictly comply to their infection control interventions to balance the risk of COVID-19 spread and residents' non-COVID-19 well-being.

DECLARATIONS

Ethics Approval

This research has been approved by the Ethics Committee of the Department of Management Science, Strathclyde University.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.urolonc.2021.07.001.

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