IMPACT OF VISITATION AND COHORTING POLICIES TO SHIELD RESIDENTS FROM COVID-19 SPREAD IN CARE HOMES: AN AGENT-BASED MODEL

Controlling COVID-19 in care homes

Ms. Le Khanh Ngan Nguyen[1,*], MPH, nguyen-le-khanh-ngan@strath.ac.uk, Prof. Susan Howick[1], Ph.D., susan.howick@strath.ac.uk, Mr Dennis McLafferty[2], MSc, McLaffertyDe@northlan.gov.uk, Mrs. Gillian Hopkins Anderson[1], BA, gillian.anderson.101@strath.ac.uk, Dr. Sahaya Josephine Pravinkumar[3], MPH, Josephine. Pravinkumar@lanarkshire.scot.nhs.uk, Dr. Robert Van Der Meer[1], Ph.D., robert.van-der-meer@strath.ac.uk, Dr. Itamar Megiddo[1], Ph.D., itamar.megiddo@strath.ac.uk

[1]Department of Management Science, Strathclyde Business School, University of Strathclyde, 199 Cathedral Street, Glasgow, G4 0QU, United Kingdom

[2]Adult Services, Health & Social Care North Lanarkshire, 1st Floor Civic Centre, Windmillhill St, Motherwell, ML1 1AB, United Kingdom

[3]Department of Public Health, National Health Services Lanarkshire, Kirklands Hospital, Fallside Road, Bothwell, G71 8BB, United Kingdom

[*]Corresponding author: PGR Suite, Department of Management Science, Strathclyde Business School, University of Strathclyde, 199 Cathedral Street, Glasgow, G4 0QU, United Kingdom

HIGHTLIGHTS

- **Shielding residents in care homes is not as effective as previously predicted ~~in a number of studies~~.**
- Maintaining a low risk of transmission per contact helps reduce the effect of relaxing visitation.
- Cohorting of residents and staff reduces the spread of COVID-19.
- The risk of outbreak occurrence in a care home is associated with its population size.

ABSTRACT

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.

KEYWORDS

Long term care, care homes, COVID-19, visitation, cohorting, agent-based models

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 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. six months). We assumed that all staff and residents are susceptible at the beginning of the simulation.

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)

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 nine 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 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 three 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 (Figure 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 two to five (95%CI) for the value of 0.1 (Figure 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 one to six days (95%CI) when visiting was banned across the values of infection probability per contact (Figure 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 (Figure 1-A).

Figure 1:

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 two to three (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) (Figure 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 (Figure 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 (Figure 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 three infections (95%CI: 3–4) when it was very high (0.1) (Figure 2-A). The elapsed time until the first resident is infected was prolonged by 26-41 days (95%CI) (Figure 2-B). Likewise, the risk of outbreak occurrence increased when allowing visitors into the care home (Figure 2-C).

Figure 2

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

Figure 3

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 (Figure 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 (Figure 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 (Figure 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 (Figure 4B).

Figure 4

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 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 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

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.

Funding: University Research Excellence Award (REA) Studentship

Ethics Approval

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

Conflicts of interests

We declare that all authors have no conflict of interest.

Acknowledgements

We would like to thank managers and staff in Highgate care home and other care homes in Lanarkshire for helpful discussion.

REFERENCES

1. van Bunnik BA, Morgan AL, Bessell P, et al. Segmentation and shielding of the most vulnerable members of the population as elements of an exit strategy from COVID-19 lockdown. *medRxiv.* 2020.

2. Van Zandvoort K, Jarvis C, Pearson C. Response strategies for COVID-19 epidemics in African settings: a mathematical modelling study. medRxiv. *Preprint Posted online May.* 2020;3(2020):10.1101.

3. McKeigue PM, Colhoun HM. Evaluation of" stratify and shield" as a policy option for ending the COVID-19 lockdown in the UK. *medRxiv.* 2020.

4. Neufeld Z, Khataee H, Czirok A. Targeted adaptive isolation strategy for Covid-19 pandemic. *Infectious Disease Modelling.* 2020.

5. Weitz J, Beckett S, Coenen A, Demory D, Dominguez-Mirazo M, Dushoff J. Intervention Serology and Interaction Substitution: Modeling the Role of'Shield Immunity'in Reducing COVID-19 Epidemic Spread. medRxiv. 2020 Apr; p. 2020.04. 01.20049767. In.

6. Stall NM, Johnstone J, McGeer AJ, Dhuper M, Dunning J, Sinha SK. Finding the Right Balance: An Evidence-Informed Guidance Document to Support the Re-Opening of Canadian Nursing Homes to Family Caregivers and Visitors during the COVID-19 Pandemic. *Journal of the American Medical Directors Association.* 2020.

7. Rajan S, Mckee M. Learning from the impacts of COVID-19 on care homes: a pilot survey. In: LTCcovid, International Long-Term Care Policy Network; 2020.

8. Lee T, Jordan NN, Sanchez JL, Gaydos JC. Selected nonvaccine interventions to prevent infectious acute respiratory disease. *American journal of preventive medicine.* 2005;28(3):305-316.

9. Burton JK, 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. *medRxiv.* 2020:2020.2007.2009.20149583.

10. Abrams HR, Loomer L, Gandhi A, Grabowski DC. Characteristics of U.S. Nursing Homes with COVID-19 Cases. *Journal of the American Geriatrics Society.* 2020.

11. Nguyen LKN, Howick S, McLafferty D, et al. Evaluating intervention strategies in controlling COVID-19 spread in care home. Manuscript submitted for publication. 2020.

12. National Records of Scotland. Deaths involving coronavirus (COVID-19) in Scotland. https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/vital-events/general-publications/weekly-and-monthly-data-on-births-and-deaths/deaths-involving-coronavirus-covid-19-in-scotland Published 2020. Accessed 20 June, 2020.

13. Public Health Scotland. Coronavirus (COVID-19) data. https://publichealthscotland.scot/our-areas-of-work/sharing-our-data-and-intelligence/coronavirus-covid-19-data/. Published 2020. Accessed 20 June, 2020.

14. Scottish Government. Coronavirus (COVID-19): daily data for Scotland. https://www.gov.scot/publications/coronavirus-covid-19-daily-data-for-scotland/ Published 2020. Accessed 9 August, 2020.

15. Perez-Reche F, Strachan N. Importance of untested infectious individuals for the suppression of COVID-19 epidemics. *medRxiv.* 2020.

16. van den Dool C, Bonten MJM, Hak E, Heijne JCM, Wallinga J. The Effects of Influenza Vaccination of Health Care Workers in Nursing Homes: Insights from a Mathematical Model. *PLoS medicine.* 2008;5(10):e200.

17. Chamchod F, Ruan S. Modeling the Spread of Methicillin-Resistant Staphylococcus aureus in Nursing Homes for Elderly. *PloS one.* 2012;7(1):e29757.

18. Port CL, Hebel JR, Gruber-Baldini AL, et al. Measuring the frequency of contact between nursing home residents and their family and friends. *Nursing Research.* 2003;52(1):52-56.

19. Wang K, Lu Z, Wang X, et al. Current trends and future prediction of novel coronavirus disease (COVID-19) epidemic in China: a dynamical modeling analysis. *Mathematical Biosciences and Engineering.* 2020;17(4):3052.

20. Tang B, Bragazzi NL, Li Q, Tang S, Xiao Y, Wu J. An updated estimation of the risk of transmission of the novel coronavirus (2019-nCov). *Infectious disease modelling.* 2020;5:248-255.

21. Ferguson N, Laydon D, Nedjati Gilani G, et al. Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID19 mortality and healthcare demand. 2020.

22. Scottish Government. National Clinical and Practice Guidance for Adult Care Homes in Scotland during the COVID-19 Pandemic. https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2020/03/coronavirus-covid-19-clinical-and-practice-guidance-for-adult-care-homes/documents/clinical-guidance-for-nursing-home-and-residential-care-residents/clinical-guidance-for-nursing-home-and-residential-care-residents/govscot%3Adocument/National%2BClinical%2BGuidance%2Bfor%2BCare%2BHomes%2BCOVID-19%2BPandemic-%2BMASTER%2BCOPY%2B-%2BFINAL%2B-%2B15%2BMay%2B2020.pdf. Published 2020. Accessed.

23. Hodgson K, Grimm F, Vestesson E, Brine R, Deeny S. Briefing: Adult social care and COVID-19. 2020.

24. 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. *Journal of Infection.* 2020.

25. Jarvis CI, Van Zandvoort K, Gimma A, et al. Quantifying the impact of physical distance measures on the transmission of COVID-19 in the UK. *BMC medicine.* 2020;18:1-10.

SUPPLEMENTARY MATERIALS

APPENDIX S1: ODD PROTOCOL (Adapted from the ODD Protocol in Appendix S1 in Nguyen LKN, Howick S, McLafferty D, et al. Evaluating intervention strategies in controlling COVID-19 spread in care home. *Infection Control and Hospital Epidemiology*. 2020.)

1. Purpose and Patterns

The purpose of the model is to understand the spread of COVID-19 and anticipate the prevalence and number of infected residents over time in a care home. It also aims to examine the effectiveness of infection prevention and control strategies in controlling COVID-19 in this setting. We evaluate our model by its ability to reproduce the patterns of the dynamics of outbreaks, reflecting the number of infections and deaths in Scottish care homes that have experienced outbreaks. We also evaluate the model's ability to reproduce the proportion of asymptomatic infections, reflecting reported outcomes in long term aged care setting in literature.

2. Entities, State Variables, and Scales

The following entities are included in the model: two types of agents, namely resident and staff agents, representing residents and staff in the care home. Each agent entity is characterized by a unique set of state variables which is described in greater detail in Table S1-1.

The resident agents are split into two units, each with their own group of staff agents representing care staff members (nurses and nursing/care assistants). A separate group of staff agents are shared between the two units and represent staff in other roles including housekeepers and wellbeing coordinators.

The model runs at a daily time step as epidemiological data are collected on a daily basis and the unit of time commonly used to describe clinical characteristics of COVID-19 in the literature is one day. Simulations are 365-day time steps long as this covers the period since the beginning of the pandemic until now and the upcoming period for which the clients are planning.

3. Process Overview and Scheduling

The model includes five actions executed in the following order at each time step (Fig. S1-2):

Entering:

<u>*Resident agents:*</u> New residents (AdmissionScheduled is "true") are admitted. Residents could be admitted from either hospitals or the community at equal probabilities based on discussions with care homes. Their ResidentInState is set to "exposed" at the corresponding probability determined by the parameters InfectionPrevalenceHospital and InfectionPrevalenceCommunity; otherwise, it is set to "susceptible". AdmissionScheduled is returned the value "false". The variable Age is drawn from an empirical distribution. Other state variables are reset as in *Initialization*.

<u>*Staff agents:*</u> If a staff agent's state variable Replaced is "true", it is altered to "false". If its variable AtWork is "false", it is set to "true" and vice versa. Susceptible permanent staff agents whose state variable AtWork is "true" and casual staff can introduce infections into the care home at the probability defined by (InfectionPrevalenceCommunity x RelativePrevalence). Infected staff agents can either be exposed or infectious (asymptomatic or presymptomatic) at equal probabilities.

Contact and Transmission: Agents (residents and staff agents whose state variable AtWork is "true") interact with one another following the corresponding contact rates and the rules described in the sub-model *Contact_Pattern*. Transmission occurs at the transmission probability per contact determined by the parameter InfectionProbability when a susceptible agent comes into contact with an infectious agent. When transmission occurs, the infection status of the susceptible agent (i.e.

ResidentInState or StaffInState) changes to “exposed”. Interactions between residents and visitors are described in the sub-model *Visitor_Interaction*. Interactions with isolated residents will result in no infection. The order of agents coming into contact with one another is executed randomly within this process.

State Transition:

Exposed → Pre/Asymptomatic: Exposed residents and staff agents transit to either the pre-symptomatic state at the probability pSymptomatic and pStaffSymptomatic respectively, or the asymptomatic state at the end of the period determined by the parameter ExposedTime.

Presymptomatic → Symptomatic: Presymptomatic agents develop symptoms (the infection status changes to “symptomatic”) at the end of their pre-symptomatic period defined by the parameter PresymptomaticTime. The probability that a symptomatic agent has severe symptoms is defined by the parameter pSevere and pStaffSevere for resident and staff agents respectively. Symptomatic residents are isolated (Isolation = “true’) without delay. Staff agents who develop symptoms have to self-isolate at home in the next time step until they recover and be covered by another staff member described in the sub-model *Change_Schedule*.

Asymp/Symptomatic → Recovered: Asymptomatic and symptomatic agents recover at the probability of (1 – DeathProbability) or (1 – StaffDeathProbability) for residents and staff respectively at the end of their Infectiousness duration corresponding to the severity of their symptoms (i.e. asymptomatic, mild or severe symptoms). Their state of infection changes to “recovered”. The variable Isolation of resident agents and SelfIsolation of staff agents are set to “false”. If such staff agents’ state variable Employment is “casual” implying that they have been covered by Bank/Agency staff, it is changed back to “permanent”.

Leaving: The AdmissionScheduled variables of residents who die or leave the care home are set to “true”. These agents represent residents admitted to the care home in the next time step to replace those dying or leaving in this time step. Infected residents die at the end of their infectiousness period at the probability DeathProbability specific to their Age. Residents in other states of infection could die or leave the care home for other reasons at the rate determined by the parameter LeavingRate. Infected staff could die at the probability StaffDeathProbability. Permanent staff could leave the care home for non-covid reasons at a rate defined by the parameter StaffTurnover. Staff who die or leave are replaced by new “susceptible” staff agents with other state variables being set as in Initialization.

4. Design Concepts

Basic principles:

The model simulates the transmission dynamics of COVID-19 via contacts between individuals, including residents, staff, and visitors within a hypothetical care home that represents a Scottish care home. The progression of COVID-19 infection after transmission is described in Fig. S1-3 and is based on the current understanding and evidence [1-3]. Recovered individuals are assumed to be immune to re-infection in the short term, and pre-/asymptomatic individuals are just as likely to transmit infection as symptomatic ones [4]. Individuals’ characteristics and behaviors, the contact network and pattern, and the operational and managerial features of the care home all influence how the virus spreads. These model processes and data are informed by discussions, surveys, and interviews with stakeholders, including Social Care, Council, and nursing homes in Lanarkshire. Infections can be imported into the care home by asymptomatic residents upon admission or by staff or visitors who acquired an infection in their community. Infection control measures are implemented to reduce the imported infections (e.g., testing upon admission and visit restriction), contain the intra-facility transmission by reducing contact rates (e.g., social distancing, isolation) and/or the risk of transmission per contact (e.g., hand hygiene and use of personal protective equipment (PPE)).

Emergence:

The key outcomes of the model are patterns for the occurrence and recurrence of outbreaks, surges of COVID-19 related deaths and staff acquiring infections in the care home. These outcomes emerge from the care home structure, contact network and pattern among residents and staff, how infections are imported into the facility, infection control measures implemented, and staff's compliance with such measures.

Adaptation:

Staff agents that exhibit symptoms or test positive leave the care home. In isolation scenarios, residents who exhibit symptoms or test positive are isolated. When social distancing is implemented, staff and residents adapt to the situation by decreasing their contact rate with other staff members and residents respectively. Residents do not come into contact with other residents in the other unit either.

Objectives:

Staff agents' implicit objective when deciding whether to comply with infection control measures such as hand hygiene, using PPE, practicing social distancing is preventing an outbreak in the care home. Their adaptive behaviors aim to reduce transmission rates and help contain the outbreak.

Learning:

Learning is not implemented.

Prediction:

Staff agents' adaptive behavior is based on implicit predictions that leaving when exhibiting symptoms and social distancing will reduce the number of contacts. Further, increasing compliance to hand hygiene and using PPE will reduce the risk of transmission per contact. Both reduce the spread of infections.

Sensing:

Agents can sense with whom they are in contact. Staff agents can sense the infection status of residents who display symptoms and exposed or asymptomatic residents who are tested positive. Staff who develop symptoms can also sense their own state of health and do not return to work the next day.

Interaction:

Agents direct interactions are shown in Fig. S1-4. Residents can interact with other residents, staff, and visitors. Staff can interact with other staff and visitors. The network and rates of interactions between residents and staff are defined based on the management policy of a care home and the implemented infection control interventions.

Stochasticity:

Residents' age is initialized stochastically as this characteristic affects residents' risk of death as an outcome of the infection. Stochasticity is used to describe variability in the parameters that determine the transitions of individuals between different states of infection, including the incubation time and the transmission probability. This represents variations in the risk of acquiring the infection and the progression and outcome of the infection among people, influenced by factors such as their health status, underlying conditions, and immune system. Additionally, the interaction between individuals is a stochastic process as randomness exists in contact rates, with whom they come into contact, and the order in which contacts between individuals occur. Another stochastic element is individuals' compliance to an infection control intervention. These stochastic elements demonstrate how heterogeneous behaviors, contact network and pattern can affect the spread of the infection. The time at which individuals (staff members, new residents, and visitors) introduce the infection into the care home is also stochastic and is based on the infection probability and the prevalence in the community.

***Collectives*:**

The model has three collectives: the two units and the shared ancillary staff group. The collective to which agents belong affects whom they can interact with.

Observation:

The primary outputs of interest are the cumulative number of infected residents, the elapsed time until first resident is infected, and the risk of outbreak occurrence.

5. Initialization

The number of residents and staff and the operational structure in the base case model are informed by discussions with the manager of a representative care home for older people. The model is initialized with 80 resident agents and 72 staff agents in the base case. The first unit (UnitID = 1) has 40 resident agents and 33 staff agents. The second unit (UnitID = 2) has 40 resident agents and 32 staff agents. A group of seven staff agents are shared between the two units (UnitID = 3). The number of staff agents present in the care home is 16 and 15 for Unit 1 and 2 respectively. All shared staff are on duty. There are two Bank/Agency staff in Unit 1 and one in Unit 2.

The variable Age of residents is drawn from an empirical distribution based on the demographic data of older people adult care homes in North Lanarkshire. Initial values of variables and parameters for the baseline scenario (no intervention) are summarized in Table S1-5. In intervention scenarios, interventions start on day 1 and remain for the entire simulated time. How relevant state variables and parameters are altered for each intervention is described in greater details in the sub-model *Intervention.*

Depending on the aims, in some simulations one random resident is exposed to the virus at the beginning of the simulation and others are susceptible. In other simulations, no agents are infected at the beginning of simulation. Instead, infection in the care home occurs through visitor and care worker interactions with the community.

6. Input Data

A time-series of Covid-19 infection prevalence in Scotland adjusted for undetected cases describes prevalence in the community. We adopted the worse situation that the undetected cases represent 80% of the total cases in the community.[6] The adjusted prevalence is, therefore, calculated by multiplying the infection prevalence reported by Public Health Scotland by five.

7. Submodels

Parameters used in the model are described in Table S1-6.

Intervention:

Parameter values dependent on interventions are described in Table S1-7.

Contact_Patterns:

The patterns for interactions between individuals are informed by discussions with the manager and care staffs in a representative care home, in the base case:

- A staff member (UnitID = 1 or 2) can interact with any random staff in the same unit at the rate *ContactRateSS*.

- A staff member (UnitID = 1 or 2) can interact with any random resident in the same unit at the rate *ContactRateRR*.
- A resident can interact with any random resident in the other unit at the probability *ContactAcrossUnits*.
- A staff member in the shared group (UnitID = 3) can interact with any random resident or staff member from any unit at the rate *ContactRateSR* and *ContactRateSS* respectively.
- Isolation of infected residents is assumed to be 100% effective at preventing further transmission (i.e. interactions with isolated residents result in no infection).
- Only staff agents that are present in the care home (the state variable AtWork = true) can interact with other agents.

Visitor_Interaction:

Susceptible residents could acquire the infection when coming into contact with visitors who are asymptomatic. Visitors are not explicitly represented as agents in the model as there is no need to consider visitors at an individual level. The model only considers the transmission from visitors to residents. Whether visitors may acquire the infection from residents or staff in the care home and how they spread it elsewhere are not within this model's scope. In each time step, the number of infectious visitors that come into contact with each susceptible resident are drawn from a Poisson distribution with a mean that equals to (VisitorsPerDay x InfectionPrevalenceCommunity). Similarly, the number of infectious visitors that interact with a staff member are drawn from a Poisson distribution with the mean of (ContactRateSV x InfectionPrevalenceCommunity). Transmission of such contacts occurs at the probabilities InfectionProbabilityRV and InfectionProbability respectively.

Change_Schedule:

A staff agent who develops symptoms and self-isolates will be covered by another staff member. Its state variable SelfIsolation is set to "true". The replaced staff agent is randomly chosen from the corresponding staff pool including staff agents that have the same UnitID, are not already on duty (AtWork = false) or in self-isolation (SelfIsolation = false), and have not been scheduled to replace someone else (Replaced = false). The state variables Replaced of both replacing and replaced agents are altered to "true". If none of staff agents in the pool satisfies these conditions, the agent' Employment is set to "casual".

APPENDIX S2: CONFIDENCE BUILDING

.

APPENDIX S3: ADDITIONAL PLOTS OF MODELLING RESULTS

.

REFERENCES

1. Ferguson N, Laydon D, Nedjati Gilani G, et al. Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID19 mortality and healthcare demand. 2020.

2. Verity R, Okell LC, Dorigatti I, et al. Estimates of the severity of coronavirus disease 2019: a model-based analysis. *The Lancet infectious diseases.* 2020.

3. He X, Lau EH, Wu P, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nature medicine.* 2020:1-4.

4. Centers for Disease Control and Prevention. COVID-19 Pandemic Planning Scenarios. https://www.cdc.gov/coronavirus/2019-ncov/hcp/planning-scenarios.html. Published 2020. Accessed 13 June, 2020.

5. Information Services Division. Care Home Census for Adults in Scotland, 2016. Edinburgh: ISD; 2016. Available from: http://www.isdscotland.org/Health-Topics/Health-and-Social-CommunityCare/Publications/2016-10-25/2016-10-25-CHCensus-Report.pdf.

6. Perez-Reche F, Strachan N. Importance of untested infectious individuals for the suppression of COVID-19 epidemics. *medRxiv.* 2020.

7. National Records of Scotland. Deaths involving coronavirus (COVID-19) in Scotland. https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/vital-events/general-publications/weekly-and-monthly-data-on-births-and-deaths/deaths-involving-coronavirus-covid-19-in-scotland Published 2020. Accessed 20 June, 2020.

8. Public Health Scotland. Coronavirus (COVID-19) data. https://publichealthscotland.scot/our-areas-of-work/sharing-our-data-and-intelligence/coronavirus-covid-19-data/. Published 2020. Accessed 20 June, 2020.

9. Scottish Government. Coronavirus (COVID-19): daily data for Scotland. https://www.gov.scot/publications/coronavirus-covid-19-daily-data-for-scotland/ Published 2020. Accessed 9 August, 2020.

10. Kulu H, Dorey P. The contribution of age structure to the number of deaths from Covid-19 in the UK by geographical units. *medRxiv.* 2020.

11. van den Dool C, Bonten MJM, Hak E, Heijne JCM, Wallinga J. The Effects of Influenza Vaccination of Health Care Workers in Nursing Homes: Insights from a Mathematical Model. *PLoS medicine.* 2008;5(10):e200.

12. Chamchod F, Ruan S. Modeling the Spread of Methicillin-Resistant Staphylococcus aureus in Nursing Homes for Elderly. *PloS one.* 2012;7(1):e29757.

13. Port CL, Hebel JR, Gruber-Baldini AL, et al. Measuring the frequency of contact between nursing home residents and their family and friends. *Nursing Research.* 2003;52(1):52-56.

14. Scottish Care. Care home workforce data report. https://scottishcare.org/wp-content/uploads/2019/11/Care-Home-Workforce-Data-2018.pdf. Published 2018. Accessed 15 August, 2020.

15. Wang K, Lu Z, Wang X, et al. Current trends and future prediction of novel coronavirus disease (COVID-19) epidemic in China: a dynamical modeling analysis. *Mathematical Biosciences and Engineering.* 2020;17(4):3052.

16. Tang B, Bragazzi NL, Li Q, Tang S, Xiao Y, Wu J. An updated estimation of the risk of transmission of the novel coronavirus (2019-nCov). *Infectious disease modelling.* 2020;5:248-255.

17. Lauer SA, Grantz KH, Bi Q, et al. The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application. *Annals of internal medicine.* 2020.

18. McAloon CG, Collins A, Hunt K, et al. The incubation period of COVID-19: A rapid systematic review and meta-analysis of observational research. *medRxiv.* 2020.

19. Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. *International journal of infectious diseases.* 2020.

20. Gatto M, Bertuzzo E, Mari L, et al. Spread and dynamics of the COVID-19 epidemic in Italy: Effects of emergency containment measures. *Proceedings of the National Academy of Sciences.* 2020;117(19):10484-10491.

21. Byrne AW, McEvoy D, Collins A, et al. Inferred duration of infectious period of SARS-CoV-2: rapid scoping review and analysis of available evidence for asymptomatic and symptomatic COVID-19 cases. *medRxiv.* 2020.

22. Wölfel R, Corman VM, Guggemos W, et al. Virological assessment of hospitalized patients with COVID-2019. *Nature.* 2020;581(7809):465-469.

23. Kerr CC, Stuart RM, Mistry D, et al. Covasim: an agent-based model of COVID-19 dynamics and interventions. *medRxiv.* 2020.

24. Matrajt L, Leung T. Evaluating the Effectiveness of Social Distancing Interventions to Delay or Flatten the Epidemic Curve of Coronavirus Disease. *Emerging infectious diseases.* 2020;26(8).

25. Watson J, Whiting PF, Brush JE. Interpreting a covid-19 test result. *Bmj.* 2020;369.

26. Arevalo-Rodriguez I, Buitrago-Garcia D, Simancas-Racines D, et al. False-negative results of initial RT-PCR assays for COVID-19: a systematic review. *medRxiv.* 2020.

27. Scottish Government. National Clinical and Practice Guidance for Adult Care Homes in Scotland during the COVID-19 Pandemic. https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2020/03/coronavirus-covid-19-clinical-and-practice-guidance-for-adult-care-homes/documents/clinical-guidance-for-nursing-home-and-residential-care-residents/clinical-guidance-for-nursing-home-and-residential-care-residents/govscot%3Adocument/National%2BClinical%2BGuidance%2Bfor%2BCare%2BHomes%2BCOVID-19%2BPandemic-%2BMASTER%2BCOPY%2B-%2BFINAL%2B-%2B15%2BMay%2B2020.pdf. Published 2020. Accessed.

28. Taylor R. Interpretation of the correlation coefficient: a basic review. *Journal of diagnostic medical sonography.* 1990;6(1):35-39.

Figure 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

Figure 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

Figure 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

Figure 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.

Fig. S1-2. The process overview and scheduling of the model at each time step

Fig. S1-3. The progression of Covid-19 infections
Susceptible people may acquire the infection when exposed to infectious sources. They are infected but not yet infectious (exposed state). Once exposed people become infectious, they can either remain asymptomatic for the entire infectious period or develop symptoms after a pre-symptomatic period. Symptoms could be mild or severe and require hospitalizations. Infectious people will eventually recover or die

Fig. S1-4. Interactions between residents, staff and visitors in a care home
The dashed lines linking individuals denote their possible ways of interaction. Different colours are used for these lines to distinguish different types of interaction: blue – staff-resident interaction; green: resident-resident interaction; red: staff-staff interaction; black: resident-visitor interaction; purple: staff – visitor interactions.

Fig. S2-1. Cross-validation for time series prevalence of COVID-19 among residents
The time series prevalence of COVID-19 among residents of the model over 1,000 runs (boxplot) is compared with that of the observed data from a care home in Lanarkshire (red points). The care home implements the reference intervention and is closed to admission of new residents and visitors 10 days after the first resident develops COVID-19 symptoms. Boxplot: lower hinge: 25% quantile; lower whisker: smallest observation greater than or equal to lower hinge − 1.5×IQR; middle: median; upper hinge: 75% quantile; upper whisker: largest observation less than or equal to upper hinge + 1.5×IQR

Fig. S3-1.: Impact of visiting policy and transmission risk per contact on the spread of COVID-19
A: Distributions of the cumulative number of infected residents 90 days after the simulation starts
B: Distribution of the elapsed time until the first resident is infected in the care home
Under no visitation and normal visitation policy across different values of infection probability per contact for the base case care home with population size of 80 residents. Vertical lines denote the means of distributions. The weekly testing of staff is implemented. The care home operates at full capacity; residents who decease or leave are replaced by admissions of new residents. Other parameters take the base case values. All infectious-susceptible contacts have the same infection probability. The community prevalence of COVID-19 where staff live and where residents live are equal.

Fig. S3-4. Impact of unit size on the risk of an outbreak occurrence
The impact of splitting the care home with size of 80 residents into one, two, four, and eight units with 80, 40, 20, and 10 residents per unit respectively on the probability that an outbreak occurs across a range of values of infection probability per contact in the reference intervention and weekly staff testing scenarios. 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. Points represent the mean values of 1000 simulations; error bars represent 95% CIs of the means.

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
InfectionPrevalence Hospital	Infection prevalence in the hospital	0.02	Triangular distribution (min = 0, max = 0.5, mode = 0.2)	[12-14](estimated)
InfectionPrevalence 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
ContactRateRR	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	Mean of the Poisson distribution is drawn from a triangular distribution (min = 1, max = 5, mode = 3.9)	[16,17]

		resident per day		
ContactRateSS	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]
ContactRateSR	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]
ContactRateSV	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
ContactAcross 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
VisitorsPerDay	The average number of people visiting a resident per	1.0 visitor per resident per day	Triangular distribution (min = 0, max = 2.0, mode = 1.0	[16,18]

	day			
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
InfectionProbability 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

Table S1-1: The state variables of resident and staff agents and the global environment

Variable name	Variable type, units and range	Meaning and rationale
Resident-agent-specific state variables		
unitID	Integer, static; no unit; [1,2,3]	The ID of the unit where a resident stays. It affects who a resident can come into contact with. E.g., In specific simulation runs, a resident only comes into contacts with other residents living in the same unit.
Age	Integer, static; years old; [18 – 110]	The age of a resident which affects their infection fatality rate.

ResidentInState	String, dynamic; no unit; "susceptible", "exposed", "asymptomatic", "presymptomatic", "symptomatic", or "recovered"	The infection state of a resident. Asymptomatic, presymptomatic and symptomatic residents are infectious.
Severity	Integer, dynamic; no unit; 0 = no symptom, 1 = mild, 2 =severe	The severity of symptoms in symptomatic cases, which affect the duration of infectiousness
AdmissionScheduled	Boolean, dynamic; no unit; true/false	This variable denotes a resident agent leaving the care home or dying, and waiting for admission as a new agent.
Isolation	Boolean, dynamic; no unit; true/false	This variable indicates whether a resident is isolated.
Tested	Boolean, dynamic; no unit; true/false	This variable indicates whether a resident receives a RT-PCR test for COVID-19.
Staff-agent-specific state variables		
unitID	Integer, static; no unit; [1, 2, 3]	The ID of the unit where a member of staff works. It affects with whom a staff can come into contact.
Employment	String, static; no unit; "casual" (Bank or Agency staff) or "permanent"	The employment status of a staff
StaffInState	String; dynamic; no unit; "susceptible", "exposed", "asymptomatic", "presymptomatic", "symptomatic" or "recovered"	The infection state of a member of staff
Severity_Staff	Integer, dynamic; no unit; 0 = no symptom, 1 = mild, 2 =severe	The severity of symptoms in symptomatic cases, which affects the duration of infectiousness
AtWork	Boolean; dynamic; no unit; true/false	The variable indicates whether a staff member is on duty.
SelfIsolation	Boolean; dynamic; no unit; true/false	The variable indicates whether a staff member is self-isolating at home.
Replaced	Boolean; dynamic; no unit; true/false	The variable indicates whether a staff member is replaced by or replaces another staff member in the next time step.
Tested	Boolean, dynamic; no unit; true/false	This variable indicates whether a resident receives a RT-PCR test for COVID-19.

Table S1-5: Initial values of entities' state variables and parameters

Variable/ Parameter	Initial value	Sources
Resident-agent-specific state variables		
unitID	1 for 40 resident agents 2 for the remaining 40 resident agents	Discussions with the manager of a Scottish care home for older people
Age	Drawn from empirical distribution: 18-64 years old: 3%	[5] (Calculated from data for older people care homes in North Lanarkshire)

	65-74 years old: 13% 75-84 years old: 39% 84-94 years old: 39% 95 and older: 6%	
ResidentInState	"susceptible" with one resident assigned "exposed"	
Severity	0	
AdmissionScheduled	False	
Isolation	False	
Tested	False	
Staff-agent-specific state variables		
unitID	1 for 33 staff agents 2 for the other 32 staff agents 3 for the remaining seven staff agents	
Employment	"casual" for two staff from unit 1 and one staff from unit 2 "permanent" for the rest	Discussions with the manager of a Scottish care home for older people
StaffInState	"susceptible"	
AtWork	True for all causal staff and 14 permanent staff agents from each unit False for the rest	
SelfIsolation	False	
Replaced	False	
Tested	False	

Table S1-6: Parameters used in the model

Parameter name	Meaning and rationale	Default Value	Sensitivity Analysis	Source
InfectionPrevalenceHospital	Infection prevalence in the hospital	0·02	Triangular distribution (min = 0, max = 0·5, mode = 0·2)	[7-9] (estimated)
InfectionPrevalenceCommunity	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)	[6,8] 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)
Relative-prevalence	Ratio of infection prevalence in the community where staff live to the	1·0	Triangular distribution (min = 0, max = 0·5, mode = 1·0)	Discussions with care home stakeholders in Lanarkshire

	prevalence where visitors come from			
DeathProbability	The probability that an infected resident deceases (age-specific)	Drawn for each individual resident from empirical distribution: 80+ years old: 11% 70-79 years old: 6·0% 60-69 years old: 2·6% 50-59 years old: 0·71% 40-49 years old: 0·18% 30-49 years old: 0·09% 20-29 years old: 0·04% 18-20 years old: 0·007%	No (This parameter does not impact our main model outcome, the number of infected residents, significantly. It will likely be the most important parameter when we consider deaths as an outcome of the model)	[1,10] (The Infection Fatality Rate (IFR) for Scotland is adjusted based on the overall aged-adjusted IFR value for the UK and the relative IFR value (= 1·18) for other urban areas in Scotland. The majority of population (>80%) in North Lanarkshire live in areas classified as other urban areas.)
StaffDeath Probability	The probability that an infected staff member dies	Drawn for each individual staff member from a uniform distribution (0·0003 – 0·022)	No	[1,10]
ContactRateRR	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)	[11,12]
ContactRateSS	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)	[11,12]
ContactRateSR	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)	[11,12]
ContactRateSV	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
ContactAcrossUnits	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
VisitorsPerDay	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	[11,13]
LeavingRate	The rate at which residents leave the care home because	0.005 deaths or discharges per resident	Triangular distribution (min = 0·001, max = 0·005,	[5] (Calculated from data for care homes in North

	of deaths caused by other reasons, moving to another facility, admitted to hospitals, or returning to their own home (rare)	per day	mode = 0·004)	Lanarkshire)
StaffTurnover	Staff turnover rate	24% per year	Triangular distribution (min = 0·1, max = 0·5, mode = 0·24)	[14]
pSymptomatic	The probability that an infected resident will develop symptoms	Drawn for each individual resident from empirical distribution: 80+ years old: 0·9 70-79 years old: 0·85 60-69 years old: 0·8 50-59 years old: 0·75 40-49 years old: 0·7 30-49 years old: 0·65 20-29 years old: 0·6 18-20 years old: 0·55	Triangular distribution (min = 0·5, max = 0·9, mode = 0·8)	[1,2]
pStaffSymptomatic	The probability that an infected staff member will develop symptoms	0·7	Triangular distribution (min=0·5, max=0·9, mode=0·7)	[1,2] (For a population like the UK or US)
pSevere	The probability that a symptomatic resident has severe symptoms	Drawn for each individual resident from empirical distribution: 80+ years old: 0·28 70-79 years old: 0·25 60-69 years old: 0·17 50-59 years old: 0·11 40-49 years old: 0·05 30-49 years old: 0·03 20-29 years old: 0·01 18-20 years old: 0·001	No (This parameter does not affect the model outcomes)	[1,10] The proportion of symptomatic cases requiring hospitalizations for Scotland is adjusted based on the overall aged-adjusted value for the UK
pSatffSevere	The probability that a symptomatic staff member has severe symptoms	Drawn for each individual staff member from a uniform distribution (0·01-0·17)	No	[1,10]
InfectionProbability	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)	[1,15,16]
InfectionProbabilityRV	The infection probability per contact between	0·02	Triangular distribution (min = 0·001, max = 0·1, mode	[1,15,16]

	residents and visitors		= 0·02)	
ExposedTime	The time elapsed between first exposure and becoming infectious	Lognormal (μ = 1·16, σ = 0·85)	No (This parameter does not significantly affect number of infections as exposed individuals are not infectious. Also, values for this parameter are relatively consistent across studies.)	[17-19] (Lognormal (mean = 4·6, std = 4·8)
Presymptomatic Time	The time elapsed between becoming infectious and onset of symptoms	Discrete uniform distribution (1,3)	No (Values for this parameter are consistent across studies)	[3,20,21]
Infectiousness	The time elapsed between onset of symptoms and recovery (or recovery time for those who remain asymptomatic)	Asymptomatic: Lognormal (μ = 2·049, σ = 0·246) Symptomatic: -Mild: Lognormal (μ = 2·049, σ = 0·246) -Severe: Lognormal (μ = 2·624, σ = 0·170)	No (There is a strong consensus about the distribution of this parameter in literature.)	[22,23]
SocialDistancing Compliance	The reduction of resident-resident and staff-staff interactions when social distancing is implemented	0·75	Triangular distribution (min = 0·2, max = 0·9, mode = 0·75)	Assumed (based on other models' assumption [1,24] and discussions with care home staff and managers)
TestSensitivity	The sensitivity of RT-PCR test	0·7	Triangular distribution (min = 0·6, max = 0·98, mode = 0·7)	[25,26]
TestInterval	The interval between tests in routine testing scenarios	7 days		Discussion with representatives from Public Health Medicine (NHS Lanarkshire) and Lanarkshire Health and Social Care Partnership
TestDelay	The lag between testing and test result	2 days	No (Implemented in scenario-based uncertainty analysis in our previous work)	Discussion with representatives from Public Health Medicine (NHS Lanarkshire) and Lanarkshire Health and Social Care Partnership
Isolation Effectiveness	Effectiveness of isolation of infected residents	100%	Triangular distribution (min = 50%, max = 1000%, mode = 75%)	Assumed (based on other models' assumption [1,24] and discussion with care homes in Lanarkshire)

Table S1-7: Infection control measures and how model parameters are modified when a measure is adopted

Infection Control Intervention		Modified Parameter
Temporary closure to admissions	Closed to admissions	ClosedToAdmission = true;
	Opened to admissions	ClosedToAdmission = false;
Social distancing		The parameter SDCompliance is used to control the compliance rate to the social distancing measure. ContactRateRR and ContactRateSS are reduced by (1 –SDCompliance). Residents in different units do not interact with each other (ContactAcrossUnits = 0).
Testing upon admission		Residents can be admitted after two negative tests [27]. The probability of identifying true positive after two tests equals to (1 - (1 -TestSensitivity)^2)
Isolation of infected residents		Their state variable Isolation is set to "true". Interactions between isolated residents and other individuals result in no infection at the probability *IsolationEffectiveness*. The model assumes no delay between onset of symptoms and isolation.
Testing of staff		Staff members who are tested have their state variable Tested set to "true". After the time delay from testing to test result determined by the parameter TestDelay, the state variable Tested is set to "false" and infected staff are detected at the probability TestSensitivity and have to self-isolate.
Change of visiting policy		The parameter VisitorsPerDay is changed depending to the care home's visiting policy. The contact rate between staff and visitors (i.e. ContactRateSV) also changes accordingly.
Cohorting		Staff and residents in the same cohort are assigned the same UnitID. Interactions only occur between individuals with the same UnitID. When there are some contacts across cohorts, residents and staff can contact with other residents and staff in any other cohorts at a predefined probability *ContactAcrossUnits*.

Table S2-1: Set up for uncertainty analyses of care home capacity, structure, and staff pool system

Capacity (Total residents)	Number of units	Unit size (Residents per unit)	Care staff member per units per day	Total staff
Base case model				
80	2	40	16/15	33/32 staff members per unit
Population Size				
30	2	15	6	12 staff members per unit
50	2	25	10	21 staff members per unit
120	2	60	24	50 staff members per unit
Number of units				
80	1	80	31	65 staff members
80	4	20	8	16 staff members per unit
80	8	10	4	8 staff members per unit
Residents per staff ratio				

(Staff-resident contact rate is adjusted accordingly)				
80	2	40	8	16 staff members per unit
80	2	40	32	64 staff members per unit

Table S2-2: Outputs from Partial Rank Correlation Coefficient analyses

Parameter	Reference intervention		Weekly staff testing	
	PRCC	**p-value**	**PRCC**	**p-value**
	Outcome 1: Cumulative number of infected residents after 180 days			
Infection prevalence in hospitals	0·00	2·8E-01	0·01	7·4E-05
Infection prevalence in the community	0·51	0·0E+00	0·68	0·0E+00
Relative infection prevalence	0·00	2·2E-01	0·30	0·0E+00
Average resident-resident contact rate	0·06	2·0E-89	0·21	0·0E+00
Average staff-staff contact rate	-0·01	6·0E-02	0·01	4·1E-02
Average staff-resident contact rate	0·21	0·0E+00	0·38	0·0E+00
Average staff-visitor contact rate	0·37	0·0E+00	0·22	0·0E+00
Contact across units	0·00	7·6E-01	0·01	3·9E-02
Average number of visitors per reisdent per day	0·41	0·0E+00	0·36	0·0E+00
Leaving rate	0·29	0·0E+00	0·17	0·0E+00
Staff turnover	0·05	4·1E-58	0·11	8·7E-257
Probability of symptomatic among infected residents	-0·01	4·8E-03	0·01	2·0E-02
Probability of symptomatic among infected staff	0·04	4·5E-37	-0·09	7·4E-191
Infection probability	0·82	0·0E+00	0·93	0·0E+00
Infection probability per resident-visitor contact	0·06	6·2E-89	0·24	0·0E+00
Social distancing compliance	-0·07	2·3E-110	-0·27	0·0E+00
Isolation effectiveness	0·01	3·8E-03	0·06	7·0E-78
Test sensitivity	-0·01	2·8E-04	-0·28	0·0E+00
	Outcome 2: Time until the first resident is infected			
Infection prevalence in hospitals	0·00	7·2E-01	0·00	1·5E-01
Infection prevalence in the community	-0·52	0·0E+00	-0·52	0·0E+00
Relative infection prevalence	-0·15	0·0E+00	-0·15	0·0E+00
Average resident-resident contact rate	0·00	6·7E-01	0·00	5·6E-01
Average staff-staff contact rate	-0·01	1·0E-01	0·00	6·0E-01
Average staff-resident contact rate	-0·03	4·9E-22	-0·04	5·2E-31
Average staff-visitor contact rate	-0·01	1·5E-03	-0·01	4·3E-06
Contact across units	0·01	1·5E-02	0·00	8·5E-01
Average number of visitors per reisdent per day	-0·19	0·0E+00	-0·20	0·0E+00
Leaving rate	0·00	8·1E-01	0·00	2·3E-01
Staff turnover	0·00	8·5E-01	0·00	7·5E-01

Probability of symptomatic among infected residents	0·00	8·0E-01	0·00	8·3E-01
Probability of symptomatic among infected staff	0·00	8·1E-01	0·00	4·2E-01
Infection probability	-0·17	0·0E+00	-0·17	0·0E+00
Infection probability per resident-visitor contact	-0·23	0·0E+00	-0·24	0·0E+00
Social distancing compliance	0·00	3·3E-01	0·00	3·8E-01
Isolation effectiveness	0·01	6·1E-02	0·01	2·2E-02
Test sensitivity	0·00	3·4E-01	0·00	2·1E-01
	Outcome 3: The risk of outbreak occurrence within 90 days			
Infection prevalence in hospitals	0·00	7·6E-01	0·00	4·5E-01
Infection prevalence in the community	-0·51	0·0E+00	-0·52	0·0E+00
Relative infection prevalence	-0·25	0·0E+00	-0·24	0·0E+00
Average resident-resident contact rate	0·00	3·2E-01	0·00	7·3E-01
Average staff-staff contact rate	-0·01	5·2E-03	0·00	5·1E-01
Average staff-resident contact rate	-0·07	6·1E-112	-0·07	9·0E-118
Average staff-visitor contact rate	-0·03	4·0E-24	-0·04	3·1E-29
Contact across units	0·01	1·9E-02	0·00	9·4E-01
Average number of visitors per reisdent per day	-0·19	0·0E+00	-0·20	0·0E+00
Leaving rate	0·00	4·0E-01	0·01	1·3E-02
Staff turnover	0·00	8·0E-01	0·00	9·1E-01
Probability of symptomatic among infected residents	0·00	6·3E-01	0·00	6·6E-01
Probability of symptomatic among infected staff	0·00	9·0E-01	0·00	4·1E-01
Infection probability	-0·35	0·0E+00	-0·35	0·0E+00
Infection probability per resident-visitor contact	-0·21	0·0E+00	-0·22	0·0E+00
Social distancing compliance	0·01	7·9E-02	0·00	2·5E-01
Isolation effectiveness	0·01	8·9E-02	0·00	7·3E-01
Test sensitivity	0·00	4·1E-01	0·01	1·9E-04

A negative value indicates a negative correlation – increasing the parameter decreases the outcome. A positive value indicates a positive correlation – increasing the parameter increases the outcome. In PRCC analysis in general, the parameters with large PRCC values (> 0·5 or < – 0·5) and corresponding small p-values (< 0·05) are deemed the most influential in the model [28]

Table S3-2: Percent of simulations in which an outbreak occurs 30, 60, and 180 days after the simulation starts

The results presented are for care homes with different capacities in reference intervention and weekly staff testing scenarios (1,000 runs for each scenario). Base case values are used for other parameters.

Population Size (residents)	Percent of simulations with the presence of an outbreak (%)					
	Reference Intervention			Weekly Staff Testing		
	Infection probability per contact					
	0·005	**0·02**	**0·05**	**0·005**	**0·02**	**0·05**
	After 30 days					
10	0·1	1·1	1·9	0·2	0·3	1·1
20	0·3	2·2	4·8	0·2	0·8	3·2
30	0·3	3·4	6·1	0·3	2·3	5·0
40	0·4	3·7	10·4	0·3	2·6	5·2
50	0·7	5·3	13·8	0·3	2·7	7·1
60	1·2	6·3	15·1	0·8	3·7	10·0
70	1·8	7·5	16·7	0·9	4·1	10·8
80	1·9	9·2	20·1	1·0	5·1	12·1
90	1·9	9·7	22·2	1·2	5·3	15·9
100	2·6	12·4	24·7	1·3	6·5	14·0
	After 60 days					
10	4·2	21·5	42·6	1·5	9·1	23·1
20	8·5	42·5	65·0	2·0	16·5	43·0
30	12·2	57·0	81·0	3·4	27·7	53·8
40	20·6	69·5	88·8	6·0	37·1	63·2
50	23·1	75·8	94·0	9·9	45·7	73·5
60	32·9	83·8	97·0	12·9	53·6	82·4
70	38·5	89·5	98·6	15·2	57·9	86·9
80	41·9	91·9	99·0	17·4	63·7	90·4
90	48·2	95·0	99·6	22·1	69·9	92·9
100	53·8	96·1	99·5	22·2	71·7	95·0
	After 90 days					
10	11·4	52·7	80·4	4·2	24·6	53·0
20	26·0	82·5	96·1	7·0	45·4	80·3
30	41·0	92·0	99·5	13·4	62·6	89·4
40	52·8	97·3	99·7	20·5	76·4	95·2
50	65·0	99·4	100·0	29·4	82·5	97·4
60	74·5	99·7	100·0	34·6	88·8	99·4
70	80·4	100·0	100·0	41·8	93·8	99·8
80	85·7	100·0	100·0	46·0	95·5	99·9
90	89·5	100·0	100·0	55·0	96·9	100·0
100	93·2	100·0	100·0	59·5	98·7	100·0
	After 180 days					
10	29·3	91·7	99·7	12·0	55·6	88·1
20	59·9	99·7	100·0	25·6	84·3	99·2

30	81·5	99·8	100·0	38·9	95·8	99·9
40	90·7	100·0	100·0	53·3	98·3	100·0
50	96·9	100·0	100·0	66·6	99·5	100·0
60	98·5	100·0	100·0	73·4	99·9	100·0
70	99·2	100·0	100·0	83·6	100·0	100·0
80	99·7	100·0	100·0	86·7	100·0	100·0
90	99·9	100·0	100·0	92·6	100·0	100·0
100	100·0	100·0	100·0	95·1	100·0	100·0