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Factors associated with transmission of COVID-19 in long-term care facility outbreaks

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Background: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has had a disproportionate impact on residents in long-term care facilities (LTCFs).
Aim: To identify risk factors associated with outbreak severity to inform current outbreak management and future pandemic preparedness planning efforts.
Methods: A retrospective cohort study design was used to evaluate the association between non-modifiable factors (facility building, organization level, and resident population characteristics), modifiable factors (measured through an assessment tool for infection prevention and control (IPC) and pandemic preparedness), and severity of COVID-19 outbreaks (attack rate) in LTCFs.
Findings: From March 1st, 2020 to January 10th, 2021, a total of 145 exposures to at least one confirmed case of COVID-19 in 82 LTCFs occurred. Risk factors associated with increased outbreak severity were older facility age, a resident (vs staff) index case, and poorer assessment tool performance. Specifically, for every item not met in the assessment tool, a 22% increase in the adjusted rate ratio was observed (1.2; 95% confidence interval: 1.1–1.4) after controlling for other risk factors.
Conclusion: Scores from an assessment tool, older building age, and the index case being a resident were associated with severity of COVID-19 outbreaks in our jurisdiction. The findings reinforce the importance of regularly assessing IPC measures and outbreak preparedness in preventing large outbreaks. Regular, systematic assessments incorporating IPC and outbreak preparedness measures may help mitigate impacts of future outbreaks and inform future pandemic preparedness planning.

Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has had a disproportionate impact on vulnerable populations, especially residents in long-term care facilities (LTCFs). The proportion of COVID-19 deaths from LTCFs in Canada has been higher compared to other countries [1]. Between March 1st, 2020 to February 15th, 2021, around 70% of deaths from SARS-CoV-2 in the province of British Columbia, Canada, were among LTCF residents [2]. A considerable amount of evidence has emerged to understand potential risk factors for COVID-19 outbreaks and spread [3–12]. Furthermore, evidence has also emerged on useful strategies to contain and prevent the spread of infection in LTCFs [13–16].

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Previous studies examining risk factors of COVID-19 cases and outbreaks in LTCFs have focused on resident level and organization level factors only. Several other risk factors such as building design, community incidence (facilitating frequent introductions), for-profit status, rating status, and resident population characteristics, such as the proportion with dementia, have been identified to increase both the risk of an outbreak occurring at LTCFs and its severity [3,6,7,17–21]. A number of these risk factors are challenging to address and not within the control of LTCF operators. Therefore, infection prevention and control (IPC) best practices are necessary to reduce transmission and to prevent outbreaks.

Standardized audit tools that assess the implementation of IPC measures have been demonstrated to reduce communicable disease transmission in LTCFs [22,23]. Near the beginning of the COVID-19 pandemic, a standardized outbreak prevention assessment tool was created and deployed to LTCFs in the Fraser Health region in British Columbia, Canada, at the start of an outbreak in order to prevent further transmission. The tool identifies areas of weakness in IPC practices, public health measures, and pandemic preparedness, and requires LTCF operators to respond immediately to mitigate identified areas of concern for further transmission [24]. As the majority of the COVID-19 outbreaks in LTCFs in the province of British Columbia occurred in the Fraser Health region, a robust examination of a large sample of LTCF outbreaks was possible to evaluate the tool and identify both modifiable and non-modifiable risk factors associated with COVID-19 transmission within LTCFs.

The objective of our study was to identify risk factors associated with LTCF outbreak attack rates (as a measure for severity) to inform both current outbreak management strategies in LTCFs and future pandemic preparedness planning efforts. Factors examined included: building characteristics; organization-level characteristics; resident population characteristics; IPC and public health measures based on an assessment during the outbreak; the community COVID-19 incidence rate; and the index case being a resident or a staff member.

Methods

Study design

A retrospective cohort design was utilized to evaluate the association between non-modifiable factors (facility building, organization level, and resident population characteristics), modifiable factors (assessments for IPC and public health measures), and severity of COVID-19 outbreaks in LTCFs. This analysis was exempt from ethics review as it was a public health surveillance and quality improvement activity in response to the COVID-19 emergency response.

Our analysis was divided into two steps. The first was a descriptive summary of LTCF building, organization level, and resident population characteristics to inform variables to include in the regression analysis. The second step was to use a regression analysis to identify factors associated with outbreak severity while controlling for other factors. Predictors included in the regression analysis included factors identified from the descriptive analysis, scores from the assessment tool, and other confounding variables identified from the literature described later in the methods.

Study setting

Responsibilities for healthcare services in the province of British Columbia, Canada, are organized into a Provincial Health Services Authority, five geographic regional health authorities (RHAs), and a First Nations Health Authority [25]. Provincially, 33% of publicly funded LTC beds are operated by RHAs, 32% are operated by not-for-profit societies contracted by RHAs, and 35% are operated by for-profit businesses (private-pay LTCFs) [26].

Fraser Health is an RHA serving more than 1.9 million people (~38% of the province's population) across a mixed urban and rural geographic area straddling 20 different communities, including ~62,000 Indigenous Peoples. The region has had the highest burden of COVID-19 cases and LTCF outbreaks in the province. Fraser Health operates 12 acute care hospitals, and operates or is affiliated with around 8400 beds in 82 LTCFs [27]. Almost 80% of the publicly funded LTCF beds are operated by affiliated providers and the remainder are in health authority-owned and -operated LTCFs. There were 12 private pay LTCFs at the time of this study.

In the event of a COVID-19 exposure or outbreak, the health authority supports all LTCFs in the region regardless of funding structure. Fraser Health provides standardized protocols for COVID-19 exposure and outbreak management. At the onset of monitoring for a COVID-19 exposure or a declared outbreak, a standardized assessment is made of facility readiness for COVID-19 outbreaks and to inform outbreak management by identifying areas of weakness in IPC practices and public health measures. Additional details regarding outbreak management and the assessment tool are located in Appendix A.

An LTCF is considered to have a COVID-19 exposure when a laboratory-confirmed COVID-19 case among staff, residents, or another individual who was at the LTCF during their infectious period is identified, and there is risk of exposure to other individuals on-site [28]. Up until November 9th, 2020, an outbreak was declared whenever there was a COVID-19 exposure at an LTCF. From November 9th onwards, an outbreak was declared only when there was suspected or confirmed transmission within the LTCF. LTCFs being monitored due to a COVID-19 exposure are still required to maintain IPC practices and protocols similar to when an outbreak is declared, including isolation of exposed residents/staff, testing of exposed residents and staff, as well as cessation of group activities, social visits, and admissions and transfers of residents.

Study population (inclusion criteria)

All LTCFs in the region ($N = 93$ unique facilities) were considered for inclusion in the analysis. Private-pay LTCFs ($N = 12$), a new LTCF built in April 2020 ($N = 1$), and a paediatric LTCF ($N = 1$) were excluded from the descriptive analysis, as building, organization-level, and resident population characteristics were only available for publicly funded or Fraser Health-owned adult LTCFs in operation during April 1st, 2019 to March 31st, 2020. The period of analysis was from March 1st, 2020 to January 10th, 2021, and any LTCFs being monitored for exposures or outbreaks were included. If multiple exposures or outbreaks occurred at a facility, the one with the highest attack rate was selected. A total of 74 LTCFs with a COVID-19 exposure or outbreak were included for the descriptive analysis.

For the regression analysis, a total of 48 LTCFs from an initial cohort of 82 LTCFs were included. Appendix B outlines reasons for facility exclusion.

Data sources

Various sources were used in our analysis. Data for each exposure or outbreak came from the Fraser Health Public Health COVID-19 dataset which included information on all COVID-19 cases and exposures/outbreaks in the region. Aggregate case counts for each LTCF exposure or outbreak, the index case, date of the start of monitoring for an exposure or outbreak declaration and date of end of monitoring or date declared over were obtained from this dataset. For calculation of attack rates, LTCF resident and staff census were based on bed capacity and staff payroll information, respectively. To estimate community COVID-19 burden, case data were also used to calculate the incidence rate of COVID-19 in the Local Health Area of the LTCF for the two weeks prior to the outbreak being declared or the start of monitoring due to an exposure [29].

Building, organization-level, and resident characteristics were obtained from the Office of the Seniors Advocate British Columbia [30]. Lastly, data from the outbreak prevention assessment tool were obtained from the Fraser Health outbreak response teams deployed to the LTCFs following a COVID-19 exposure or outbreak.

Primary outcome

The primary outcome variable was outbreak severity measured as the COVID-19 attack rate. The variable consisted of the total number of laboratory-confirmed COVID-19 cases using the BC Centre for Disease Control case definition divided by the sum of the resident population (estimated by the number of facility beds) and staff population (staff counts from payroll data from the week of the first exposure) [28]. For the descriptive analysis, attack rates were analysed as a categorical variable (very low, low, medium, high), with cut-points based on the quartile distribution. An additional category of very high was created for LTCFs with an attack rate of $>35\%$ based on visual inspection of a plot of the distribution of attack rates which showed a grouping of LTCFs with attack rates $>35\%$. For the regression analysis, the attack rate was modelled as a continuous variable.

Predictor variables

Various building, organization-level and resident population characteristics for the 2019/20 reporting year were examined (Appendix C) as potential risk factors. The complete list of variables examined is available online [30]. Since this public data source does not include private-pay LTCFs and newly opened LTCFs after the 2019/20 reporting year, the data for these predictors used for the regression analysis were obtained from contacting the LTCF directly for any included LTCF missing data.

From the outbreak prevention assessment performed (Appendix D) during the monitoring or outbreak period, the score (total number of unmet items) was included as a predictor variable in the model. The categories of items in the assessment tool as predictor variables were also examined, based on whether the facility was in full adherence to all items in a category (yes vs no).

Other risk factors identified from the literature were also included as predictors. This included community COVID-19 incidence around the LTCF and whether the facility was built prior to 1972, which is when design standards for LTCFs changed in other Canadian jurisdictions [3]. Although for-profit status is considered a strong risk factor in other regions, private-pay LTCFs account for a minority of facilities in our region (12/93, 13%) and in the regression analysis (3/48, 6%), so we did not include for-profit status in our analysis. The Local Health Area where the LTCF is located was specified as a random effect to account for variation of COVID-19 cases across regions of the health authority [29]. The month of outbreak declaration or start of monitoring was included to account for temporal variation of COVID-19 incidence and adjustments in the protocols for outbreak management over time.

Statistical analysis

For the descriptive analysis, each potential risk factor variable was compared across the categorical measure of attack rate (very low, low, medium, high, very high). Due to the small sample size and non-normal distribution, the non-parametric Kruskal—Wallis test (more than two groups) or Wilcoxon signed-rank test (two groups) for continuous variables and the Fisher's exact test for categorical variables were utilized.

The attack rates were then modelled using a mixed-effect negative binomial regression model and included as an offset term the (log-transformed) total population size of staff and residents for each facility. A negative binomial regression model was used to correctly estimate standard errors after the initial Poisson model (traditionally used for count and rate outcomes) demonstrated overdispersion (violating the assumption that the conditional mean is equal to the conditional variances). A primary model was created in which the assessment tool score was used as a predictor variable. In secondary models, the score from each major category of items in the assessment tool was assessed as the predictor variable. The community in which the LTCF was situated was specified as a random effect to account for clustering of COVID-19 cases by geography. Community incidence was calculated as incidence rate in the LTCF community (defined as the Local Health Area or LHA) during the two weeks before symptom onset of index case. Model assumptions were met and residuals tested using 'DHARMa' package (in R) demonstrated good model fit. All statistical analyses were done in R version 4.0.5.

Results

Descriptive analysis

During the period of analysis, 145 COVID-19 exposures in 82 LTCFs occurred in the Fraser Health region. Excluding LTCFs where building, organization-level, and resident population characteristics were not available, the descriptive analysis included 74 facilities (results available in Appendix E). The factors found to be associated with COVID-19 attack rates in LTCFs are summarized in Table I, along with additional community and outbreak characteristics that were identified as potential risk factors from the literature. Based on the descriptive analysis, the only building characteristics considered as potential risk factors for the regression analysis were the age of the facility and the proportion of single-bed rooms.

Table I
Descriptive analysis of significant risk factors associated with COVID-19 attack rate in long-term care facilities in Fraser Health, March 1st, 2020 to January 10th, 2021

	Very low	Low	Medium	High	Very high	*P*-value
No.	19	18	18	12	7	
Community characteristics						
Community incidence within 2 weeks prior to exposure/outbreak (median (IQR))	1.22 (0.67, 1.96)	0.96 (0.52, 2.44)	1.38 (0.24, 2.24)	0.33 (0.26, 1.31)	1.25 (0.80, 2.69)	0.591
Outbreak characteristics						
Index case role						
Resident (%)	0	1 (6)	7 (39)	3 (25)	1 (14)	0.006**
Staff (%)	19 (100)	17 (94)	11 (61)	9 (75)	6 (86)	
Facility characteristics						
% single-bed rooms (median (IQR))	0.96 (0.93, 1.00)	0.96 (0.69, 1.00)	0.97 (0.93, 1.00)	0.96 (0.91, 0.98)	0.71 (0.47, 0.88)	0.048*
Facility opened (median year (IQR))	2000 (1991, 2008)	1989 (1980, 2008)	2001 (1977, 2008)	2000 (1990, 2006)	1974 (1962, 1975)	0.030*

Very low: 0–0.81%; low: 0.82–2.9%; medium: 3.0–13.2%; high: 13.3–35%; very high: >35%.
**$P < 0.01$; *$P < 0.05$.

None of the organization-level or resident population characteristics were considered for the regression analysis based on the results of the descriptive analysis.

Regression analysis

A total of 48 LTCFs with available data for all potential risk factors were included for the regression analysis. Among these 48 LTCFs, 44 (92%) had a declared outbreak and four (8%) were monitored for a COVID-19 exposure with no further transmission. The size of the facilities ranged from a total of 26 beds to 252 beds, with a median of 101 beds. The median attack rate was 2.4% (range: 0.2–79.2%; IQR: 19.5%). Among residents, the median attack rate was 3.1% (range: 0–91.3%; IQR: 16.6%), and among staff, the median attack rate was 2.2% (range: 0–83.0%; IQR: 7.87%).

From the regression analysis examining the association between potential risk factors and attack rates (Figure 1), the age of the LTCF was significantly associated with increasing attack rates, with LTCFs that opened prior to 1972 having attack rates six times greater than LTCF that opened after 1972 (adjusted rate ratio: 5.9; 95% CI: 2.3–14.9). The proportion of single rooms in the LTCF, despite being marginally significant in the descriptive analysis, was not associated with attack rates after controlling for other factors.

The assessment tool score, a measure of the IPC and public health measures and readiness of the LTCF for an outbreak, was significantly associated with increasing attack rates. For every item not met in the assessment tool, a 22% increase in the attack rate was observed (adjusted rate ratio: 1.2; 95% CI: 1.1–1.4).

Whether the index case was a staff member or resident was also a significant predictor, with LTCF outbreaks having 66% lower attack rates when the index case identified was a staff member (adjusted rate ratio: 0.3; 95% CI: 0.1–0.9). The association between COVID-19 community incidence rate and LTCF attack rates was not statistically significant when controlling for other factors, although the model estimate suggested increased attack rates with increasing incidence in the community (adjusted rate ratio: 1.4; 95% CI: 1.0–1.9).

Secondary models that included a predictor variable for the LTCF's adherence to various categories of items in the assessment tool (Appendix F) demonstrated that if at least one item in the hallway, dining, housekeeping, or personal protective equipment (PPE) categories was not met, the LTCFs were more likely to have higher attack rates. In particular, the dining area category had the strongest magnitude of association with attack rates, with an adjusted rate ratio of 6.4 (95% CI: 2.7–15.0).

Discussion

A total of 145 COVID-19 exposures and/or outbreaks occurred from March 1st, 2020 to January 10th, 2021 in the Fraser Health region. A total of 74 unique LTCF exposures and outbreaks were included in our descriptive analysis which demonstrated that building age, proportion of single-bed rooms, and facility size were associated with increasing outbreak severity as measured by attack rates. Resident population and organization-level factors including LTCFs with greater proportion of residents with dementia, wandering, previous complaints/licensing infractions, and nursing care hours were not associated with greater outbreak severity. After controlling for other factors in a regression analysis, building age (LTCFs that opened prior to 1972) and the index case being a resident were associated with increased attack rates at the LTCFs.

As the building age and the category of index case (resident vs staff) are non-modifiable, this study also examined adherence to IPC and public health measures as modifiable risk factors by including the score from an outbreak prevention assessment tool in our regression model. After controlling for other factors, a linear relationship was found between the number of unmet items in the assessment tool and LTCF attack rates. Specifically, when the LTCF had unmet items in the assessment tool pertaining to measures in the dining area, measures in the hallways, housekeeping/cleaning or PPE

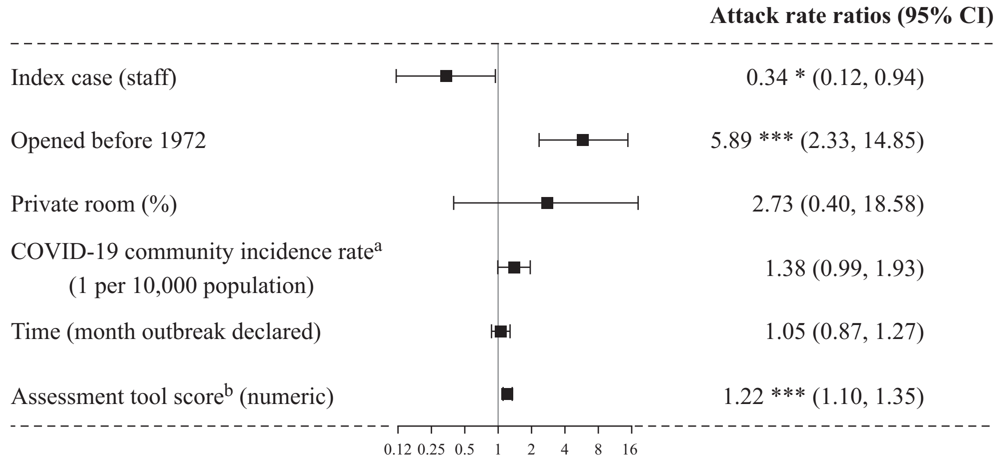

Figure 1. Results of negative binomial regression models to examine risk factors associated with COVID-19 attack rates in long-term care facilities (LTCFs) in Fraser Health, March 1st, 2020 to January 10th, 2021 ($N = 48$ unique facilities). Standard errors are heteroskedasticity robust. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$. [a]Community incidence calculated as incidence rate in the Local Health Area of the LTCF during the two weeks before symptom onset of index case. [b]Assessment score indicates the number of assessment items that were not met.

availability, there was an increasing likelihood of higher attack rates. These findings support the importance of rigorous adherence to IPC and public health measures but also the complexity of factors that can impact attack rates.

Our findings align with other studies examining factors affecting severity of COVID-19 outbreaks. In terms of LTCF building age, our findings matched those found in Ontario, Canada — indicating that beds meeting or exceeding 'C bed' design standards (beds that meet or exceed the structural standards of the 1972 Nursing Homes Act Regulation in Ontario) may be a protective factor for COVID-19 transmission [3]. Additionally, the effect of building age may also be due to lack of proper ventilation in older buildings, which has been linked to worsening spread in LTCFs [31].

Other studies have found that for-profit status [3,5,32—34] and low staff-to-bed ratios, particularly low nurse staffing [32,35—39] result in more COVID-19 cases and severe outbreaks in LTCFs. The present study did not include for-profit status due to the small number of private-pay LTCFs in the dataset. Staffing levels were less applicable in the current setting, as Fraser Health provided staffing support during an outbreak.

In the regression analysis, the index case being a resident was associated with increased attack rates at the LTCFs. From contact-tracing data, the acquisition information for the six outbreaks with a 'resident index' case was either 'unknown' (3/6) or attributed to the LTCF (3/6). The three outbreaks with 'unknown' resident acquisition involved one situation where a resident left the LTCF and went into the community during their acquisition period but was unable to provide a detailed history, as well as two situations where a resident attended a hospital during their acquisition period. For both of these residents who attended hospital during their acquisition period, another case could not be linked to definitively attribute acquisition to the hospital. Whereas it may be possible that the residents acquired COVID-19 during their time in hospital, it is also plausible that acquisition occurred in the LTCF.

Half of the outbreaks with 'resident index' cases were identified with no associated visitors/community visits or residents leaving the LTCF to go to acute care settings. These likely represent situations where there was an undiagnosed staff index case, and that the resident case happened to be the initial case identified. In such situations, having a resident 'index case' was likely an indication that transmission was already occurring within the LTCF.

Our findings support a large body of research around the importance of IPC measures in outbreak control and severity [5,32,35]. Interestingly, the size of the LTCF and the community incidence rate — two factors found to be significantly associated with outbreak severity in other studies [3,32] — were not statistically significant in our analysis, indicating a potential protective effect when IPC and public health measures are in place.

Failure to meet assessment tool items associated with the dining area was a strong risk factor for LTCF attack rates in our jurisdiction. This could be explained by several reasons: (i) an appropriately heightened focus on maintenance of IPC measures in patient care areas and with a potential lack of understanding of the importance of IPC measures in dining areas; (ii) dining areas may be greater risk areas due to increased bioburden, which, combined with poor cleaning/hand hygiene efforts, could lead to transmission [40,41]; and (iii) as indoor dining areas have been found to be important settings for transmission in other contexts, dining in the assessment tool may be a surrogate for measures across other parts of the facility that were not directly measured but are globally encompassed within indoor dining practices [42].

Our findings support the importance of undertaking a holistic approach to managing COVID-19 outbreaks in LTCFs. In particular, ventilation and building design standards require a more rigorous review as they could inform modified IPC precautions (including within assessment tools and protocols), renovation plans of current LTCFs, and design of future buildings. Some approaches to address ventilation in older LTCFs have been described and more research is needed on what ventilation counter-measures are most effective [31]. Our analysis did not assess the role of worker policies (e.g. paid sick-days) and this is an important area for further assessment

[5]. Pandemic checklists and surveys are in place for LTCFs and can be updated to include our findings [43–46]. The assessment tool used in Fraser Health can also be adapted for other communicable disease outbreaks in LTCFs. We examined exposures and outbreaks prior to or at the start of the COVID-19 vaccination programme in British Columbia. Understanding how vaccination efforts reduce outbreak severity will be of interest in elucidating whether the same rigour of outbreak control measures and public health resources will be required in the setting of a highly vaccinated population.

The current analysis has a number of strengths. First, a standardized assessment tool was applied in a uniform fashion across many LTCFs in the region. Second, a significant number of LTCFs were included as the Fraser Health region accounted for the majority of the LTCF outbreaks and COVID-19 burden in British Columbia. Third, our final model was able to estimate the impact of each risk factor on outbreak severity while controlling for other risk factors. Fourth, we investigated a significant number of building, organization-level, and resident population characteristics due to a publicly available dataset [30].

There are, however, limitations to our data and analysis. First, the sample size for our modelling analysis was small, which may have underpowered the analysis and failed to detect significant characteristics. For example, community incidence was found to be a strong determinant for COVID-19 outbreaks in other studies but this was not identified as a major contributor in our model [3,23]. Second, resident population characteristics were taken from the 2019/20 cycle and may not accurately reflect characteristics of the population at the time of the outbreak. Third, certain variables that may have contributed to outbreak severity may not have been identified in our analysis as they were not measured in the publicly available data. Fourth, our results may not be generalizable to other jurisdictions where private pay LTCFs are more prevalent, as they represent a small proportion of LTCFs in our region. Fourth, due to the rapid and evolving nature of the pandemic response, some outbreak prevention assessments were missing or not carried out during the exposure monitoring or outbreak period. The assessment process underwent continual quality improvement and reconciliation, resulting in a smaller dataset available for analysis and could lead to a potentially introduced bias in our results.

In conclusion, scores from an assessment tool, the building age, and whether the index case was a staff or resident were associated with severity of COVID-19 outbreaks in our jurisdiction. The analysis suggests that a higher number of unmet items in a standardized assessment tool deployed routinely at the start of a COVID-19 exposure or outbreak was associated with larger outbreaks. Furthermore, the age of the LTCF and the design standards may be important components to understand outbreak severity and transmission, requiring a standardized evaluation of each LTCF with appropriately paired interventions.

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Author contributions
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Conflict of interest statement
None declared.

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Appendix A. Supplementary data

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