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Featured Article

A 2-year pandemic period analysis of facility and county-level characteristics of nursing home coronavirus deaths in the United States, January 1, 2020–December 18, 2021

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ABSTRACT

Nursing home residents are highly susceptible to COVID-19 infection and complications. We used a generalized linear mixed Poisson model and spatial statistics to examine the determinants of COVID-19 deaths in 13,350 nursing homes in the first 2-year pandemic period using the Centers for Medicare and Medicaid Services and county-level related data. The average prevalence of COVID-19 mortality among residents was 9.02 (Interquartile range = 10.18) per 100 nursing home beds in the first 2-year of the pandemic. Fully-adjusted mixed model shows that nursing homes COVID-19 deaths reduced by 5% (Q2 versus Q1: IRR = 0.949, 95% CI 0.901–0.999), 14.4% (Q3 versus Q1: IRR = 0.815, 95% CI 0.718–0.926), and 25% (Q2 versus Q1: IRR = 0.751, 95% CI 0.701–0.805) of facility ratings. Spatial analysis showed a significant hotspot of nursing home COVID-19 deaths in the Northeast US. This study contributes to nursing home quality assessment for improving residents' health.

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Introduction

Coronavirus disease 2019 (COVID-19), caused by the Severe Acute Respiratory Coronavirus 2 (SARS-CoV-2), has a pronounced incidence rate and higher mortality in people aged 60 and above and in people with underlying medical conditions.^{1,2} Notably, people in long-term care facilities (LTCFs) such as nursing homes (NHs) are highly susceptible to SARS-CoV-2 infection. Communal settings in NHs and LTCFs increase the risk of exposure for residents mainly because of the adverse health outcomes, the advanced age of residents, proximity to other highly vulnerable facilities such as meat and livestock plants, interacting with exposed staff and family members, and the in-and-out-movement of health care workers among facilities and communities.^{3–9} Contact network and quality health outcome models help us to understand the medical geography of nursing home COVID-19 mortality in the United States (US).

Quality health outcome models¹⁰ assume that multiple factors, including general facility conditions (staffing, number of beds, presentable environment), affect the quality of care relative to the health outcomes in LTCFs.¹¹ Systematic and meta-analysis studies have found a strong relationship between NHs facility ownership status and health outcomes.^{12,13} For example, a meta-analysis examining

quality care and health outcomes concluded that for-profit NHs provided poor quality care.¹³ Research on community spread of SARS-CoV-2 at the beginning of the pandemic links health care facility characteristics such as the lack of emergency preparedness and training to handle the pandemic, shortage of personal protective equipment, staff shortages, and general physical conditions.^{14–17} However, these studies overlooked the role of facility ratings as a determinant of nursing home COVID-19 outbreaks. Nevertheless, the importance of facility quality rating has been confirmed in several studies investigating heart failure, patients with dementia, and consumer demand and choices about nursing homes in different locations.^{18–21}

Studies based on epidemiological models emphasize how the contact networks lead to SARS-CoV-2 spread in society.^{22–25} The micro- and macro-contextual conditions (MM2C) are essential in transmitting SARS-CoV-2 in LTHCs, and they determine control and prevention strategies. The MM2Cs can be modeled spatially and systematically to examine the complex situations of disease spread in nursing homes. Chen et al.'s study using device-level geolocation data from 50 million smartphones in the US provided empirical evidence of visitor infection in NHs.²⁵ Sugg et al. used GIS techniques to model community-level determinants of COVID-19 transmission in NHs compared to the general population.²⁶ The study showed regional similarity in COVID-19 transmission in Northeast US.

From an urban structure perspective, researchers acknowledge the role of compact space and urbanization in the diffusion of

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diseases. However, studies investigating the association between facility characteristics and health outcomes underemphasized the importance of geography and facility proximity to other highly susceptible facilities such as meat and livestock plants (e.g., Bui et al.,¹⁴ Li et al.²⁷ He et al.²⁸) in COVID-19 infection, hospitalization, and mortality rates. Facility location is an important spatial determinant of health, and addressing disparities in health outcomes is a place-based issue.^{29,30,48}

Study objectives and hypotheses

The purpose of this study is to further the World Health Organization's¹ (WHO) objectives toward infection and prevention control (IPC) in LTCFs. Our study examines the consequence of failed IPC strategies leading to COVID-19 deaths by assessing facility and community-level characteristics. In addition, we examined the geographic distribution of nursing home COVID-19 deaths across the contiguous US. We hypothesize that (1) nursing home characteristics (e.g., facility ratings, nursing home facility ownership, and facility locations) determine the prevalence of nursing home COVID-19 deaths, and (2) nursing home COVID-19 deaths are randomly distributed across the US. Findings from this study contribute to disease prevention that would improve the health and well-being of older populations in nursing homes.

Methods

Study design and data sources

This cross-sectional study examined the prevalence of nursing home COVID-19 deaths since the beginning of the pandemic in the US. In addition, we examined the association between NHs characteristics (e.g., facility ratings, nursing home facility ownership, and facility locations) and the prevalence of nursing home COVID-19 deaths. We used the nursing home facility dataset and county-level dataset.

Nursing home data sources

We linked facility profile data and nursing homes COVID-19 health data from the Centers for Medicare and Medicaid Services (CMS).³¹ We used the most recently released version of the COVID-19 data published on December 8, 2021. Nursing homes systematically report daily and weekly COVID-19 infection, complications, and deaths to the Center for Disease Control (CDC) through the National Healthcare Safety Network (NHSN) COVID-19 Long Term Care Facility Module beginning May 24, 2020. The CDC's CMS full dataset provides facility information, including the location, facility ownership, number of nursing home beds, number of complaints in a nursing home facility, and the dollar amount paid for offenses. The facility-level data contained the facility ratings based on quality measure scores and other information used in the Five-Star Rating System.³²

County-level data sources

Non-nursing home data included the county-level demographic data from the American Community Survey (ACS) provided by the US Census Bureau.³³ We selected the 5-year estimates from the 2015–2019 ACS (DPO5) with a specific interest in the estimates of the older population and race/ethnicity variables.³⁴ Also, we included a county-level air quality index from the National Environmental Public Health Tracking website.³⁵ County-level COVID-19 vaccination rates and social vulnerability index (SVI) were retrieved from the CDC Wonder,³⁶ while urban-rural continuum data came from the U. S. Department of Agriculture.³⁷ For our spatial analysis, we included butcher locations data provided by ESRI Business Analytics to examine connections between the nursing home and community transmission that may contribute to COVID-19 infection and deaths, and

mapping visualization was done in ArcGIS Pro⁴⁵ and JMP Pro (Version 16., SAS Institute Inc., Cary, NC, 1989–2021).

Data processing

Out of the 15,450 nursing homes in the United States, the full facility-level dataset used in this study contained only records of 15,250 nursing homes. Thus, we successfully joined 13,335 nursing homes addresses to county-level datasets using the county names as the primary key identifier. This current study was exempted from ethical approval because the data is publicly available online and has no direct human contact.

Definition of measures

Outcome variable

The primary outcome variable in this study was the cumulative COVID-19 deaths among residents in nursing homes across the US from January 1, 2020, and December 18, 2021, which represents the 2-year pandemic period in this study. COVID-19 attributed deaths among nursing home residents are self-reported by nursing homes administrators. We treated COVID-19 deaths as a count variable in our analysis because there are several facilities without any reported COVID-19 related deaths. We determined the prevalence rates by dividing the cumulative reported resident COVID-19 related deaths by facility size, calculated as the number of nursing home beds per 100 residents.

Explanatory variables

The main facility-level variable of interest was the facility ratings based on several characteristics, including quality measure rating, health inspection rating, staff rating, short-term rating, longtime rating, and registered nurse staff rating. The composite facility rating³¹ was primarily used as an exposure variable at Level 1. Other facility-level control variables used were coronavirus infection rates among staff and residents, contributing to COVID-19 mortality. We also included data on resident and staff coronavirus vaccination because it is expected that an increase in vaccination among staff and residents should reduce the prevalence and incidence (new death reports) in nursing homes and society. Additionally, we used the 2013 National Center for Health Statistics of urban-rural continuum codes to form a classification scheme that distinguishes metropolitan counties by the population size of their metro area and non-metropolitan counties by the degree of urbanization and adjacency to a metro area.³⁷ Hence, the urbanization status for each nursing home facility was based on the corresponding rural-urban category (see Appendix A).

Statistical analyses

Geospatial and nonspatial techniques were used to achieve the current research objectives presented under the 'Study Objectives and Hypotheses' subsection.

Nonspatial analysis

We examined descriptive statistics (mean, median, standard deviation, frequency, and percentages) for continuous and categorical variables used in this present study. Kolmogorov-Smirnov test and visualization of the histogram of the outcome variable (COVID-19 deaths) indicate a rightly skewed distribution with many zeros. Following a similar approach,¹⁴ we used nonparametric analysis of variance (ANOVA) when $k > 2$ to determine whether the average count of nursing home COVID-19 death varies among three categorical explanatory variables (i.e., quartiles of facility ratings, ownership status, and urbanization status). We assessed all continuous variables

for multicollinearity using the variance impact factor (VIF) and retained variables with a VIF value of less than three.

In the preliminary analyses, we included several county-level variables including a measure of the urbanization status (i.e., urbanity), proportion of the population ages 65 and above who had received at least two doses of COVID-19 vaccines, SVI, and air quality index. We selected these variables based on a priori knowledge of potential facility and community conditions that increase potential exposure of older people living in LTCFs^{26,38,39} and existing epidemiological findings indicating the impact of location on health outcomes from different facilities.^{40,41} Consequently, we included the six classifications of rural-urban and the proportion of the urban population ages 65 and above who were completely vaccinated at the county level. The urbanization status assesses the role of place as a determinant factor of COVID-19 facility deaths in the US and serves as the primary county-level variable in our multilevel and spatial analyses.

In the multivariate analysis, we fit poisson regression using the generalized linear mixed model (GLMM) in SPSS version 28⁴² to examine the association between facility ratings and prevalence of nursing home COVID-19 deaths across the US. Because NHs are nested within each county, facility ratings are expected to cluster at the county level based on the idea of MM2Cs. Hence, we used a Poisson generalized mixed-effect model with a random intercept for facility ratings to account for the clustered data structure at the county level.

Next, we estimate poisson regression for facility attributed COVID-19 deaths from nursing homes using pseudo-likelihood estimation (PL) rather than ordinary least squares estimation used in OLS regression because of the zero-inflation in COVID-19 mortality.⁴³ We adjusted for multiple comparisons using the least significant difference (LSD). This study estimated five multilevel Poisson regression models to evaluate facility-based and county-based measures' contribution to COVID-19 deaths in US nursing homes. We added variables in sequence to the five different multilevel Poisson regression models. In model 1, we fit a null model which only examined county-level random intercept of COVID-19 death in nursing homes. Our second

fitted a multilevel poisson regression model for only the facility rating variable. In model 3, we fitted a multilevel poisson regression model with county-specific random intercepts that added facility ratings (quartiles: Q1-Q4, Q1 = reference category), facility ownership, and urbanization status. Our model 4 included variables in model 3 but adjusted for total confirmed coronavirus cases among staff [Stf_TotCfC] and residents [Res_TotCfC], complete vaccination for resident [Res_FVBst] and staff [Stf_FVBst]). The full model included model 4 and adjusted for county-level percentage ages 65 and older who received at least two doses of coronavirus vaccines in urban areas [%Vc65URB], and controlled for state-level COVID-19 health policies (e.g., mask and vaccination mandates) using the unique State FIP codes. All models assumed that the random effects structure follows a variance components structure and used robust estimation to account for model misspecification and poisson assumptions (i.e., robust covariances). The exponential coefficients were interpreted using the incidence rate ratio (IRR) with 95% confidence intervals. Detailed statements on sensitivity analysis are presented in Appendix B.

Spatial analysis

To examine the spatial dimension of nursing home COVID-19 deaths, we run Forest-based Classification and Regression⁴⁴ on selected variables used in the nonspatial analysis in addition to the location of butchery sites in predicting nursing home COVID-19 deaths in the contiguous US (see Appendix for variable performance). Furthermore, we performed optimized hotspot analysis on predicted nursing home COVID-19 deaths in ArcGIS Pro-version 2.8.3.⁴⁵

Results

Descriptive statistics

Fig. 1 shows a positively skew distribution of nursing home COVID-19 data for the 2-year period (Kolmogorov-Smirnov

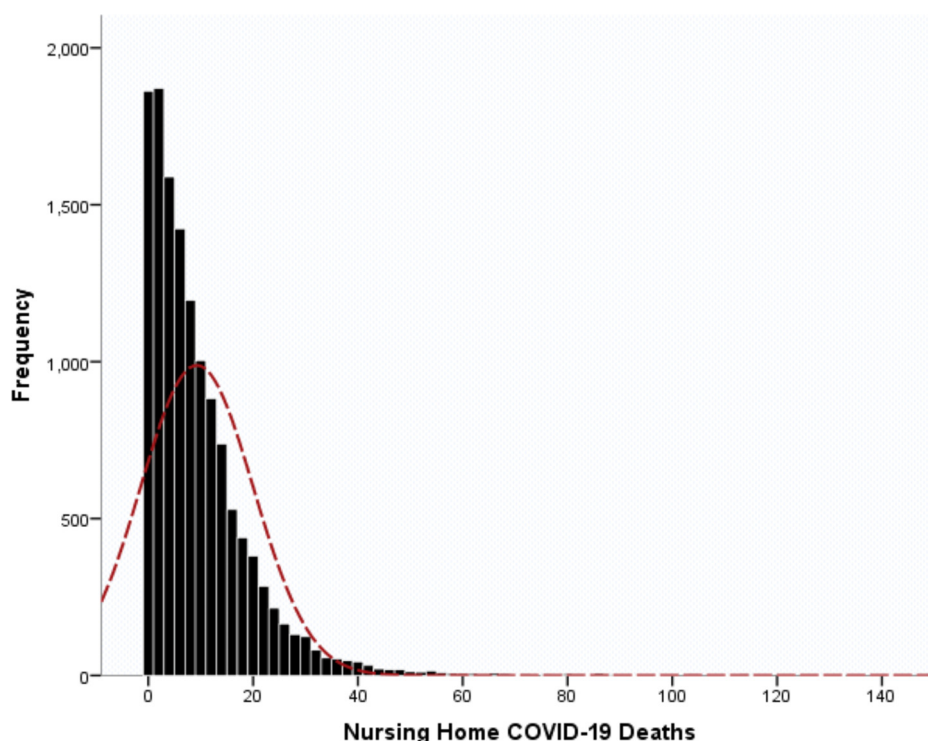


Fig. 1. Distribution of nursing home COVID-19 deaths, January 1, 2020–December 18, 2021.

Table 1
Descriptive statistics of nursing home COVID-19 death by categorical variables.

	Mean	Std. Error	Median	Variance	SD
<i>Prevalence</i>					
-COVID-19 mortality per 100 beds	9.02	0.080	7.00	83.81	9.19
<i>Facility Rating*</i>					
Q1 (Lowest Quartile)	10.21	0.252	8.00	125.35	11.19
Q2	9.86	0.214	7.00	119.17	10.91
Q3	9.01	0.219	6.00	115.40	10.74
Q4 (Highest Quartile)	7.48	0.199	5.00	93.02	9.64
(Test-Statistics _(df = 3))	= 226.41, $p < 0.000$, 2-tailed)				
<i>Urbanization status</i>					
Large central metro = 1	9.40	0.280	6.00	134.39	11.59
Large fringe metro = 2	10.39	0.263	7.00	131.47	11.46
Medium metro = 3	9.61	0.225	7.00	123.13	11.09
Micropolitan = 4	8.52	0.215	6.00	95.39	9.76
Noncore/rural = 5	8.82	0.168	6.00	106.44	10.31
Small metro = 6	9.27	0.278	7.00	111.52	10.56
(Test-Statistics _(df = 5))	= 39.127, $p < 0.000$, 2-tailed)				
<i>Ownership</i>					
Nonprofit	8.66	0.190	6.00	112.18	10.59
For profit	9.49	0.109	7.00	111.24	10.54
Government	8.93	0.456	5.00	177.23	13.31
(Test-Statistics _(df = 2))	= 102.58, $p < 0.000$, 2-tailed)				

* Treated as a categorical variable in this table; SD standard deviation.

test = 0.195, $p < 0.005$; Skewness statistics = 3.32, std. error = 0.021). The average prevalence of nursing home COVID-19 mortality among residents across the US was 9.02 (Interquartile range = 10.18) per 100 nursing home beds (Table 1). Table 1 indicates that the average COVID-19 deaths was highest in the poorest rated facilities (Quartile, Q1) but decreased as facility ratings increased in the fourth quartile (Test Statistics_(df = 3) = 226.41, $p < 0.000$, 2-tailed). The prevalence of nursing home COVID-19 deaths also varies by urbanization status (Test Statistics_(df = 5) = 39.127, $p < 0.000$, 2-tailed). As shown in Table 1, resident deaths attributed to COVID-19 were higher in ‘for-profit’ nursing home facilities compared to ‘Government-owned’ nursing homes or ‘not-for-profit’ facilities (Test Statistics_(df = 2) = 102.58, $p < 0.000$, 2-tailed).

Multivariate visualization

To examine the relationship between the dependent and categorical explanatory variables, four variables were overlaid: Log of COVID-19

deaths, facility ratings (Quartile 1- Quartile 4), facility ownership (3 levels), and urbanization status (6 categories) Fig. 2. shows that resident deaths attributed to COVID-19 vary by facility ownership across sublevels of urbanization.

Large metropolitan and large fringe metropolitan areas

COVID-19 deaths in the government-owned facility were higher in the first, third, and fourth quartile than nonprofit facilities in ‘Large metropolitan areas. We observe that the ‘for-profit’ type of facility consistently had higher COVID-19 deaths. Similarly, COVID-19 deaths were higher in government nursing home facilities in ‘large fringe metropolitan areas’ across the subdivision of facility ratings except in the third quartile. Also, we noticed that COVID-19 prevalence in ‘for-profit’ nursing home facilities was higher in the upper quartile but lowest in the facility in the third quartile.

Medium metro and micropolitan areas

Compared to the second and third quartile, the prevalence of COVID-19 deaths in the government-owned facilities in the medium metro areas was lower in the first and upper quartiles. As seen in Fig. 2, COVID-19 mortality was higher in ‘for-profit’ facilities in the first quartile (Q1) in medium metropolitan and higher in the micropolitan areas in the second and third quartile of facility ratings. Compared to government and not-for-profit facilities, nursing home COVID-19 death was higher in poorest rated ‘for-profit’ facilities than high-rated facilities in micropolitan areas.

Nonurban and small metro areas

The prevalence of COVID-19 deaths in nursing homes in nonurban areas decreased with increased facility ratings for the three categories of facility ownership. In small metro areas, COVID-19 deaths decreased in the first and second quartiles in government-owned facilities and increased in ‘for-profit’ owned facilities in the third and fourth quartiles.

Results of Poisson generalized linear mixed model

A significant value of the random effect in the null model of the average log count of COVID-19 mortality varies significantly across US counties or Level 2 (variance intercept = 6.81, $p < 0.000$, one tail). This result suggests clustering evidence and justifies the need to fit GLMM on our count outcome variable based on the Poisson

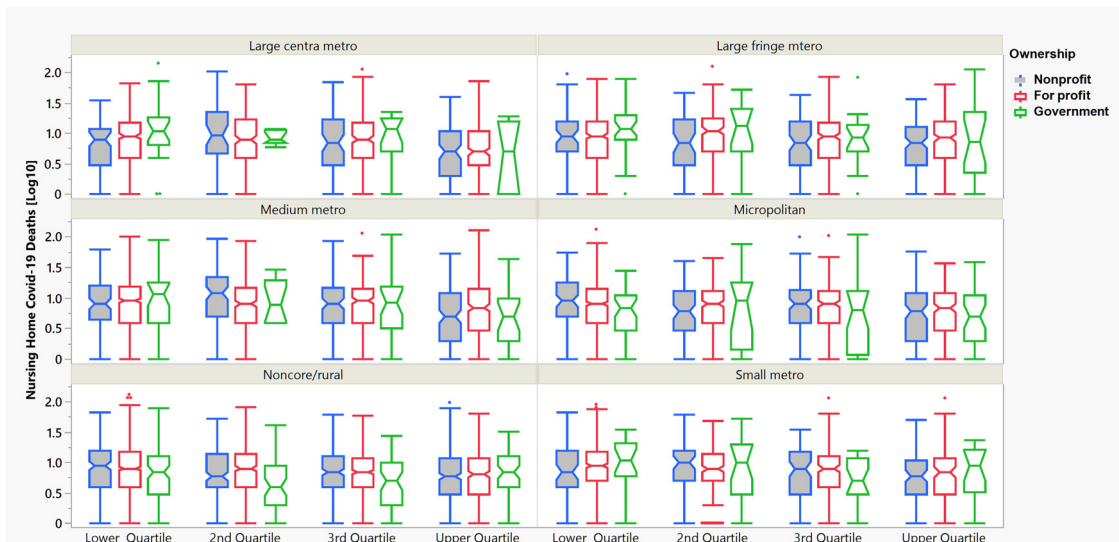


Fig. 2. Variation of nursing home COVID-19 deaths by facility ownership across the rural-urban continuum.

Table 2
Predictors of nursing home COVID-19 deaths in the United States^a.

	Facility ratings model only (Model 2)			Model 3			Model 4			Full model		
	IRR	95% CI LB UB	UB	IRR	95% CI LB UB	UB	IRR	95% CI LB UB	UB	IRR	95% CI LB UB	UB
Intercept	9.249	8.046	10.633	8.732	7.27	10.48	3.823	3.193	4.576	2.599	1.912	3.533
Facility rating (Q1 = ref)												
Q2	0.913	0.853	0.978	0.908	0.851	0.969	0.94	0.886	0.998	0.949	0.901	0.999
Q3	0.815	0.718	0.926	0.768	0.704	0.838	0.824	0.75	0.905	0.856	0.806	0.908
Q4 = Highest	0.654	0.554	0.772	0.558	0.499	0.624	0.751	0.658	0.857	0.751	0.701	0.805
Facility ownership (Not-for-profit = ref)												
2 = 'for-profit'				1.064	1.003	1.129	0.993	0.936	1.053	0.990	0.940	1.043
3 = Government				1.223	1.079	1.386	0.88	0.731	1.059	0.937	0.827	1.062
Urbanity (County; large fringe metro 1 = ref.)												
2 = Large fringe metropolitan				0.948	0.765	1.175	0.998	0.906	1.098	1.127	0.939	1.354
3 = Medium metro				0.871	0.706	1.075	0.966	0.875	1.066	1.045	0.873	1.251
4 = Micropolitan				0.806	0.658	0.987	0.99	0.903	1.085	1.033	0.852	1.252
5 = Noncore area				0.669	0.55	0.812	1.002	0.915	1.096	0.937	0.774	1.133
6 = Small metro				0.925	0.747	1.146	1.005	0.889	1.135	1.045	0.827	1.251
Cases (staff)							1.004	1.003	1.005	1.004	1.002	1.005
Cases(residents)							1.009	1.008	1.01	1.01	1.009	1.011
Vaccine (staff)							1.002	1.000	1.003	1.001	1	1.003
Vaccine (resident)							1.000	0.999	1.001	1	0.998	1.002
% Complete vaccine (county; Tot. Pop)										1.002	1.000	1.005
%Vc65URB (county)										1.009	0.99	1.028
State										1.000	0.998	1.002
Random effect (Rating)	0.007*			0.011*			0.005*			0.017*		

LB = lower bound of confidence interval.

UB = upper bound of confidence interval.

%VC65URB = percentage of population 65 years and above who received 2 doses of COVID-19 vaccination at the county level.

^a Null model not presented in the table.

* Means a significant random effect of facility rating at Level 2.

distribution assumptions. Table 2 shows the fixed-effect association of facility rating and COVID-19 deaths in nursing homes in the US. The incidence rate ratio of COVID-19 deaths reduced by 9% in the second quartile (Q2 versus Q1: IRR = 0.91, 95% CI 0.853–0.978), 19% in the third quartile of facility rating (Q3 versus Q1: IRR = 0.815, 95% CI 0.718–0.926), and 35% in the upper quartile (Q4 versus Q1: IRR = 0.65, 95% CI 0.554–0.772) in the unadjusted model 2 of Table 2.

Holding other variables constant in the adjusted model (model 3 in Table 2), the prevalence of COVID-19 deaths was reduced by 9% in the second quartile (Q2 vs Q1: IRR = 0.908; 95% CI 0.851–0.969), by 24% in Q3 of facility ratings (Q3 vs Q1: IRR = 0.768; 95% CI 0.704–0.838), and 44% in Q4 of facility ratings (Q4 vs Q1: IRR = 0.558; 95% CI 0.499–0.624). Holding facility rating constant, nursing home COVID-19 deaths vary by facility ownership, with a statistically significant 6.4% increase in 'for-profit' nursing homes (IRR = 1.064, 95% CI 1.003–1.129) and a 22.3% increase in government-owned nursing homes compared to not-for-profit facilities. Compared to facilities in large central metropolitan areas, COVID-19 deaths decreased by 20% and 33.1% in nursing homes in micropolitan and non-core areas, respectively.

In model 4, COVID-19 death prevalence reduced by 6% in the second quartile (Q2 vs Q1: IRR = 0.94; 95% CI 0.886–0.998); by 18% in the third quartile (Q3 vs Q1: IRR = 0.824; 95% CI 0.750–0.905); and 24.9% in the highest quartile (Q4 vs Q1: IRR = 0.751; 95% CI 0.658–0.857). Adjusting for other variables in the full model, nursing home COVID-19 deaths significantly reduced consistently from poorly rated to highly rated nursing home facilities (Table 2).

Sensitivity analysis

Linear and interaction analyses show a similar pattern of association between the prevalence of COVID-19 facility deaths and facility rating (Appendix C). COVID-19 facility deaths decreased with a 16.4% increase in nursing home facility rating (IRR = 0.843, 95% CI

0.802–0.887), controlling for facility ownership and geographic factors. In addition, we observed a 16.7% decrease in COVID-19 facility death in 'for-profit' nursing homes compared to not-for-profit facilities. We also saw a 17% statistically significant decrease in COVID-19 facility deaths in micropolitan areas. However, there was no significant interaction between facility rating and urbanization status. Next, the GLM results for count data which ignores the potential impact of clustering were consistent with the main analyses. There were statistically significant negative associations for Q4, Q3, and COVID-19 facility deaths (see Appendix D). However, the statistically significant association observed in GLMM for Q3 disappeared in the GLM due to failure to account for clustering or random effects. In addition, the model with removed zero records of COVID-19 deaths shows a significant negative association with Q3 and Q4 of overall facility rating (Appendix E). Summarily, the association between COVID-19 deaths in nursing homes and facility rating remained consistent in all the models.

Spatial analysis results

Forest-based Classification and Regression showed that proximity to butchery sites was the most important explanatory variable explaining the geographic pattern of COVID-19 deaths in nursing homes followed by the numbers of staff and residents who had received 2-dose COVID-19 vaccination (Appendix F). Fig 3. shows the spatial pattern of predicted nursing home COVID-19 deaths and the hotspot of predicted nursing home COVID-19 deaths in Northeastern US, the most urbanized region in the United States after the Western US.

Discussion

We investigated facility- and community-level determinants of nursing home COVID-19 deaths for the first 2-year pandemic period

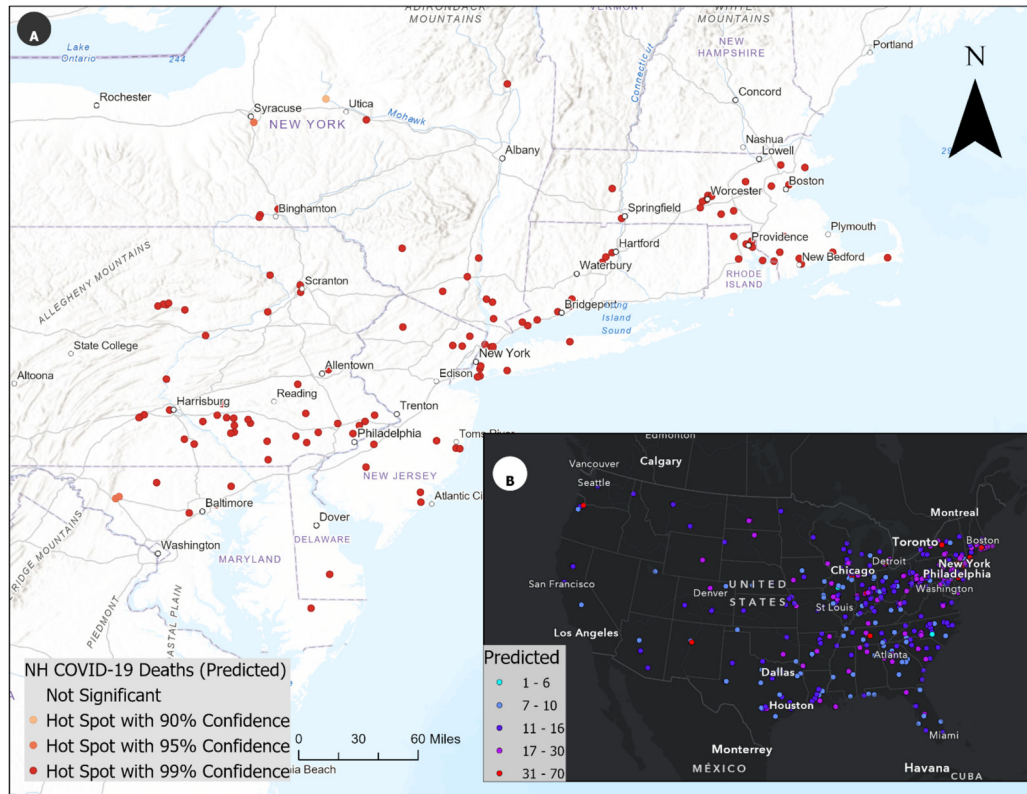


Fig. 3. Hotspots and predicted nursing home COVID-19 deaths in the United States. (Note: The figure shows only significant facility locations, and the full model of Fig. 3A is presented in the Appendix).

using the Centers for Medicare and Medicaid Services and other county-level data. This assessment is important for public health intervention of COVID-19 related death among the adult population in NHs. We found that COVID-19 deaths were higher in the facilities in the lowest quartile of facility ratings and least in facilities with high facility ratings. Our results also indicate that the prevalence of COVID-19 deaths varies by facility ownership, notably increasing resident death in ‘for-profit’ facilities. Additionally, we found a high COVID-19 facility deaths prevalence in NHs in large fringe metropolitan areas compared to non-core or less-urbanized areas, and spatial analysis indicated a significant hotspot of predicted COVID-19 deaths in the Northeastern US.

The observed association between facility rating and COVID-19 deaths is consistent with several previous State-level studies that found significant associations between CMS facility rating and COVID-19 cases and fatalities in nursing homes.^{14,27,28} For example, He et al.²⁸ found reduced cases and death rates of COVID-19 with increasing quality rating in California State. Similarly, Li et al.’s²⁷ study of COVID-19 health outcomes in Connecticut nursing homes found that for every 20 min increase in RN staffing, there is a significant 26 percent decrease in COVID-19 deaths associated with a lower probability of a larger outbreak and fewer deaths.³⁸(p2466)

Our findings on the effect of urbanization status on COVID-19 facility death were consistent with Gorge and Konetzka’s study, which found the largest magnitude effects for counties with a higher percentage of metropolitan status.³⁸ However, the study did not examine the nuanced variation in COVID-19 deaths by urbanization status. Complemented by the spatial analysis, our nonspatial analysis showed that the average count of COVID-19 deaths significantly varies by urbanization status along Bos-Wash megapolis, which extends from Boston through New York and Philadelphia down to Washington, D.C. It is important to note that although this present

study found that COVID-19 mortality significantly reduced in facilities in micropolitan and non-core/rural areas, this association disappeared after adjusting for staff and residents COVID-19 cases and vaccination status and remained statistically insignificant in the fully-adjusted model. This effect was attenuated by community-level total COVID-19 vaccination suggesting the role of vaccination in reducing deaths in society and NHs. Health disparity is a place-based issue; hence, improving the locational conditions of these facilities could make a difference in improving health outcomes.²⁹

Additionally, we found a statistically significant increase in COVID-19 death in ‘for-profit’ and government-owned nursing homes. However, the incidence rate ratio of COVID-19 deaths in government-owned nursing homes was 22.3 percent and 6.4 percent in ‘for-profit’ nursing homes. This means that COVID-19 deaths prevalence was (predicted) three times higher in government-owned nursing homes facilities than ‘for-profit’-owned nursing homes facilities in the multivariate analysis. Similar to a study in Real Madrid, Spain,⁴⁶ this current study found increased COVID-19 death in government and ‘for-profit’ nursing homes may suggest differences in nursing home management and perhaps funding status. Damian et al.’s study found that the differences in nursing home facility mortality were related to facility subsidy, ownership status, and facility size.⁴⁶ Cohen and Spector studied the effect of different reimbursement types on NHs mortality and found lower death rates in public and not-for-profit compared to for-profit in a sample of 2663 residents from 658 nursing homes.⁴⁷

Implications for action and policy

This study has broad research implications in caring for the older population. In addition, findings from this work can further inform research and policy actions at the facility and regional levels. First,

investigating the facility level disparity of COVID-19 deaths in government and for-profit-owned warrants in-depth study, especially in poorly rated nursing home facilities. Second, research investigating medical, social, and environmental factors contributing to the pattern of COVID-19 deaths in the Northeast US is required. Third, research and policy considering the travel patterns of unvaccinated nurses (travel nurses) may help understand and curb the excess deaths in nursing homes in the US. Therefore, further investigation of facility conditions at the micro, meso, and macro levels may provide informative insights that can drive local and regional policies to address nursing home excess deaths from infectious disease, including COVID-19.

Study limitation and strength

This investigation of COVID-19 related deaths in nursing homes in the US had a number of limitations. We did not include all individual facility quality ratings but instead used the overall facility rating due to the evidence of moderation of the individual rating scores. A moderator affects the strength and direction of the relationship between the dependent variable (i.e., nursing home COVID-19 deaths) and overall facility rating. Furthermore, this study was unable to control for residents' demographic characteristics and underlying health conditions, which may modify the main effect of facility ratings in our models. We used county-level demographic variables in our models, which may not truly account for the demographic of residents at the county level. We also acknowledge possible misdiagnosis of non-SARS-CoV-2 mortality that may have contributed to incorrectly reporting to CMS, which may have caused over- or under-estimation in our analyses. Despite these limitations, this study has some strengths. This is the work to present a holistic report of facility overall quality measure on the COVID-19 deaths in nursing homes for the first 2-year pandemic period in the US.

Conclusion

The findings on nursing homes COVID-19 deaths presented in this study echo the importance of facility-based intervention toward eradicating SARS-CoV-2 infection. Nursing home COVID-19 deaths were reduced in high-ranking facilities, and NHs in the Northeast US had a significant hotspot of nursing home COVID-19 deaths between January 2020 and December 2021. We suggest location-based intervention by increasing COVID-19 vaccination in most nursing homes in most at-risk locations close to meat and livestock plants. Factors that contribute to increased COVID-19 deaths in 'for-profit' and government-owned facilities warrant further research. Finally, findings from this 2-year pandemic period analysis can provide valuable guidance for managing long-term care facilities in the US as we advance in the pandemic and other regions of the world.

Data availability

Nursing home data used for this study are freely available online from <https://data.cms.gov/covid-19/covid-19-nursing-home-data>. Please, see 'Method' section for sources of other data used in this study.

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Declaration of Competing Interest

The authors declare no conflict of interest

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:[10.1016/j.gerinurse.2022.02.013](https://doi.org/10.1016/j.gerinurse.2022.02.013).

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