Evaluation of a state-wide effort to improve COVID-19 infection control in Massachusetts nursing homes

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Abstract
Background: During the deadly 2020 SARS-CoV-2 surge in nursing homes (NHs), Massachusetts (MA) initiated a multicomponent infection control intervention to mitigate its spread.

Methods: We aimed to assess the intervention's impact by comparing the weekly risk of PCR-confirmed infections among MA NH residents to those in neighboring New England states, all managed similarly by a single NH provider. We studied 2085 residents in 20 MA NHs and 4493 residents in 45 comparator facilities. The intervention included: (1) A 28-item infection control checklist of best practices, (2) incentive payments to NHs contingent on scoring ≥24 on the checklist, meeting 6 core competencies, testing residents and staff for SARS-CoV-2 RNA, uploading data, and enabling virtual visits; (3) on-site and virtual infection control consultations for deficient facilities; (4) 6 weekly webinars; (5) continuous communication with the MA Department of Public Health; and (6) access to personal protective equipment, temporary staff, and SARS-CoV-2 testing. Weekly rates of infection were adjusted for county COVID-19 prevalence.

Results: The adjusted risk of infection started higher in MA, but declined more rapidly in its NHs compared to similarly managed facilities in other states. The decline in infection risk during the early intervention period was 53% greater in MA than in Comparator States (state-by-time interaction HR = 0.47; 95% CI 0.37–0.59). By the late intervention period, the risk of infection continued to decline in both groups, and the change from baseline in MA was marginally greater than that in the Comparator States (interaction HR 0.80; 95% CI 0.64–1.00).

Conclusions: The MA NH intervention was associated with a more rapid reduction in the rate of SARS-CoV-2 infections compared to similarly managed NHs in neighboring states. Although several unmeasured factors may have confounded our results, implementation of the MA model may help rapidly reduce high rates of infection and prevent future COVID-19 surges in NHs.

KEYWORDS
COVID-19 intervention, infection control, long-term care, public health, SARS-CoV-2

See related Editorial by Boltz and Murphy in this issue.
INTRODUCTION

The COVID-19 pandemic has taken the lives of over 140,000 nursing home residents and staff in the United States, due in part to the frailty of the nursing home population as well as inadequate knowledge, staffing, personal protective equipment (PPE), and financial resources in nursing facilities. During the summer of 2020, the State of Massachusetts addressed each of these factors to mitigate the surge in COVID-19 cases by supporting a multicomponent infection control intervention in 360 nursing homes across the State. From May 10th through July 5th, the Massachusetts Department of Public Health audited these facilities for their compliance with a 28 item checklist of infection control practices and provided incentive payments to support the costs of staff and supplies if they achieved a score of 24 or above. Troubled facilities received additional on-site and virtual educational support from external consultants, and all nursing homes were invited to attend weekly webinars. Details of this intervention and associated outcomes are reported in a previous publication. However, at the time, we were unable to compare outcomes to similar facilities that were not exposed to the intervention. For the current report, we compared infection rates during this time period in Massachusetts facilities that received the intervention to those in other New England States that did not receive it. We used data from a large, single provider of nursing homes that served residents across the New England region. This approach enabled us to examine the impact of the intervention on infection rates, independent of differences in facility management practices.

METHODS

Data sources

This study used de-identified data on nursing home residents, nursing facilities, and the surrounding communities captured between April 1 and August 12, 2020 (20 weeks). This time span was divided into three periods: a baseline period before the Massachusetts intervention began (April 1 to May 10, weeks 1–5), an early intervention period (May 10 to June 3, weeks 6–9), and a late intervention period (June 3 to August 12, weeks 10–20). All residents who were represented in the dataset at the beginning of the study period were followed for 20 weeks or until they developed COVID-19, were discharged, or died. We did not include new admissions during the study period for two reasons: (1) some states were restricting new admissions while others were not and we wanted to study a similar population in all states, and (2) new admissions who were recovering from previous SARS-CoV-2 infections were relatively immune to new infections and were less likely to benefit from the NH intervention.

The temporal unit of data capture was nursing home resident-week, such that each resident contributed up to 20 records to the project dataset. Information on nursing home residents and their infections was obtained from a large provider of post-acute and long-term care services that operated nursing homes across the country at the time of data collection. Resident-level data were comprised of Minimum Data Set (MDS) assessments and SARS-CoV-2 infection tracking logs obtained from the provider organization. The MDS is a standardized assessment administered to all residents of government-certified nursing homes at the time they are admitted and regularly thereafter until a final discharge or death record. The MDS captures residents' demographic characteristics, clinical diagnoses, and functional status measures, among hundreds of other clinical data elements.

Nursing home characteristics were obtained from the Certification and Survey Provider Enhanced Reporting
(CASPER) database and quality report cards available publicly at the Medicare Care Compare website. CASPER contains a variety of nursing home organizational characteristics such as facility size, staffing levels, and payer mix. Care Compare report cards contain numerous measures of nursing home quality, many of which are summarized into aggregate 5-star ratings.

The community-level data used for this analysis were county-level SARS-CoV-2 infection rates, obtained from a surveillance database maintained by Johns Hopkins University and updated daily during the time period analyzed here.

Intervention

The state-wide Massachusetts intervention has been described in detail elsewhere. Briefly, it included: (1) A 28-item infection control competency checklist of best practices in infection control, the use of PPE, staffing plans, clinical care, and communication with staff, residents, and families; (2) Additional incentive payments totaling $130 million for 2 months that were contingent on passing unannounced state inspection audits by achieving a score of 24 or more on the checklist while meeting all 6 core competencies, testing 90% of residents and staff for SARS-COV-2 RNA nasopharyngeal positivity by a given date, uploading key data each week, and providing residents with technology for virtual visits with family and friends; (3) On-site and virtual infection control consultation for facilities that were deficient in infection control practices; (4) 6 weekly webinars that focused on the checklist competencies and areas of poor performance on the audits; (5) Continuous Question and Answer (Q&A) communication with representatives of MassHealth and the Department of Public Health who provided answers and included them in a running Q&A document; and (6) Resources for PPE procurement, the recruitment of temporary staff (Resident Care Assistants, Certified Nursing Assistants, and in emergency situations, the National Guard), and SARS-COV-2 testing.

Study population

We included residents of the long-term care operator’s facilities in Massachusetts where the intervention was implemented, and three neighboring New England states (Rhode Island, New Hampshire, and Connecticut) that served as the Comparator States. The study observation period was from April 1, 2020 until August 12, 2020 for a total of 20 weeks.

Outcome

The primary study outcome was infection with SARS-CoV-2, as defined above, with each participant’s status updated weekly during the observation period. All infections were confirmed via polymerase chain reaction (PCR) testing.

Covariates

We included resident demographics, functional status, clinical conditions, and other factors related to SARS-CoV-2 infection risk. The demographic variables were age at the start of the study, sex, and race (here categorized as Black, White, and other based on reporting). Functional status was approximated with the Morris Activities of Daily Living (ADL) score derived from the MDS. The range of this ADL measure is 0–28, with higher scores signifying a greater degree of functional impairment. Several clinical conditions listed as active diagnoses on the MDS baseline assessment were included for covariate adjustments. These were: diabetes mellitus, hypertension, coronary artery disease, chronic kidney disease, chronic obstructive pulmonary disease (COPD) or asthma, and dementia.

In addition, we included two quality indicators at the facility level, which were obtained from CASPER data. These were staffing rating and bed size category (because COVID infection risk is greater in facilities with more beds).

We also considered two key factors related to SARS-CoV-2 infection risk: whether a resident was in the facility for post-acute care (versus being a long-stay resident), and the SARS-CoV-2 prevalence in the nursing homes’ surrounding community (county), which has been linked to nursing home infection rates in multiple previous studies. Our analysis, discussed below, is conducted at the resident-week level and allows for the use of community infection rate as a time-varying covariate. To avoid contaminating assessment of community risk with contributions from nursing home residents, each model of incidence also included community prevalence from 2 weeks prior.

Statistical analysis

We compared the difference in infection risk among Massachusetts nursing home residents versus infection risk among other Comparator State residents during the first 5 weeks of the pandemic before May 10 when the intervention was started, to the difference in infection risk after it was implemented. To achieve this, we used a
A discrete-time survival model with a difference in differences framework. In this person-week-level analysis, residents could contribute up to 20 weeks of data. To contribute data for a given week, a resident had to be under observation, and be known not to have contracted SARS-CoV-2 at the start of each interval. This approach allowed us to: (i) examine the time to infection for a given resident who was at risk at the outset, but not yet infected, (ii) censor residents when they became infected, were discharged, or died, and (iii) account for possible confounding due to important time-varying factors such as community SARS-CoV-2 prevalence levels.

We used a generalized linear regression model with a complementary log–log link – that is, a discrete time proportional hazards model - to estimate the relative hazard of infection as a function of being in a Massachusetts nursing home, discrete time, and their interaction, controlling for covariates. The state by time interaction terms are the parameters of interest, as they indicate how infection risk changed in Massachusetts relative to Comparator States. For the purposes of analysis, time was divided into the three ranges described above: a baseline period before the intervention (weeks 1–5), an early intervention period (weeks 6–9), and a late intervention period (weeks 10–20). This was necessary because infection rates became increasingly uncommon and infection risk could not be estimated for all post-implementation weeks. To facilitate the interpretability of findings, we calculated the adjusted mean probability of infection risk during the three time periods for Massachusetts residents and residents of Comparator States, holding all covariates at their observed values (predictive margins).

All analyses were conducted with Stata MP 16.0 (College Station, TX). Standard errors were clustered at the treatment (state) level. Null hypotheses were tested with a two-sided type I error rate of 0.05. The Institutional Review Board serving Brown University and the Marcus Institute for Aging Research at Hebrew Senior-Life (Advarra) approved the study protocol and waived the need for resident consent.

**RESULTS**

Table 1 shows the baseline resident characteristics in each of the two groups of nursing homes, one group in Massachusetts that experienced the intervention, and the other in New England Comparator States that did not experience the intervention. There were small, but statistically significant differences in age, sex, racial distributions, and average activities of daily living scales (ADL). The prevalence of dementia, congestive heart failure, and
hypothesis was slightly higher in Massachusetts homes. The county prevalence of SARS-CoV-2 during April, 2020 was nearly 3-fold higher in Massachusetts.

The characteristics of the two groups of facilities are shown in Table 2. More residents in Massachusetts homes paid privately for long-term care and more facilities in the other states were in rural locations as defined by the US Department of Agriculture.9 according to their proximity to major cities.

Table 3 shows the results of the discrete time proportional hazards regression estimating the adjusted impact of the intervention on the probability of becoming infected with SARS-CoV-2. During the first 5 weeks of the study (the baseline period), Massachusetts residents were on average 1.69 (95% Confidence Interval [CI] 1.60–1.78) times more likely to have become infected with SARS-CoV-2.

### Impact of the intervention

During weeks 6 through 9, early in the intervention period, the adjusted probability of SARS-CoV-2 infection declined for both Massachusetts and Comparator State nursing home residents (see Figure 1). Among Comparator State residents, the adjusted risk of infection declined by about 27% (Hazard Ratio [HR], 0.73; 95% CI 0.54–1.00) relative to the baseline period. Among Massachusetts residents, the adjusted risk of infection during the early intervention

### Table 2: Baseline characteristics of nursing facilities by state

| Characteristic, median (iqr) or %     | Massachusetts n = 20 | Comparator states n = 45 |
|---------------------------------------|----------------------|--------------------------|
| Facility size                         |                      |                          |
| Small (0–59 beds)                     | 0                    | 7                       |
| Medium (60–120 beds)                  | 15                   | 36                      |
| Large (beds >120)                     | 85                   | 58                      |
| Total beds                            | 124 (123–146)        | 108 (82–146)            |
| % Residents financed by Medicare      | 10 (6–14)            | 14 (10–22)              |
| % Residents financed by Medicaid      | 59 (51–66)           | 67 (56–75)              |
| % Residents financed privately        | 30 (20–37)           | 17 (12–22)              |
| Overall star-rating (1–5, lower worse)| 3 (2–4)              | 3 (2–4)                 |
| Staffing star-rating (1–5, lower worse)| 3 (3–4)              | 3 (3–4)                 |
| Infection control citationa           | 25                   | 23                      |
| Ruralb                               | 0                    | 29                      |

**Note:** Comparator states include New Hampshire, Rhode Island, and Connecticut.

aBased on whether an infection control citation (F880) was recorded on Medicare’s care compare website during 2019.

bRurality was defined using rural-urban continuum codes developed by the US Department of Agriculture.

### Table 3: Discrete time proportional hazards regression results

| Variable                                      | Risk Ratio (95% CI) | p    |
|-----------------------------------------------|---------------------|------|
| MA versus comparator states, baselinea        | 1.69 (1.60–1.78)    | <0.001|
| Post-baseline risk relative to baseline, comparator states | 0.73 (0.54–1.00)    | 0.049|
| Early intervention period (6–9 wks.)         | 0.02 (0.01–0.04)    | <0.001|
| Late intervention period (≥10 wks.)          |                     |      |
| Additional decline in risk in MA relative to comparator states | 0.47 (0.37–0.59)    | <0.001|
| Early intervention period                    | 0.80 (0.64–1.00)    | 0.048|
| SARS-CoV-2 Prevalence (standardized)         | 2.32 (1.75–3.09)    | <0.001|
| Age (ref. 80–84 years old)                   |                     |      |
| <65                                           | 1.05 (0.83–1.35)    | 0.67 |
| 65–69                                         | 1.14 (0.97–1.34)    | 0.12 |
| 70–74                                         | 1.14 (1.03–1.27)    | 0.011|
| 75–79                                         | 0.98 (0.89–1.09)    | 0.75 |
| 85–89                                         | 0.80 (0.78–0.83)    | <0.001|
| ≥90                                           | 0.85 (0.79–0.92)    | <0.001|
| Female sex                                    | 1.06 (0.96–1.17)    | 0.23 |
| Race (ref. White)                             |                     |      |
| Black                                         | 1.80 (1.08–3.00)    | 0.024|
| Other                                         | 1.20 (0.98–1.45)    | 0.07 |
| ADL score (0–28)                              | 0.99 (0.98–0.99)    | 0.013|
| Dementia diagnosis                            | 1.31 (0.97–1.75)    | 0.08 |
| Heart failure                                 | 1.00 (0.87–1.17)    | 0.95 |
| Coronary artery disease                       | 1.06 (1.04–1.08)    | <0.001|
| Asthma/COPD                                    | 1.04 (0.95–1.12)    | 0.46 |
| Chronic kidney disease                        | 0.98 (0.92–1.03)    | 0.38 |
| Hypertension                                  | 1.09 (0.98–1.21)    | 0.12 |
| Diabetes                                      | 1.07 (0.93–1.24)    | 0.34 |
| Post-acute patient                            | 0.51 (0.41–0.64)    | <0.001|

**Note:** Chronic kidney disease includes renal insufficiency, renal disease, or end-stage renal disease. Massachusetts is being compared to New Hampshire, Rhode Island, and Connecticut, the reference group.

Abbreviations: ADL, activities of daily living; COPD, chronic obstructive pulmonary disease; MA, Massachusetts.

aThe coefficient on this variable represents the adjusted hazard of infection for Massachusetts residents relative to comparator state residents during the baseline period (1–5 weeks).
period declined by 66% relative to baseline (Figure 1), which is a 53% additional reduction in risk beyond that observed in comparator states (state-by-time interaction HR 0.47; 95% CI 0.37–0.59). During the early intervention period, therefore, the incidence in MA declined sharply enough that its magnitude became similar to that in comparator states (Figure 1). During weeks 10–20 the weekly risk continued to decline, by some 98% in comparator states (Table 3); the decline additional to this that occurred in Massachusetts was of marginal statistical significance (interaction HR 0.80; 95% CI 0.64–1.00).

Figure 1 shows the average adjusted weekly risk of infection (estimated likelihood of infection conditional on infection-free survival to that point) of SARS-CoV-2 infection during each study period. In the baseline (pre-intervention) period, the adjusted weekly risk of infection was 12% for Massachusetts residents and 7.6% for Comparator State residents. During the first 3 weeks of the early intervention period, the adjusted probability of acquiring SARS-CoV-2 became 4.6% for Massachusetts residents at continued risk of first infection, and 5.7% for their counterparts residing in Comparator States. During weeks 10–20, the adjusted probability of infection was 0.3% for Massachusetts residents versus 0.2% for Comparator State residents. The change in MA infection rates was significantly greater than the change in Comparator States’ infection rates from the baseline to both early and late intervention periods (Table 3 and Figure 1). As a result, the risk of infection during each intervention period was comparable in Massachusetts to that in Comparator States, despite having been substantially higher during the baseline period.

**DISCUSSION**

The results of this study suggest that the multicomponent statewide Massachusetts intervention for nursing homes that provided education, protective equipment, and payment incentives to comply with a checklist of infection-control procedures, more rapidly attenuated the risk of COVID-19 infection compared to similarly-managed facilities in surrounding states without such a statewide intervention. Moreover, the Massachusetts intervention appeared to be effective despite a high prevalence of COVID-19 infections in neighboring counties, which is known to drive high infection rates in nursing homes.8 The intervention was most effective during the first
3 weeks of implementation, after which infection rates declined at similar rates in Massachusetts and comparison states. Our working hypothesis is that the 3 weeks of early intervention was sufficient to overcome the excess risk in Massachusetts homes, whereas continued implementation of the intervention in the later period was sufficient to equalize the risks in MA and other states.

A number of states have launched similar efforts to mitigate the spread of COVID-19,\textsuperscript{10} and the Center for Medicare and Medicaid Services has issued infection prevention and control recommendations.\textsuperscript{11} However, their success has been limited\textsuperscript{12} and to our knowledge, none of the state-wide interventions has been rigorously studied for its impact on infection rates. A recent rapid narrative review by Dykgraaf et al.\textsuperscript{13} identified 77 observational studies in a variety of long-term care settings from around the world that suggested widespread surveillance, early identification and response, and rigorous infection prevention and control measures were most effective in mitigating the spread of COVID-19. Similar to the Massachusetts intervention, other factors included less crowding, higher nurse staffing ratios, facility-level leadership, interagency collaborations, and access to critical resources.\textsuperscript{13}

There are many limitations inherent in the observational population-based nature of our study. These include the many potential confounding variables that are very difficult to acquire or measure. Differences in the percentages of rural and urban facilities between Massachusetts and comparator states could have affected COVID-19 exposures during the intervention period. The definitions of urban and rural depend on the proximity of nursing homes to large metropolitan areas, which is more likely in Massachusetts and Rhode Island. Almost all of the rural homes are in New Hampshire. We accounted for this difference as much as possible by adjusting for the county prevalence of COVID-19 infections. We also acknowledge that each of the comparator states probably had some of their own unmeasured COVID-19 mitigation strategies underway, which could have lessened the difference in decline of infection rates between them and Massachusetts. Because we still found more rapid declines in early infection rates in Massachusetts facilities compared to those in neighboring states, the interventions in our comparison states may have been less effective.

Many other unmeasured resident-, facility-, and state-based factors may have confounded our results, but were minimized as much as possible by the management of all facilities by the same long-term care organization that employed similar operational procedures and policies. In addition, as shown in Table 2, the intervention and control facilities had similar five-star quality and staffing ratings. The uniform corporate structure could have led to some contamination of control facilities by elements of the Massachusetts intervention, but this would only lessen the likelihood of any differences in outcomes. Furthermore, aspects of the intervention such as incentive payments and on-site consultations were not likely to be replicated in other states.

As unmeasured resident and nursing home characteristics, as well as other state and federal policies may have influenced infection rates over time, we cannot assume there was a causal relationship between the Massachusetts intervention and decline in infections, although their coterminous relationship suggests this might have been the case. While the analysis of this relationship in one large nursing home provider organization is a strength, our results may not be generalizable to other nursing homes that have different management practices. It is also possible that mortality masked some events that would have been observed, although we have no reason to believe this would occur differentially in Massachusetts or surrounding states, and results were adjusted for a substantial number of risk factors.

As Massachusetts nursing homes had higher hazard rates in the baseline period, it is also possible that there were fewer susceptible residents and staff who had not previously been infected during the intervention, or that uninfected residents and staff changed their behaviors to reduce transmission after seeing the devastation from larger outbreaks. This might have resulted in a more rapid decline in infection rates, regardless of the intervention. Finally, in this study, we could not assess which of the many Massachusetts intervention components might have been most effective in reducing the risk of infection, although our previous study demonstrated that the facilities that were adherent to proper cohorting and PPE use had the largest reduction in infection rates.\textsuperscript{2}

In conclusion, the implementation of a multicomponent statewide intervention to mitigate the spread of COVID-19 in Massachusetts nursing homes was associated with a more rapid than expected rate of reduction in SARS-CoV-2 infections compared to similarly managed nursing homes in neighboring New England States.

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CONFLICT OF INTEREST
None.

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None.

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