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Original Study

Absence of COVID-19 Disease Among Chronically Ventilated Nursing Home Patients

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A B S T R A C T

Objective: To describe the experience of COVID-19 disease among chronically ventilated and non-ventilated nursing home patients living in 3 separate nursing homes.
Design: Observational study of death, respiratory illness and COVID-19 polymerase chain reaction (PCR) results among residents and staff during nursing home outbreaks in 2020.
Setting and Participants: 93 chronically ventilated nursing home patients and 1151 nonventilated patients living among 3 separate nursing homes on Long Island, New York, as of March 15, 2020. Illness, PCR results, and antibody studies among staff are also reported.
Measurements: Data were collected on death rate among chronically ventilated and nonventilated patients between March 15 and May 15, 2020, compared to the same time in 2019; prevalence of PCR positivity among ventilated and nonventilated patients in 2020; reported illness, PCR positivity, and antibody among staff.
Results: Total numbers of deaths among chronically ventilated nursing home patients during this time frame were similar to the analogous period 1 year earlier (9 of 93 in 2020 vs 8 of 100 in 2019, $P = .8$), whereas deaths among nonventilated patients were greatly increased (214 of 1151 in 2020 vs 55 of 1189 in 2019, $P < .001$). No ventilated patient deaths were clinically judged to be COVID-19 related. No clusters of COVID-19 illness could be demonstrated among ventilated patients. Surveillance PCR testing of ventilator patients failed to reveal COVID-19 positivity (none of 84 ventilator patients vs 81 of 971 nonventilator patients, $P < .002$). Illness and evidence of COVID-19 infection was demonstrated among staff working both in nonventilator and in ventilator units.
Conclusions and Implications: COVID-19 infection resulted in illness and death among nonventilated nursing home residents as well as among staff. This was not observed among chronically ventilated patients. The mechanics of chronic ventilation appears to protect chronically ventilated patients from COVID-19 disease.

COVID-19 disease is caused by the SARS-CoV2 virus, which is a respiratory pathogen associated with severe systemic disease and death.[1,2] The mortality rate is increased among very old patients and those with underlying disease. Among hospitalized patients requiring intubation and ventilation during management of acute illness, the mortality rate in initial reports was greater than 80%,[3] although rates have decreased with increasing experience caring for these patients.[4]

Conflicts of Interest: I.H.G., G.K., and D.S. receive stipends for medical director activities at Townhouse, Cold Spring Hills, and Gurwin, respectively.

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Nursing home outbreaks have been prevalent and account for a large proportion of fatalities in the community. Nursing home patients, particularly, are at increased risk because of congregate living, advanced age, and underlying disease.[5,6]

Given the advanced age, multiple comorbidities and underlying respiratory pathology, one might expect outbreaks to occur in nursing home ventilator support units and with attendant high mortality.

We describe the absence of COVID-19 respiratory disease among 93 chronically ventilated nursing home patients residing in 3 separate nursing homes.

All 3 facilities' ventilators were from Ventec Life Systems (model VOCSN; Bothell, WA). These facilities had converted all their ventilators to this system between September 2019 and February 2020.

Methods

We report outcomes of all 93 long-term ventilated nursing home patients residing in dedicated ventilator units in 3 separate nursing facilities starting March 15 through May 15, 2020. These 93 patients were admitted prior to and resided on one of these ventilator units on March 15, 2020. Outcomes of these patients were compared to the outcomes of all the other patients residing in each facility on March 15, 2020, and who were not ventilated during this time. This period was chosen because widespread disease and excess deaths due to COVID-19 were noted throughout these facilities during this period consistent with the New York City area experience.[7] For each facility, we reviewed the number of deaths due to any cause in the entire facility and on each ventilator unit in particular. Similarly, we report the outcomes of 41 nonventilated patients with tracheostomies during this period. We compared these outcomes to those observed during the same time frame in 2019.

COVID-19 polymerase chain reaction (PCR) nasal swab testing was not readily available during this time and was performed on a limited basis at each facility among ventilated and other patients with suspected acute infectious respiratory syndromes.

In late May 2020 and consequent to a New York State Department of Health mandate,[8] widespread PCR nasal swab testing of patients and staff became more readily available and was undertaken. We report the results of staff and resident testing obtained during COVID-19 surveillance. Surveillance testing started coincident with the apparent cessation of widespread COVID-19 illness in these facilities. In 1 facility, serologic antibody testing of some staff was performed simultaneously with the first nasal swab PCR surveillance test.

The study was determined to be exempt from Institutional Review Board (IRB) review by the Biomedical Research Alliance of New York (BRANY) IRB.

Statistical Analyses

Demographic characteristics are provided as means, standard deviations, and ranges for continuous variables, and as counts and percentages for categorical outcomes. Comparisons between these variables were made using Wilcoxon 2-sample tests for continuous variables and Fisher exact test for categorical variables. Logistic regression models were fitted using data from 2 facilities to evaluate the contribution of year and ventilation status on mortality. Models were fitted separately for these 2 facilities. A combined analysis was performed after it was established that the directionality of effects was the same across these 2 facilities. Dates of death were not ascertained in the third facility (Facility C) and, therefore, data from this facility were not included in these models.

Results

Total numbers of deaths among chronically ventilated nursing home patients during this time frame were similar to the analogous period 1 year earlier (9 of 93 in 2020 vs 8 of 100 in 2019; $P = .8$), whereas deaths among nonventilated patients were greatly increased (214 of 1151 in 2020 vs 55 of 1189 in 2019, $P < .001$) (Table 1) No ventilated patient deaths were clinically judged to be COVID-19 related.

Twelve chronically ventilated patients among the 3 facilities developed a febrile illness during this time frame and were tested for COVID-19 but only 1 had a positive nasopharyngeal COVID-19 test (facility A). This patient had a mild febrile syndrome and recovered. This one and only documented COVID-19–positive ventilator patient resided among 37 other ventilated patients. Six other ventilated patients on this unit had febrile illnesses during this period, and all tested COVID-19 negative and recovered from illness. Clusters of illness did not occur. However, 17 staff working on that unit developed COVID-19 illness. These staff included 5 registered nurses (4 tested positive), 3 nursing assistants (1 tested positive), 1 physical therapy aide, and 8 respiratory therapists (5 tested positive). This facility also encouraged antibody screening of staff between May 10 and May 18, 2020, in conjunction with NY State–mandated COVID-19 swab testing surveillance of employees. Sixty-nine of 151 of these employees demonstrated antibody, 10 of whom worked on this particular ventilator unit (7 respiratory therapy staff, 3 nursing staff).

Another facility (facility B) reported at least 4 staff who worked on their ventilator unit during this time and who developed COVID-19 PCR swab–positive confirmed illness, including 2 respiratory therapists, 1 licensed practical nurse, and 1 nurse practitioner.

During this time period, 11 patients (3 from facility A, 4 from facility B, and 4 from facility C) were successfully weaned and liberated from the ventilator. Five (3 from facility A and 2 from facility B) were discharged home several weeks later. Eight (2 from each of Facility A and B, 4 from facility C) were also decannulated following liberation from the ventilator.

Nonventilated patients with tracheostomies fared less well. Of 41 such patients residing in the 3 facilities, 6 died during this time—3 of 19 (facility A) and 3 of 13 (Facility B), similar to the overall nonventilator nontracheotomy death rate for the 3 facilities (6/41 vs 208/1110, $P = .5$) Three of 6 patients with tracheostomies who died were demonstrated to be COVID-19 positive. Three additional tracheotomy patients were clinically ill and tested positive and survived. Patients with tracheotomies resided in separate units from the ventilator patents but otherwise resided among other nursing home residents.

Data on outcomes for tracheostomy patients during the analogous time frame in 2019 was available for facilities A and B. During this time in 2019 there was 1 death among 28 tracheostomy patients vs the 6 deaths among 32 tracheostomy patients in 2020, 3 of which were among a cluster in facility B ($P = .07$).

Chronically ventilated patients had the same death rate despite the 2020 COVID outbreak compared to the same time frame in 2019 (odds ratio for death 0.57; $P = .2$), whereas the death rate among the rest of the nursing home residents increased 5-fold in 2020 compared to 2019 (odds ratio for death 5.25; $P < .001$). As would be expected, the death rate for ventilated patients during the non–COVID-19 experience of 2019 was greater compared with nonventilated residents (odds ratio 3.54; $P = .005$), whereas the death rate tended to be greater among nonventilated patients compared with ventilated patients during the COVID-19 outbreak of 2020 (odds ratio 1.75; $P > .05$) (Table 2).

With cessation of most COVID-19 activity in the 3 facilities by the end of May 2020 and on availability of testing, the 3 facilities undertook COVID-19 swab surveillance testing of all residents. Although the prevalence of positive tests among nonventilator patients varied

Table 1
Characteristics and Outcomes Among Chronically Ventilated and Nonventilated Nursing Home Patients During the 2020 COVID-19 Outbreak

	Facility A		Facility B		Facility C		Total	
	2019	2020	2019	2020	2019	2020	2019	2020
Number of patients (total)	269	267	570	555	450	422	1289	1244
Number of ventilated patients	39	38	38	36	23	19	100	93
Ventilator female patients, n (%)	28 (71.7)	26 (68.4)	26 (68.4)	24 (66.7)	14 (60.1)	11 (57.8)	68 (68)	61 (65.5)
Ventilator patient age, y, mean (SD); range	69.3 (15.6); 25-98	66.1 (18.5); 25-98	65.6 (17.9); 25-95	70.1 (14.7); 28-97	69.8 (18.2); 28-95	64.9 (16.5); 30-83	68.0 (17.2); 23.8-97.2	67.4 (16.7); 24.9-98.2
Total facility deaths	19	35	23	105	21	83	63 of 1289	223 of 1244*
Total ventilator patient deaths	3	1	4	5	1	3	8 of 100	9 of 93†
Total nonventilator patient deaths	16	34	19	100	20	80	55 of 1189	214 of 1151‡
COVID-19 surveillance total tested	227		495		333		1055	
Total nonventilator positive	60 of 194		14 of 463		7 of 314		81 of 971	
Total ventilator positive	0 of 33		0 of 32		0 of 19		0 of 84§	
	2019	2020	2019	2020	2019	2020	2019 (facility A and B)	2020 (all 3 facilities)
Number of tracheostomy patients	18	19	10	13	NA	9	28	41
Number with tracheostomy who died	1	3	0	3	NA	0	1	6‖

NA, not available.
*$P < .001$ (2019 vs 2020).
†$P = .8$ (2019 vs 2020).
‡$P < .001$ (2019 vs 2020).
§$P < .001$ (ventilator vs nonventilator).
‖$P = .5$ (tracheotomy vs nonventilator/nontracheotomy).

Table 2
Effect of Ventilation on Mortality in 2019 and 2020

Ventilation Status and year	Odds Ratio for Death (95% Confidence Interval)	*P* Value
Ventilated 2020 vs 2019	0.57 (0.24-1.37)	.21
Nonventilated 2020 vs 2019	5.25 (3.5-7.87)	<.001
Ventilated vs nonventilated in 2019	3.54 (1.47-8.53)	<.001
Nonventilated vs ventilated in 2020	1.75 (0.73-4.2)	>.05

among the 3 facilities (60 of 194 facility A; 14 of 463 facility B; 7 of 314 facility C; total 81 of 971), among the 84 tested ventilator patients, none demonstrated COVID-19 swab positivity ($P = .002$). The initial surveillance testing of staff among the 3 ventilator units at the end of May demonstrated COVID-19 positivity in 5 staff. Continued weekly surveillance of staff revealed COVID-19 swab positivity among 2 certified nursing assistants working on the ventilator unit of facility A. These were obtained on July 21 but resulted on August 2. Despite continued exposure of patients to these nursing assistants until results were obtained, nasal COVID-19 was again not detected among any of the 37 ventilated patients of facility A who were subsequently swabbed on August 4 and 5. Weekly testing of ventilator patients continues in facility A without demonstration of positivity among any ventilated patients.

Discussion

COVID-19 disease is a respiratory syndrome that is transmitted through contact, droplet, and airborne routes with virus gaining access to the respiratory tract.[9] This renders an individual at risk for developing a clinical syndrome that varies from an asymptomatic carrier state to severe respiratory illness characterized by pneumonia, adult respiratory distress syndrome, and severe systemic disease with death. COVID-19 lower respiratory tract disease and systemic illness is mediated by viral attachment to ACE2 receptors on alveolar type II cells.[10]

We were surprised that COVID-19 disease did not produce obvious clusters of severe respiratory disease and death among chronically ventilated nursing home patients. First, we noted widespread activity on other units of each of the 3 nursing facilities. Second, 1 ventilated patient was found to be PCR positive (although potentially a false positive). Third, importantly but not surprisingly, illness and asymptomatic carriage occurred among staff working with these patients. Staff working in nursing homes have been found to subsequently transmit disease.[11] Our overall experience with COVID-19 illness and death among nursing home residents in general is consistent with the experience in the New York City area.[7] The experience with chronically ventilated patients on the other hand is not. The absence of COVID-19 disease among these ventilated patients is consistent with the lack of COVID-19 positivity documented during subsequent surveillance testing of these patients despite presence in all facilities including widespread positivity among nonventilated patients in one of the facilities.

The observed findings may reflect extreme vigilance and infection control interventions that each of these 3 facilities instituted on their ventilator units. Were it so, however, the considerable mortality and morbidity observed clinically on most other units in 3 separate facilities should also have resulted in less disease.

We surmise that the mechanics of ventilation among chronically ventilated patients may provide a protective environment preventing virus from entering the lower respiratory tract and gaining access to the receptors on nasal, airway, and lung endothelium.

First, air and oxygen delivered by the particular ventilators used in these 3 facilities pass through 2 electrostatic filters providing submicron filtration, with 99.99% bacterial and viral filtration

efficiency before reaching a patient. This feature, notwithstanding, would not preclude colonization of the upper respiratory tract above the tracheostomy site. However, the positive pressure by which ventilators deliver air to a patient may provide a barrier to the usual negative inspiratory pressure that draws air into the lungs during normal respiration. Normal respiration involves inhalation. Patients on ventilators do not draw air into the lungs through the nasopharynx with negative forces. All 3 facilities used the same model ventilator, and so this study cannot determine whether the observed effect can be generalized to other ventilator systems. Additional studies are required to confirm ours and to better elucidate ventilator-specific outcomes.

We were also surprised that surveillance testing of chronically ventilated patients residing in nursing homes did not reveal any COVID-19 carriage even in the absence of lower respiratory tract and systemic acute symptoms. This was supported by a negative test result in the 84 ventilator patients in our study and by a negative result on repeat testing of 37 patients in facility A with continued weekly retesting of these until the time of this writing.

The lack of such finding may reflect the success of barrier precautions despite infected staff but this seems unlikely to account for our findings to the contrary. We surmise that because ventilated patients do not actively inhale though the mouth and nares, viral access and entry into the nasopharyngeal mucosa is mitigated. Whether negative nasal testing among these non-nasal breathers is valid requires confirmation but the lack of clustered disease and excess mortality suggests its validity.

This hypothesis is also supported by our experience with non-ventilated patients with tracheostomies. Although these patients may bypass the nasopharynx when inhaling, their mechanics of ventilation might still create negative inspiratory forces. As such, attachment of virus to the nasal mucosa and entry of virus to the respiratory tract via the nares or direct inhalation through the tracheostomy would not be impeded by the positive pressure forces otherwise produced by mechanical ventilation and thereby resulting in infection and death.

These findings require confirmation by others and further study but, in the meantime, are consistent with the known pathophysiology of respiratory tract invasion by the virus, and the apparent protection afforded by mechanical ventilators. Our findings suggest that efforts to liberate ventilated patients living in nursing homes or other environments where COVID-19 is circulating can proceed. However, until this matter is further studied, we suggest that the potential risk for COVID-19 infection vs the benefit of ventilator liberation must still be considered. For patients with tracheostomies, facial masks would not be expected to provide adequate barrier protection, and the additional application of a neck mask or filtering devices to the tracheotomy tube might reduce infection.

Conclusions and Implications

COVID-19 infection resulted in illness and death among non-ventilated nursing home residents as well as among staff. This was not observed among chronically ventilated patients. Air filtration and alteration of the usual mechanics of respiration by ventilator appear to protect chronically ventilated patients in nursing homes from SARS-CoV2 infection.

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