ORIGINAL RESEARCH

Older Age and Frailty are Associated with Higher Mortality but Lower ICU Admission with COVID-19

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ABSTRACT

Background

We report characteristics and outcomes of adults admitted to Canadian Immunization Research Network (CIRN) Serious Outcomes Surveillance (SOS) Network hospitals with COVID-19 in 2020.

Methods

Patients with laboratory-confirmed COVID-19 admitted to 11 sites in Ontario, Quebec, Alberta, and Nova Scotia up to December 31, 2020 were enrolled in this prospective observational cohort study. Measures included age, sex, demographics, housing, exposures, Clinical Frailty Scale, comorbidities; in addition, length of stay, intensive care unit (ICU) admission, mechanical ventilation, and survival were assessed. Descriptive analyses and multivariable logistic regressions were conducted.

Results

Among 2,011 patients, mean age was 71.0 (range 19–105) years. 29.7% were admitted from assisted living or long-term care facilities. The full spectrum of frailty was represented in both younger and older age groups. 81.8% had at least one underlying comorbidity and 27.2% had obesity. Mortality was 14.3% without ICU admission, and 24.6% for those admitted to ICU. Older age and frailty were independent predictors of lower ICU use and higher mortality; accounting for frailty, obesity was not an independent predictor of mortality, and associations of comorbidities with mortality were weakened.

Conclusions

Frailty is a critical clinical factor in predicting outcomes of COVID-19, which should be considered in research and clinical settings.

Key words: age, frailty, frail elderly, COVID-19, SARS-CoV-2, outcomes, hospitalization, surveillance

INTRODUCTION

The COVID-19 pandemic has had dramatic impacts around the world, including in Canada. The first case in Canada was identified on January 25th, 2020, and by mid-March 2020, COVID-19 activity had been detected in all ten Canadian provinces.[1]

The Serious Outcomes Surveillance (SOS) Network of the Canadian Immunization Research Network (CIRN) was established just prior to the 2010 H1N1 influenza pandemic, and has since provided infrastructure for active influenza surveillance in sentinel Canadian hospitals to help inform the Public Health Agency of Canada (PHAC) influenza response.[2-4] In addition to providing estimates of seasonal influenza vaccine

effectiveness and informing the public health response to seasonal influenza, the CIRN SOS Network was designed to enable rapid pandemic surveillance response capacity to complement PHAC activities and the need for immediate collation of epidemiological data from across Canada. Beyond providing surveillance numbers, the SOS Network collects detailed clinical data, including on measures of health relevant to older adults (e.g., frailty and comorbidities). Given this established hospital surveillance infrastructure, it has been possible to pivot SOS Network's efforts to provide COVID-19 surveillance. This capacity supplements the routine COVID-19 surveillance performed by acute care Infection Prevention and Control and Infectious Diseases practitioners and aids the PHAC's pandemic response efforts.

With regard to COVID-19, the overarching objective of the SOS Network is to provide Canadian public health decision-makers with detailed, real-time information about the burden of COVID-19 leading to hospitalization in Canadian adults, and to characterize the clinical and epidemiologic characteristics, burden of severe disease, and outcomes of adults admitted with laboratory-confirmed COVID-19. Here we aimed to describe the characteristics and outcomes of adults admitted to hospital with COVID-19 during 2020, representing the first wave and beginning of the second wave of the pandemic in Canada.

METHODS

Eleven sites in four provinces participate in COVID-19 surveillance: Nova Scotia (Halifax/Dartmouth), Québec (Québec and Sherbrooke), Ontario (Ottawa, Hamilton, Toronto, Sudbury), and Alberta (Edmonton), representing a total of over 6,000 adult in-patient beds. Patients with admission dates until December 31, 2020 were included in the present analyses. Outcomes were included up to the data extraction date of March 25, 2021.

Case Definition

Network monitors and/or site health-care staff screened all eligible hospital admissions for COVID-19 using the most current PHAC/SOS COVID-19 case definition.[5] SOS surveillance for COVID-19 has expanded beyond usual influenza seasonal surveillance to take place year-round. For case capture purposes, the following categories of COVID-19 cases are enrolled: "confirmed" (laboratory test positive), "probable" (symptoms and epidemiological exposure criteria met, initial positive test but not confirmed, or inconclusive test result [e.g., poor sample quality]), and "clinical suspicion" (clinical impression of COVID-19 in setting of negative test results presumed false negative, or test not done). Here we report characteristics and outcomes for patients with laboratory-confirmed COVID-19.

Laboratory Testing

Samples from probable COVID-19 cases are collected as standard of care. Nasopharyngeal (NP) or oropharyngeal (OP) swabs are collected and tested using standardized real-time reverse transcriptase polymerase chain reaction (RT-PCR) methods at the local laboratory, with further confirmation at a reference laboratory or the National Microbiology Laboratory, according to local protocol.[6-8]

Measures

Research monitors at each site collect clinical data using standardized data collection forms. Data are gathered from the best available source, including chart review and interviews with patients, families, and clinicians.

Clinical characteristics including age, sex, ethnicity, residential situation (e.g., congregate living, homelessness, long term care [LTC]), admission and discharge diagnoses, length of stay, date of symptom onset, comorbidities, and influenza immunization status. Obesity was defined as BMI ≥30 or obesity noted in chart. Pre-illness level of frailty was measured using the well-validated Clinical Frailty Scale (CFS), which categorizes frailty as follows: 1=very fit, 2=well, 3=managing well, 4=vulnerable/pre-frail, 5=mildly frail, 6=moderately frail, 7=severely frail, 8=very severely frail, 9=end of life.[9,10] Treatment for COVID-19 was recorded, whether following the hospital medical guidelines or under investigation by a COVID-19 clinical trial. Additional data are collected regarding COVID-19 exposure and contact history (e.g., travel, close contact with another confirmed case).

Outcomes included hospital length of stay, intensive care unit (ICU) admission, need for mechanical ventilation, and all-cause in-hospital death.

Reporting

In addition to weekly reporting to PHAC, reporting to provincial public health is provided to complement their efforts and assessment of COVID-19 activity within their jurisdictions.

Analysis

Descriptive statistics are presented as mean (SD) for continuous variables and as frequency (%) for categorical variables. Time span variables, such as length of stay (LOS), are reported as median (interquartile range [IQR]). Independent samples *t*-tests were used to compare groups on continuous variables and chi-squared tests of independents were used to compare groups on categorical variables. Non-parametric independent samples median tests were used to compared time span variables by age group and frailty. Separate logistic regressions were conducted for each predictor to assess associations with ICU admission, mechanical ventilation, and mortality. We presented unadjusted ORs and ORs adjusted for age, sex, and frailty. The amount of missing data ranged from 60% for known direct exposure to none for mortality and province. Missing data were handled through multiple imputation (MI) (see Table 1 in Appendix A). MI is superior to listwise deletion as it reduces bias and maintains power.[11-13] All variables were included in the imputation model. We imputed 100 data sets and the results were pooled using the rules outlined by Rubin.[11,14] Imputed datasets were

created using the multivariate imputation by chained equations (MICE) package in R.[15] Analysis done with listwise deletion and more information about missing data can be found in Appendix A. Analyses were done using SPSS version 26 (IBM SPSS Statistics, Armonk, NY) and R version 4.03 (R Foundation for Statistical Computing; https://www.r-project.org/foundation/).[16]

Ethics

The protocol for active COVID-19 surveillance has been approved by each local site's Research Ethics Board.

RESULTS

During 2020, 2,011 patients with lab-confirmed COVID-19 were enrolled in the SOS Network (Figure 1). Mean age was 71.0, with a range of 19–105 years. 45.7% were women and 74.0% were white. The majority of patients (66.7%) were admitted from private dwellings; 21.5% were from assisted living facilities, 8.2% were admitted from LTC, and 2.1% from homeless shelters (Table 1). In terms of exposure, 6.4% had a documented travel history and 51.2% had a known COVID-19 exposure.

Overall, all-cause in-hospital mortality was high in this hospitalized cohort. Of those not admitted to ICU, 14.3% (226/1,583) died, compared with 24.6% (110/448) of those admitted to ICU, and 29.6% (73/247) of those who received mechanical ventilation.

Most patients (1,380/2,031 = 67.9%) were 65 or older, although a substantial number (651/2,031 = 32.1%) were under 65. Median age was 74 (IQ = 60-85). Table 2 presents age-stratified outcomes. Length of stay generally increased with age. Mortality showed a strong correlation with age: 4.5% of those <65 died compared with 28.2% aged 85 or older. Odds of dying increased by 5% each year of age, OR = 1.05, 95%CI = 1.04-1.06. Notably, ICU admission and mechanical ventilation rates were similar in those aged <65 and those aged 65–74, but decreased once age was ≥75 years (all $p < .001$).

At baseline, most patients were not frail (17.4% were very fit or well, 24.2% were managing well, and 15.5% were vulnerable/pre-frail), 12.8% were mildly frail, 15.6% moderately frail, and 14.6% severely frail (Table 1). Length of stay and mortality increased dramatically with frailty, while ICU admission and mechanical ventilation were reduced at higher levels of frailty (all $p < .001$, Table 3).

The majority of patients had at least one underlying comorbidity, the most common being cardiovascular (73.8%) and respiratory (30.2%). Only 6.5% were reported to be immunosuppressed and 2.1% were immunocompromised. 27.2% were reported to be obese (Table 1). Individuals with underlying comorbidities experienced more severe outcomes and death than those without. The death rates for cardiovascular, respiratory, immunosuppressed, and immunocompromised were 19.8%, 20.1%, 17.4%, and 21.4%, respectively. The mortality rate was 6.5% for those with none of these comorbidities. The mortality rate for obese participants was 15.0% (Table 4).

Antibiotic or antiviral use to treat the current episode of illness (including before admission, Emergency Department presentation, and within seven days of the admission or positive COVID-19 result) was reported in 1,464/2,031 (72.1%). During this period in the first wave of the pandemic, direct-acting antiviral or immune modulatory medications were used in only 192/2,031 (9.5%).

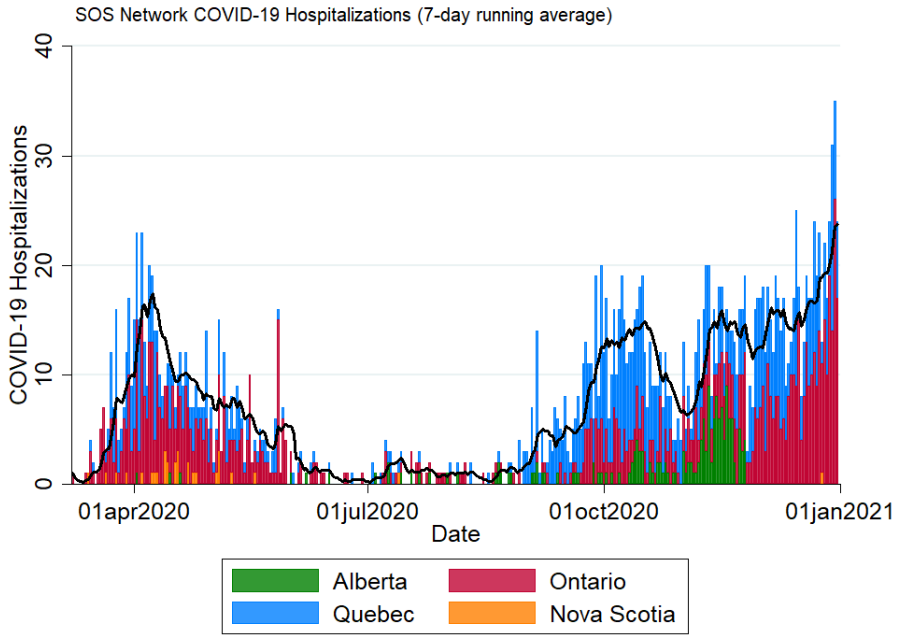

FIGURE 1. Epidemic curve of admissions to Serious Outcomes Surveillance (SOS) Network hospitals, colour-coded by province

TABLE 1.
Clinical and demographic characteristics: Mean (SD) or N (%)

Characteristic	*Full Sample Total N = 2031*	*Age < 65 yrs N = 651*	*Age 65 yrs + N = 1380*	*p*
Age	71.0 (17.4)	50.2 (11.6)	80.9 (8.9)	<.001
Female sex	928 (45.7%)	280 (43.0%)	648 (47.0%)	.10
Ethnicity:				<.001
White	1503 (74.0%)	387 (59.4%)	1116 (80.9%)	
Black	96 (4.7%)	65 (10.0%)	31 (2.3%)	
South Asian	86 (4.2%)	42 (6.5%)	43 (3.1%)	
West Asian	76 (3.8%)	40 (6.1%)	37 (2.7%)	
Chinese	102 (5.0%)	33 (5.1%)	69 (5.0%)	
Other	168 (8.3%)	84 (13.0%)	84 (6.1%)	
Housing:				<.001
Private dwelling	1355 (66.7%)	577 (88.6%)	778 (56.4%)	
Assisted living facility	438 (21.5%)	13 (1.9%)	425 (30.8%)	
Long term care facility	167 (8.2%)	18 (2.8%)	149 (10.8%)	
Homeless / shelter	43 (2.1%)	33 (5.0%)	10 (0.7%)	
Other	28 (1.4%)	11 (1.7%)	18 (1.3%)	
Province:				<.001
Alberta	130 (6.4%)	62 (9.5%)	68 (4.9%)	
Ontario	1003 (49.4%)	341 (52.4%)	662 (47.9%)	
Quebec	868 (42.7%)	230 (35.3%)	638 (46.2%)	
Nova Scotia	30 (1.5%)	18 (2.8%)	12 (0.9%)	
Clinical Frailty Scale:				<.001
1-2	354 (17.4%)	282 (43.4)	72 (5.2%)	
3	491 (24.2%)	236 (36.2%)	255 (18.5)	
4	314(15.5%)	69 (10.5%)	245 (17.8%)	
5	259 (12.7%)	28 (4.3%)	231 (16.7%)	
6	317 (15.6%)	19 (2.9%)	298 (21.6%)	
7-9	297 (14.6%)	18 (2.7%)	279 (20.2%)	
Obese (Calculated BMI ≥30 or obesity noted in medical record)	553 (27.2%)	249 (38.3%)	304 (22.0%)	<.001
Comorbidities:				
None of respiratory, cardiovascular, immunosuppressed, or immunocompromised	371 (18.2%)	249 (38.2%)	121 (8.8%)	<.001
Cardiovascular	1499 (73.8%)	312 (47.8%)	1187 (86.0%)	<.001
Respiratory	613 (30.2%)	161 (24.7%)	452 (32.8%)	<.001
Immunosuppressed	132 (6.5%)	49 (7.5%)	83 (6.0%)	.29
Immunocompromised	42 (2.1%)	11 (1.7%)	31 (2.3%)	.37
Travel history	130 (6.4%)	46 (7.1%)	84 (6.1%)	.45
Known direct exposure	1040 (51.2%)	324 (49.8%)	716 (51.9%)	.39
Occupation:				<.001
Health-care worker	116 (5.7%)	98 (15.1%)	18 (1.3%)	
Other occupation	324 (15.9%)	272 (41.7%)	52 (3.8%)	
Not working	301 (14.8%)	208 (32.0%)	93 (6.8%)	
Retired	1291 (63.5%)	74 (11.3%)	1217 (88.2%)	
Goals of Care:				<.001
Full resuscitation	1117 (55.0%)	599 (92.0%)	518 (37.5%)	
Escalation of care with exceptions	190 (9.4%)	21 (3.1%)	170 (12.3%)	
Ward based medical care, but no CPR, ICU, or intubation	454 (22.3%)	22 (3.4%)	432 (31.3%)	
Comfort Care	270 (13.3%)	10 (1.5%)	260 (18.9%)	

TABLE 2.
Medians (interquartile range (IQR)) or frequency (per cent) for outcomes by age

Outcome	*Whole sample N = 2,031*	*Age <65 N = 651*	*Age 65-74 N = 377*	*Age 75-84 N = 494*	*Age 85+ N = 509*	*p*
Length of stay (days)[b]	11 (6–25)	7 (4–14)	12 (6–27)	13 (7–28)	19 (9–36)	<.001[a] (<.001, <.001)
ICU admission	448 (22.1%)	203 (31.2%)	121 (32.1%)	91 (18.4%)	33 (6.4%)	<.001
Mechanical ventilation	247 (12.2%)	112 (17.6%)	77 (20.5%)	42 (8.5%)	16 (3.1%)	<.001
Death	336 (16.5%)	29 (4.5%)	63 (16.7%)	100 (20.3%)	144 (28.2%)	<.001
Days symptom onset to admission	4 (1 – 8)	5 (2 – 9)	5 (1 – 9)	4 (1 – 7)	2 (0 – 6)	<.001[a] (<.001, <.001)
Days Symptom onset to COVID-19 test sample	2 (0 – 6)	2 (0 – 6)	3 (0 – 7)	2 (0 – 6)	1 (0 – 4)	<.001[a] (<.001, <.001)
Days COVID-19 test sample to admission	0 (0 – 4)	1 (0 – 5)	0 (0 – 3)	0 (0 – 2)	0 (-1 – 3)	<.001[a] (<.001, <.001)
Goals of Care:						<.001
Full resuscitation	1,117 (55.0%)	599 (92.1%)	244 (64.7%)	187 (37.8%)	88 (17.2%)	
Escalation of care with exceptions	190 (9.4%)	21 (3.1%)	35 (9.3%)	75 (15.1%)	60 (11.7%)	
Ward based medical care, but no CPR, ICU, or intubation	454 (22.3%)	22 (3.4%)	67 (17.8%)	166 (33.7%)	199 (39.0%)	
Comfort Care	270 (13.3%)	10 (1.5%)	31 (8.2%)	66(13.4%)	163 (32.0%)	

[a]No known pooling method for test between medians. We present the median and IQR range of *p* values over the 100 multiply imputed datasets.
[b]For length of stay, only those whose admission date was not more than 14 days prior to symptom onset and who were alive at discharge were included (N = 1,593).

TABLE 3.
Medians (interquartile range (IQR)) or frequency (per cent) for outcomes by frailty

Outcome	*CFS = 1-2 N=354*	*CFS = 3 N=491*	*CFS = 4 N=314*	*CFS = 5 N=259*	*CFS = 6 N=317*	*CFS = 7-9 N=297*	*p*
Length of stay[b]	6 (4–11)	8 (5–18)	14 (7–26)	17 (8–33)	19 (10–39)	18 (10–35)	<.001[a] (<.001, <.001)
ICU admission	99 (27.9%)	157 (32.0%)	96 (30.5%)	39 (15.0%)	36 (11.4%)	21 (7.0%)	<.001
Mechanical ventilation	57 (16.0%)	92 (18.8%)	54 (17.3%)	20 (7.6%)	14 (4.3%)	11 (3.8%)	<.001
Death	10 (2.9%)	36 (7.4%)	49 (15.4%)	51 (19.5%)	77 (24.1%)	114 (38.3%)	<.001
Goals of Care:							<.001
Full resuscitation	337 (95.3%)	399 (81.3)	176 (56.0%)	93 (35.8%)	77 (24.1%)	36 (12.1%)	
Escalation of care with exceptions	7 (1.8%)	36 (7.4%)	41 (13.0%)	39 (15.1%)	44 (14.0%)	23 (7.8%)	
Ward based medical care, but no CPR, ICU, or intubation	7 (2.0%)	47 (9.5%)	77 (24.6%)	94 (36.3%)	108 (34.0%)	122 (40.9%)	
Comfort Care	12 (1.5%)		20 (6.4%)	33 (12.7%)	88 (27.8%)	116 (39.2%)	

[a]No known pooling method for test between medians. We present the median and IQR range of *p* values over the 100 multiply imputed datasets.
[b]For length of stay, only those whose admission date was not more than seven days prior to symptom onset were included (N = 1,593).

TABLE 4.
Demographic and clinical characteristics of patients admitted to ICU and experiencing mortality

Characteristic	*Admitted to ICU N = 448*	*Mortality N = 336*
Female sex	151 (33.6%)	155 (46.1%)
Ethnicity:		
White	309 (69.0%)	277 (82.6%)
South Asian	19 (4.3%)	9 (2.7%)
Black	25 (5.5%)	7 (2.2%)
West Asian	14 (3.1%)	
Chinese	23 (5.0%)	17 (5.0%)
Other	59 (13.1%)	25 (7.5%)
Housing:		
Private dwelling	395 (88.3%)	155 (46.1%)
Assisted living facility	20 (4.5%)	133 (39.6%)
Long term care facility	20 (4.5%)	44 (13.0%)
Homeless / shelter	12 (2.7%)	Both groups < 5[a]
Other		
Province:		
Alberta	33 (7.4%)	19 (5.7%)
Ontario	239 (53.4%)	146 (43.5%)
Quebec	169 (37.7%)	167 (49.7%)
Nova Scotia	7 (1.6%)	< 5
Obese (Calculated BMI ≥30 or obesity noted in medical record)	173 (38.7%)	83 (24.6%)
Comorbidities:		
None of respiratory, cardiovascular, immunosuppressed, or immunocompromised	76 (17.0%)	24 (7.0%)
Cardiovascular	332(74.2%)	297 (88.5%)
Respiratory	143 (32.0%)	123 (36.5%)
Immunosuppressed	32 (7.1%)	23 (6.9%)
Immunocompromised	13 (2.9%)	9 (2.8%)

[a]Cells collapsed so no single cell presented with n < 5.

In logistic regression models adjusted for age, sex, and frailty, higher frailty was inversely associated with ICU admission and mechanical ventilation, while older age was inversely associated with ICU admission. In the adjusted ICU and mechanical ventilation models, living in LTC was not an independent predictor of outcomes (Table 5). In multivariable models of death, increasing age and frailty were strongly associated with increased mortality. Obesity was associated with ICU admission and mechanical ventilation, but not death. Having at least one comorbidity and cardiovascular disease was associated with increased odds of ICU admission, mechanical ventilation, and death. Respiratory disease was associated with increased odds of death.

DISCUSSION

Among the first 2,011 patients enrolled in the SOS Network with laboratory-confirmed COVID-19, there was a wide range in age, frailty, and comorbidities. Many patients had underlying frailty and comorbidities, but a substantial proportion did not. Older age and increasing frailty were independent predictors of higher in-hospital mortality and lower odds of mechanical ventilation or admission to ICU, and obesity was also an independent risk factor for mechanical ventilation and death. Presence of underlying respiratory, cardiovascular and immunocompromising comorbidities remained independently associated with outcomes, though the strength of this association was much attenuated when adjusting for frailty.

The age range (19–105) in our hospitalized cohort was wide. Predictably, older patients were at highest risk of severe outcomes, but not exclusively so. Mortality was high at 16.5% in the sample as a whole, and was higher in the subset of patients admitted to ICU and receiving mechanical ventilation. Our findings are comparable to a published report from the Canadian Nosocomial Infection Surveillance Program[17] (though here we add consideration of frailty), and to published reports of patients hospitalized with COVID-19 in other jurisdictions. A Swedish study reported mortality of 24% in a cohort of 250 hospitalized older adults, with older age and higher frailty being associated with worse outcomes.[18] A Scottish study of 224 adults hospitalized with COVID-19 found mortality of 23%, with age ≥70 and CFS > 3 being independent predictors of mortality.[19]

We found that, while obesity was associated with ICU admission and mechanical ventilation, it was not independently associated with death, while underlying cardiovascular and respiratory conditions were. Obesity has been identified as an important risk factor in other studies.[20,21] Our findings contrast with other studies reporting a stronger increased risk associated with chronic conditions,[22] and indeed we did find stronger associations between comorbidities and mortality prior to adjusting for age and frailty in the multivariable models; this is consistent with other studies where frailty has been considered. For example, a Swedish study also reported that frailty is the strongest predictive factor for mortality in older adults.[23]

During this first wave of COVID-19 hospital admissions in Canada, and early into the second wave in some areas, most patients (72.1%) were treated with antibiotics or antiviral medications, while only 9.5% had received targeted direct-acting antiviral or immune modulatory medications. As data on the effectiveness of these targeted therapies evolve, it is likely that targeted therapies will gain more widespread use.

Our results are similar to aggregate data on hospital admission and outcomes communicated by the PHAC. During the time period of our enrolments, PHAC reported that 32% of hospitalizations occurred in patients aged 80+, while 30% were adults <60. ICU admissions peaked in the 60–69 age group and then declined. 71% of deaths occurred in those aged 80+.[1]

TABLE 5.
Odds ratios (95% CI) from logistic regressions

	ICU Admission	*Mechanically Ventilated*	*Mortality*
Unadjusted:			
Age	0.97 (0.97, 0.98)***	0.98 (0.97, 0.99)***	1.05 (1.04, 1.06)***
Sex (Female)	0.53 (0.41, 0.67)***	0.52 (0.38, 0.71)***	1.02 (0.81, 1.29)
CFS	1–3		
	1.01 (0.74, 1.38) CFS 4	0.98 (0.67, 1.42)	3.13 (2.01, 4.86)***
	0.41 (0.26, 0.62)*** CFS 5	0.38 (0.22, 0.67)**	4.16 (2.67, 6.48)***
	0.24 (0.17, 0.34)*** CFS 6–9	0.20 (0.12, 0.33)***	7.69 (5.43, 10.90)***
Non-white	1.38 (1.05, 1.80)*	1.31 (0.92, 1.86)	0.55 (0.40, 0.76)***
Long-term care facility	0.46 (0.27, 0.78)**	0.46 (0.23, 0.92)*	1.92 (1.31, 2.80)**
Obesity	2.00 (1.53, 2.61)***	2.05 (1.46, 2.88)***	0.85 (0.64, 1.13)
Cormorbidity:			
At least one[a]	1.12 (0.82, 1.52)	1.33 (0.87, 2.05)	3.43 (2.18, 5.39)***
Cardiovascular	1.03 (0.78, 1.35)	1.21 (0.84, 1.73)	3.14 (2.19, 4.52)***
Respiratory	1.11 (0.87, 1.43)	0.91 (0.66, 1.27)	1.41 (1.09, 1.82)**
Adjusted:[b]			
Age	0.98 (0.98, 0.99)***	0.99 (0.98, 1.00)	1.03 (1.02, 1.04)***
Sex (Female)	0.57 (0.45, 0.74)***	0.58 (0.42, 0.79)**	0.80 (0.62, 1.03)
CFS	1–3		
	1.27 (0.90, 1.79) CFS 4	1.13 (0.75, 1.69)	2.19 (1.38, 3.48)**
	0.57 (0.36, 0.90)* CFS 5	0.48 (0.26, 0.87)*	2.50 (1.53, 4.06)***
	0.37 (0.24, 0.55)*** CFS 6–9	0.27 (0.15, 0.47)***	4.32 (2.85, 6.55)***
Non-white	1.01 (0.75, 1.36)	0.98 (0.67, 1.43)	0.86 (0.60, 1.22)
Long-term care facility	1.08 (0.61, 1.94)	1.22 (0.56, 2.69)	0.90 (0.60, 1.36)
Obesity	1.71 (1.29, 2.27)***	1.78 (1.25, 2.54)**	1.36 (0.98, 1.89)
Cormorbidity:			
At least one[a]	2.05 (1.43, 2.94)***	2.33 (1.43, 3.77)**	1.65 (1.00, 2.71)*
Cardiovascular	1.91 (1.38, 2.64)***	2.15 (1.40, 3.31)***	1.62 (1.09, 2.42)*
Respiratory	1.20 (0.92, 1.57)	0.97 (0.68, 1.37)	1.33 (1.01, 1.74)*

[a]At least one comorbidity of cardiovascular, respiratory, immunosuppressed, or immunocompromised.
[b]Adjusted for age, sex, and Clinical Frailty Scale (CFS).
*p<.05.
**p<.01.
***p<.001.

Interestingly, over half of patients were not frail at baseline. Frailty is increasingly recognized as a predictor of outcomes from COVID-19.[18,19,24] Indeed, some (including the UK's National Institute for Health and Care Excellence) have recommended that frailty be considered in resource allocation decisions.[25,26] While this was not done in the SOS Network sites during this time period to our knowledge, we did find that ICU use and mechanical ventilation declined with frailty. This phenomenon has also been observed in influenza,[27] and likely reflects that these aggressive interventions may not be felt to be consistent with goals of care. Our findings support this, as goals of care were progressively less aggressive as age and frailty increased. Interestingly, a French study reported that older age and frailty were not independently associated with mortality among patient admitted to geriatrics units, suggesting that the field requires more research.[28]

A minority of patients was admitted from LTC or congregate living situations. Although homeless individuals are appropriately recognized as a marginalized and high-risk group for COVID-19 infection and outcomes,[29] differential outcomes were not seen among the small number of patients identified as experiencing homelessness in our study. This is similar to a Belgian study in which 14 (5.8%) of the cohort of 238 admitted patients had similar clinical courses to non-homeless patients.[30]

Just over eight per cent (8.2%) of our cohort were admitted from a LTC facility. LTC and assisted living residents experienced higher mortality (44/167=26.3% and 133/438=30.4%, respectively) than that seen for patients admitted from private dwellings (155/1,355=11.4%). However, LTC residence was not an independent predictor of mortality once age and frailty were taken into account. This

may reflect differential decisions to transfer residents who were felt to have better clinical chances of survival to hospital while pursuing treatment or palliative care on site for others. In the bigger picture, LTC has in many ways been the epicentre of COVID-19 mortality in Canada (and other industrialized countries).[31] Although reporting has been suboptimal, estimates suggest that up to 85% of early Canadian COVID-19 deaths have occurred among LTC residents.[32,33] It is also interesting to put our findings regarding LTC facility residents in policy context. In some included jurisdictions (e.g., Nova Scotia), efforts were made to re-allocate resources to the LTC in cases of outbreaks, effectively creating an on-site hospital (which would not be captured in our data), whereas other jurisdictions may have prioritized pathways that would admit LTC facility residents to hospital. This suggests that our estimates of rates of frailty, LTC residence, and mortality among people with COVID-19 are conservative, compared with the overall Canadian experience.

Given interest in understanding how to best prioritize vaccines, demographic characteristics of the admitted patients are of particular interest. Among patients aged 65+, 80.9% were white and 56.4% lived in a private dwelling. For the younger adult group, relatively more patients (40.6%) were racialized and 88.6% lived in private dwellings. Only 6.4% had a travel history, while 51.2% had a known exposure. 5.7% (15.1% of those <65) were health-care workers. Although the majority of our enrolled population was white (which may also reflect the demographics of participating sites), the relative over-representation of racialized persons in the younger cohort is consistent with reports from many other jurisdictions.[34-36] This, along with the over-representation among frontline and health-care workers (also bringing into consideration important socioeconomic and racial contributing factors),[37] supports calls for these groups to be considered when decisions are made regarding prioritization of COVID-19 vaccination.[38]

Our study is not without limitations. COVID-19 surveillance is being conducted in trying and demanding clinical settings, and data collection for some variables that are not part of core reporting to PHAC have been delayed, resulting in missing data for some variables (e.g., 448 cases missing comorbidity data), though we were able to address this in the analyses using Multiple Imputation. Our study was conducted in the real world of the pandemic response as it unfolded across Canada, and laboratory testing protocols, case definitions, and clinical management were modified at the sites as knowledge and resources evolved. SOS surveillance is conducted at 11 participating hospital sites, which each reflect the demographics of their catchment communities, but may not reflect the demographics of COVID-19 admission in Canada as a whole. Given the logistical limitations of collecting data during the pandemic, we were not able to collect data on longer term outcomes, such as worsening frailty and function, which we have previously found to be important sequelae of influenza and are likely important outcomes of COVID-19.[39,40]

Early Canadian experience with hospital-based COVID-19 surveillance demonstrates the importance of frailty and age as independent predictors of lower ICU and mechanical ventilation use and higher mortality. Even so, admitted patients represented a wide spectrum of both frailty and age, and poor outcomes were not limited to frail patients. This clinical impact across the spectrum of frailty is important for informing public health messaging and ongoing COVID-19 control efforts. Continued surveillance, along with understanding of frailty in research and clinical settings, will be critical to informing Canada's COVID-19 response.

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CONFLICT OF INTEREST DISCLOSURES

We have read and understood the Canadian Geriatrics Journal's policy on conflicts of interest disclosure and declare the following interests: MKA reports grant funding from the Public Health Association of Canada, CIHR, Canadian Frailty Network, Sanofi Pasteur and GSK group of companies, and payments from Pfizer, Sanofi Pasteur and Seqirus outside the submitted work. AM reports payments from GSK, Seqirus and Sanofi Pasteur, outside the submitted work. JEM reports payments from RestorBio, Sanofi, GSK, Merck and Medicago outside of the submitted work. TFH reports grants from Pfizer and GSK. ML reports payments from Sanofi, Medicago, Sequirus, and Pfizer outside the submitted work. SAM reports grants and payments from Pfizer, GSK, Merck, Novartis and Sanofi, outside the submitted work. JG, JJL, GB, LV, ME, DM-C, AA, KW, ST, SS, AMc and KK report no conflicts of interest.

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APPENDIX A1. Frequencies for missing data

Variable	*N present*	*N missing*	*% missing*
Days COVID-19 test sample to admission	2031	0	0.0
Mortality	2031	0	0.0
Province	2031	0	0.0
Sex	2030	1	0.0
Age	2029	2	0.1
Days symptom onset to admission	1743	288	14.2
Days symptom onset to COVID-19 test sample	1743	288	14.2
ICU	1647	384	18.9
Mechanical ventilation	1643	388	19.1
LOS	1640	391	19.3
Housing	1633	398	19.6
Antibiotics or anti-virals	1625	406	20.0
Direct acting antiviral or immunie modulatory medications	1622	409	20.1
Clinical Frailty Scale	1602	429	21.1
Cardiovascular	1584	447	22.0
At least one comorbidity	1583	448	22.1
Respiratory	1583	448	22.1
Immunosuppressed	1583	448	22.1
Immunocompromised	1583	448	22.1
Goals of care	1571	460	22.6
Travel history	1463	568	28.0
Ethnicity[a]	1419	612	30.1
Occupation	1346	685	33.7
Known direct exposure	810	1221	60.1

[a]Research Ethics Board regulations did not allow collection of ethnicity data at some sites.

APPENDIX A2. Clinical and demographic characteristics: Mean (SD) or N (%)[a]

Characteristic	*Full Sample Total N = 2031*	*Age < 65 yrs N = 651*	*Age 65 yrs + N = 1378*	*P*
Age	71.0 (17.4)	50.2 (11.6)	80.9 (8.9)	<.001
Female sex	928 (45.7%)	280 (43.0%)	646 (46.9%)	.10
Ethnicity[b]*:*				<.001
Caucasian	1133 (79.8%)	302 (65.2%)	830 (86.9%)	
Black	53 (3.7%)	38 (8.2%)	15 (1.6%)	
South Asian	46 (3.2%)	25 (5.4%)	21 (2.2%)	
West Asian	42 (3.0%)	24 (5.2%)	18 (1.9%)	
Chinese	45 (3.2%)	18 (3.9%)	27 (2.8%)	
Other	100 (7.0%)	56 (12.1%)	44 (4.6%)	
Housing:				<.001
Private dwelling	1072 (65.6%)	484 (88.6%)	588 (54.1%)	
Assisted living facility	381 (23.3%)	11 (2.0%)	369 (34.0%)	
Long term care facility	131 (8.0%)	16 (2.9%)	115(10.6%)	
Homeless / shelter	28 (1.7%)	One group < 5		
Other	21 (1.3%)	9 (1.6%)	12 (1.1%)	
Province:				<.001
Alberta	130 (6.4%)	62 (9.5%)	68 (4.9%)	
Ontario	1003 (49.4%)	341 (52.4%)	661 (48.0%)	
Quebec	868 (42.7%)	230 (35.3%)	637 (46.2%)	
Nova Scotia	30 (1.5%)	18 (2.8%)	12 (0.9%)	
Clinical Frailty Scale:				<.001
1-2	288 (18.0%)	237 (43.6%)	51 (4.8%)	
3	387 (24.2%)	197 (36.2%)	190 (18.0%)	
4	239 (14.9%)	56 (10.3%)	183 (17.3%)	
5	198 (12.4%)	22 (4.0%)	176 (16.7%)	
6	251 (15.7%)	16 (2.9%)	234 (22.1%)	
7-9	239 (14.9%)	16 (2.9%)	223 (21.1%)	
Obese (Calculated BMI ≥30 or obesity noted in medical record)	414 (28.8%)	194 (39.5%)	220 (23.3%)	<.001
Comorbidities:				
None of respiratory, cardiovascular, immunosuppressed, or immunocompromised	267 (16.9%)	179 (36.0%)	88 (8.1%)	<.001
Cardiovascular	1195 (75.4%)	251 (50.4%)	943 (86.9%)	<.001
Respiratory	508 (32.1%)	134 (27.0%)	374 (34.5%)	<.01
Immunosuppressed	96 (6.1%)	36 (7.2%)	60 (5.5%)	.19
Immunocompromised	21 (1.3%)	One group < 5		.22
Travel history	68 (4.6%)	26 (5.3%)	42 (4.3%)	.40
Known direct exposure	409 (50.5%)	157 (51.5%)	251 (49.8%)	.64
Occupation:				<.001
Health-care worker	61 (4.5%)	56 (13.9%)	5 (0.5%)	
Other occupation	198 (14.7%)	170 (42.2%)	28 (3.0%)	
Not working	179 (13.3%)	129 (32.0%)	50 (5.3%)	
Retired	908 (67.5%)	48 (11.9%)	859 (91.2%)	
Goals of Care:				<.001
Full resuscitation	850 (54.1%)	494 (92.0%)	356 (34.5%)	
Escalation of care with exceptions	137 (8.7%)	16 (3.0%)	121 (11.7%)	
Ward based medical care, but no CPR, ICU, or intubation	352 (22.4%)	18 (3.4%)	333 (32.2%)	
Comfort Care	232 (14.8%)	9 (1.7%)	223 (21.6%)	

[a]Percentages are per cent of valid data (i.e., missing not included).
[b]Research Ethics Board regulations did not allow collection of ethnicity data at some sites.

APPENDIX A3. Medians (interquartile range (IQR)) or frequency (per cent) for outcomes by age[a]

Outcome	*Whole sample N = 2031*	*Age <65 N = 651*	*Age 65-74 N = 377*	*Age 75-84 N = 493*	*Age 85+ N = 508*	*p*
Length of stay (days)[b]	10 (5–22)	7 (4–14)	12 (6–26)	12 (6.75–25.25)	20 (8–33.5)	<.001
ICU admission	358 (21.7%)	169 (30.4%)	102 (32.6%)	69 (17.7%)	18 (4.6%)	<.001
Mechanical ventilation	197 (12.0%)	94 (16.9%)	66 (21.1%)	30 (7.7%)	7 (1.8%)	<.001
Death	336 (16.5%)	29 (4.5%)	63 (16.7%)	100 (20.3%)	143 (28.1%)	<.001
Days symptom onset to admission	4 (1–8)	6 (2–9)	5 (1–9)	4 (1–7)	2 (0–6)	<.001
Days Symptom onset to COVID-19 test sample	2 (0–6)	2 (0–6)	3 (0–7)	2 (0–6)	1 (0–4)	<.001
COVID-19 test sample Days to Admission	0 (0–4)	1 (0–5)	0 (0–3.5)	0 (0–2)	0 (-1–3)	<.001
Goals of Care:						<.001
Full resuscitation	850 (54.1%)	494 (92.0%)	184 (63.2%)	127 (34.0%)	45 (12.2%)	
Escalation of care with exceptions	137 (8.7%)	16 (3.0%)	25 (8.6%)	57 (15.2%)	39 (10.6%)	
Ward based medical care, but no CPR, ICU, or intubation	352 (22.4%)	18 (3.4%)	54 (18.6%)	134 (35.8%)	145 (39.4%)	
Comfort Care	232 (14.8%)	9 (1.7%)	28 (9.6%)	56 (15.0%)	139 (37.8%)	

[a]Percentages are percent of valid data (i.e., missing not included).
[b]For length of stay, only those whose admission date was not more than 14 days prior to symptom onset and who were alive at discharge were included (N = 1166).

APPENDIX A4. Medians (interquartile range (IQR)) or frequency (per cent) for outcomes by frailty[a,b]

Outcome	*CFS = 1-2 N=288*	*CFS = 3 N=387*	*CFS = 4 N=239*	*CFS = 5 N=198*	*CFS = 6 N=251*	*CFS = 7-9 N=239*	*p*
Length of stay[c]	6 (4 – 10)	8 (4 – 16)	13 (7 – 25)	17 (7.75 – 30)	18 (10 – 40)	20 (10 – 36)	<.001
ICU admission	72 (25.1%)	125 (32.4%)	78 (32.6%)	27 (13.7%)	27 (10.8%)	14 (5.9%)	<.001
Mechanical ventilation	41 (14.3%)	74 (19.2%)	45 (18.8%)	14 (7.1%)	9 (3.6%)	7 (3.0%)	<.001
Death	10 (3.5%)	35 (9.0%)	46 (19.2%)	48 (24.2%)	73 (29.1%)	111 (46.4%)	<.001
Goals of Care:							<.001
Full resuscitation	267 (95.7%)	300 (82.0)	128 (55.9%)	62 (32.6%)	52 (22.5%)	24 (10.4%)	
Escalation of care with exceptions	29 (4.5%)		28 (12.2%)	27 (14.2%)	30 (13.0%)	15 (6.5%)	
Ward based medical care, but no CPR, ICU, or intubation	5 (1.8%)	34 (9.3%)	57 (24.9%)	73 (38.4%)	73 (31.6%)	92 (39.8%)	
Comfort Care	10 (1.6%)		16 (7.0%)	28 (14.7%)	76 (32.9%)	100 (43.3%)	

[a]Cells collapsed so no single cell presented with n < 5. Chi-squared based on full data.
[b]Percentages are percent of valid data (i.e., missing not included).
[c]For length of stay, only those whose admission date was not more than 7 days prior to symptom onset were included (N = 1132).

APPENDIX A5. Admitted to ICU and mortality by demographic information and comorbidity[a]

Characteristic	*Admitted to ICU N=358*	*Mortality N=336*
Female sex	118 (33.1%)	155 (46.1%)
Ethnicity:		
White	223 (75.1%)	255 (85.0%)
South Asian	13 (4.4%)	7 (2.3%)
Black	10 (3.4%)	5 (1.7%)
West Asian	7 (2.4%)	
Chinese	10 (3.4%)	13 (4.3%)
Other	34 (11.4%)	20 (6.7%)
Housing:		
Private dwelling	314 (88.7%)	153 (46.1%)
Assisted living facility	17 (4.8%)	132 (39.8%)
Long term care facility	15 (4.2%)	43 (13.0%)
Homeless / shelter	8 (2.2%)	Both groups < 5
Other		
Province:		
Aberta	33 (9.2%)	19 (5.7%)
Ontario	167 (46.6%)	146 (43.5%)
Quebec	151 (42.2%)	167 (49.7%)
Nova Scotia	7 (2.0%)	< 5
Obese (Calculated BMI ≥30 or obesity noted in medical record)	133 (41.2%)	74 (25.4%)
Comorbidities:		
None of respiratory, cardiovascular, immunosuppressed, or immunocompromised	53 (15.6%)	22 (6.7%)
Cardiovascular	258 (75.7%)	292 (88.8%)
Respiratory	116 (34.1%)	121 (36.8%)
Immunosuppressed	23 (6.8%)	23 (7.0%)
Immunocompromised	7 (2.1%)	9 (2.7%)

[a]Cells collapsed so no single cell presented with n < 5.

APPENDIX A6. Odds ratios and 95% CIs from logistic regressions

Characteristic	*ICU Admission*		*Mechanically Ventilated*		*Mortality*	
	Unadjusted	*Adjusted*[a]	*Unadjusted*	*Adjusted*[a]	*Unadjusted*	*Adjusted*[a]
Age N_{ICU}=1594 N_{mv} = 1594 N_{mort}=1600	0.98*** (0.97, 0.98)	0.99** (0.98, 1.00)	0.98*** (0.97, 0.99)	0.99 (0.98, 1.00)	1.06*** (1.05, 1.07)	1.04*** (1.02, 1.05)
Sex (Female) N_{ICU}=1594 N_{mv} = 1594 N_{mort}=1600	0.51*** (0.40, 0.66)	0.56*** (0.43, 0.73)	0.47*** (0.34, 0.65)	0.53*** (0.38, 0.75)	1.00 (0.78, 1.28)	0.76* (0.58, 1.00)
CFS N_{ICU}=1594 N_{mv} = 1594 N_{mort}=1600	1–3***	***	***	***	***	***
	1.18 (0.86, 1.62)	1.43* (1.01, 2.01)	1.14 (0.78, 1.66)	1.26 (0.83, 1.91)	3.33*** (2.14, 5.18)	2.18** (1.37, 3.46)
	CFS 4					
	0.39*** (0.25, 0.60)	0.52** (0.32, 0.84)	0.37** (0.21, 0.67)	0.45* (0.24, 0.84)	4.47*** (2.87, 6.97)	2.37** (1.45, 3.88)
	CFS 5					
	0.22*** (0.16, 0.32)	0.33*** (0.22, 0.51)	0.17*** (0.10, 0.29)	0.22*** (0.12, 0.40)	8.36*** (5.87, 11.91)	4.16*** (2.72, 6.35)
	CFS 6–9					
Non-white N_{ICU}=1371 N_{mv} = 1371 N_{mort}=1375	1.49* (1.10, 2.02)	1.05 (0.76, 1.47)	1.57* (1.07, 2.30)	1.15 (0.76, 1.73)	0.66* (0.46, 0.93)	1.22 (0.83, 1.81)
Long-term care facility N_{ICU}=1582 N_{mv} = 1582 N_{mort}=1587	0.47** (0.27, 0.81)	1.15 (0.62, 2.12)	0.41* (0.19, 0.90)	1.21 (0.52, 2.85)	2.13*** (1.45, 3.15)	1.00 (0.66, 1.52)
Obesity N_{ICU}=1395 N_{mv} = 1395 N_{mort}=1399	2.08*** (1.60, 2.71)	1.78*** (1.34, 2.36)	2.14*** (1.55, 2.97)	1.86*** (1.32, 2.62)	0.85 (0.63, 1.14)	1.47* (1.04, 2.03)
Cormorbidity:						
At least one[b] N_{ICU}=1528 N_{mv} = 1528 N_{mort}=1534	1.18 (0.84, 1.65)	2.29*** (1.56, 3.38)	1.48 (0.93, 2.36)	2.74*** (1.64, 4.60)	3.21*** (2.04, 5.07)	1.42 (0.87, 2.34)
Cardiovascular N_{ICU}=1529 N_{mv} = 1529 N_{mort}=1535	1.06 (0.79, 1.41)	2.01*** (1.43, 2.82)	1.30 (0.88, 1.91)	2.37*** (1.53, 3.70)	3.00*** (2.07, 4.33)	1.48 (0.99, 2.23)
Respiratory N_{ICU}=1528 N_{mv} = 1528 N_{mort}=1534	1.10 (0.85, 1.43)	1.17 (0.88, 1.54)	0.92 (0.66, 1.29)	0.96 (0.67, 1.37)	1.30* (1.01, 1.69)	1.23 (0.93, 1.62)

[a]Adjusted for age, sex, and Clinical Frailty Scale (CFS).

[b]At least one comorbidity of cardiovascular, respiratory, immunosuppressed, or immunocompromised.

*p<.05.

**p<.01.

***p<.001.