




The burden of COVID-19 care in community and academic intensive care units in Ontario, Canada: a retrospective cohort study

Le fardeau des soins liés à la COVID-19 dans les unités de soins intensifs communautaires et universitaires en Ontario, au Canada : une étude de cohorte rétrospective

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Abstract

Purpose During the COVID-19 pandemic, neighbourhoods with high material deprivation and high proportions of racialized Canadians were disproportionately affected by COVID-19. Many of these neighbourhoods were served by community hospitals. We sought to compare the burden of COVID-19 care in community and academic intensive care units (ICUs) in Ontario, Canada.

Methods We included all adult patients admitted to Ontario ICUs with COVID-19 between 1 March 2020 and 31 July 2021 in a retrospective cohort study. We compared patient volumes, demographics, interventions, and outcomes between community hospital corporations (CHCs) and academic hospital corporations (AHCs).

Results During the first three waves of the pandemic, 9,651 adult ICU admissions for COVID-19 were reported across 72 hospital corporations in Ontario: 6,902 (71.5%)

in CHCs and 2,749 (28.5%) in AHCs. Days of ICU care per baseline ICU bed were highest in large CHCs (> 10 baseline ICU beds) relative to AHCs and small CHCs (median [interquartile range], 73.7 [53.8–110.6] vs 42.2 [32.7–71.8] vs 21.4 [7.2–40.3]; Kruskal–Wallis test, $P < 0.001$). Among direct ICU admissions, CHC patients had greater severity of illness whereas among transfer ICU admissions, AHC patients were more severely ill. In a multivariable logistic regression model, mortality was similar among patients with index admission to a CHC or AHC; however, patients with index admission to an AHC were more likely to receive extracorporeal membrane oxygenation (adjusted odds ratio, 6.16; 95% confidence interval, 4.72 to 8.11).

Conclusion During the pandemic, Ontario's large CHCs provided significantly more days of ICU COVID-19 care per baseline ICU bed compared with AHCs and small CHCs. Equipping large CHCs to handle ICU surges during future emerging disease outbreaks should be a priority for pandemic preparedness.

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Résumé

Objectif Pendant la pandémie de COVID-19, les quartiers où la déprivation matérielle était plus prononcée et où la proportion de Canadien-nes racisé-es était élevée ont été touchés de manière disproportionnée par la COVID-19. Bon nombre de ces quartiers étaient desservis par des hôpitaux communautaires. Nous avons cherché à comparer le fardeau des soins contre la COVID-19 dans les unités de soins intensifs (USI) communautaires et universitaires en Ontario, au Canada.

Méthode Nous avons inclus tou-tes les patient-es adultes admis-es aux soins intensifs ontariens en raison de la COVID-19 entre le 1er mars 2020 et le 31 juillet 2021 dans une étude de cohorte rétrospective. Nous avons comparé le nombre de patient-es, les données démographiques, les interventions et les issues entre les corporations d'hôpitaux communautaires (CHC) et les corporations d'hôpitaux universitaires (CHU).

Résultats Au cours des trois premières vagues de la pandémie, 9651 admissions dans une unité de soins intensifs pour adultes en raison de la COVID-19 ont été signalées dans 72 corporations hospitalières : 6902 (71,5 %) dans les CHC et 2749 (28,5 %) dans les CHU. Le nombre de jours de soins intensifs par lit de base était le plus élevé dans les grands CHC (> 10 lits de base en soins intensifs) par rapport aux CHU et aux petits CHC (médiane [écart interquartile], 73,7 [53,8–110,6] vs 42,2 [32,7–71,8] vs 21,4 [7,2–40,3]; test de Kruskal-Wallis, $P < 0,001$). Parmi les admissions directes aux soins intensifs, les patient-es des CHC présentaient une gravité de la maladie plus élevée, tandis que parmi les personnes transférées aux soins intensifs, les patient-es des CHU étaient plus gravement malades. Dans un modèle de régression logistique multivariée, la mortalité était similaire chez les patient-es ayant été initialement admis-es dans un CHC ou un CHU; cependant, les patient-es ayant été initialement admis-es dans un CHU étaient plus susceptibles de recevoir une oxygénation par membrane extracorporelle (rapport de cotes ajusté, 6,16; intervalle de confiance à 95 %, 4,72 à 8,11).

Conclusion Pendant la pandémie, les grands CHC de l'Ontario ont fourni beaucoup plus de jours de soins intensifs liés à la COVID-19 par lit de base que les CHU et les petits CHC. La préparation aux pandémies devrait inclure la fourniture de matériel à ces hôpitaux pour gérer les pics d'unités de soins intensifs lors de futures épidémies urgentes.

Keywords community hospital · critical care · COVID-19 · extracorporeal membrane oxygenation · intensive care unit

COVID-19 had a disproportionate impact on racialized Canadians, essential workers, and those with low socioeconomic status.^{1,2} In Ontario, material deprivation was associated with increased risk of SARS-CoV-2 infection, hospitalization, and death.³ Similarly, in the UK, low socioeconomic status and Black and South Asian ethnicity were associated with increased risk of death, while in the USA, Black and Latino ethnicity, increased household density, lower educational status, and immigrant status were all associated with increased mortality.^{4,5}

Canadian hospitals are traditionally divided into teaching or “academic” hospitals and non-teaching or “community” hospitals.⁶ While academic hospitals provide the majority of medical education and perform most clinical research, community hospitals provide the majority of clinical care, particularly in suburban and rural areas.^{7–9} Previous studies have identified key differences between patient populations in academic and community hospitals.¹⁰ In Ontario, the most populous Canadian province, individuals from the lowest income quintiles are most likely to receive care in community hospitals, while those from the highest quintiles are most likely to receive care in academic hospitals.^{11–13} In addition, the five Ontario municipalities with the highest proportions of racialized individuals and newcomers are served by community hospitals.^{3,14} Together, these observations suggest that community hospitals played a central role in responding to the COVID-19 pandemic in Ontario.

In this study, we sought to use data from the Critical Care Information System (CCIS) to analyze adult patients admitted to intensive care units (ICUs) in Ontario with COVID-19 as their principal diagnosis between 1 March 2020 and 31 July 2021, during the first three waves of the pandemic.¹⁵ We aimed to examine the distribution of critically ill patients with COVID-19 between academic hospital corporations (AHCs) and community hospital corporations (CHCs) and compared patient volumes, demographics, illness severity, interventions, and outcomes.

Methods

Study design

We conducted a retrospective cohort study of adult (> 18 yr) patients admitted to ICUs in Ontario with COVID-19 as the primary admission diagnosis between 1 March 2020 and 31 July 2021.

Ethics approval

We obtained ethical approval from the Hamilton Integrated Research Ethics Board (Hamilton, ON, Canada; reference number: 10939-C) and the Research Ethics Board of William Osler Health System (Brampton, ON, Canada; reference number: 21-0009).

Setting

Ontario is the most populous province in Canada with a population of over 14 million people.¹⁶ It has 141 hospital corporations, 74 of which have ICUs.⁶

Data extraction

We extracted data from the CCIS, a web-based application that tracks all ICU patients in Ontario.¹⁷ Demographic data are automatically populated in the CCIS while clinical data are entered manually. All Ontario ICUs are required to enter patient data into the CCIS.

Inclusion criteria

We included adult patients (≥ 18 yr old), admitted to an Ontario ICU between 1 March 2020 and 31 July 2021 with COVID-19 as the primary admission diagnosis.

Exclusion criteria

We excluded patients < 18 yr old or those without a primary diagnosis of COVID-19. Patients without clinical data ($n = 179$, 1.8% of all records) were included in the demographic analyses but excluded from the clinical analyses. Intensive care unit readmission in the same hospital corporation with a primary diagnosis of COVID-19 was considered a single admission.

Variables

Patient-level variables included age, sex, hospital corporation, date of ICU admission and discharge, admission source, and discharge destination. Clinical data included daily Multiple Organ Dysfunction (MOD) score, days of invasive and noninvasive mechanical ventilation, days of renal replacement therapy, days of vasopressors, and days of extracorporeal membrane oxygenation (ECMO) support. The number of baseline ICU beds per hospital corporation was derived from CCIS data and confirmed through the Canadian Institute for Health Information.¹⁸ Hospital corporations were designated as “academic” (teaching) or “community” (non-teaching) based on the classification of the Ontario Ministry of

Health and Long Term Care.⁶ One hospital corporation included both academic and community hospital sites, which were treated as separate corporations for the purpose of analysis.

Statistical analysis

We described continuous variables as median and interquartile range [IQR] or mean and standard deviation (SD) and categorical variables as counts and proportions. We described rates with their Poisson 95% confidence intervals (CIs). We compared continuous variables using Student’s *t* test, the Mann–Whitney *U* test, or the Kruskal–Wallis test as appropriate. We compared rates and proportions using the Chi square test. For patients who were transferred between hospital corporations, date of transfer (within 24 hr), birthdate, and sex were used to match pre- and posttransfer records. The index hospital was considered the hospital of first admission and the discharge destination was determined from the final admission record. We used binomial logistic regression to examine the association between index hospital type (academic/community) and mortality or ECMO support. For each regression analysis, a second multivariable model adjusted for sex, age, and severity of illness (MOD score on admission) was also generated. All statistical tests were performed at a significance level of 0.05. We performed the statistical analysis in R Studio IDE using R language version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria).¹⁹

Results

COVID-19 intensive care unit admissions in Ontario

We analyzed all adult ICU admissions for COVID-19 in Ontario between 1 March 2020 and 31 July 2021, and identified 72 hospital corporations with at least one adult COVID-19 ICU admission. Of these, 58 (80%) were CHCs and 15 (20%) were AHCs (Table 1). At baseline, these corporations had 1,820 adult ICU beds: 1,002 (55.1%) in CHCs and 818 (44.9%) in AHCs. Community hospital corporations had a median [IQR] of 10 [5–35] adult ICU beds at baseline, while AHCs had a median [IQR] of 36 [24.5–83] adult ICU beds. These numbers did not include additional ICU beds that may have been added during the pandemic.

Between 1 March 2020 and 31 July 2021, there were 9,651 adult ICU admissions for COVID-19 in Ontario: 6,902 (71.5%) in CHCs and 2,749 (28.5%) in AHCs, corresponding to 6.9 (95% CI, 6.7 to 7.1) admissions per baseline ICU bed in CHCs and 3.4 (95% CI, 3.2 to 3.5) in

Table 1 Number of hospital corporations and baseline intensive care unit beds in community and academic hospital corporations in Ontario, Canada

	All <i>N</i> = 72 ^a	CHCs <i>N</i> = 58	AHCs <i>N</i> = 15	<i>P</i> value
Baseline ICU beds, <i>n</i> /total <i>N</i> (%)	1,820	1,002/1,820 (55.1%)	818/1,820 (44.9%)	
ICU beds per hospital corporation, mean (SD)		17.3 (17.9)	54.5 (38.2)	< 0.001 ^b
ICU beds per hospital corporation, median [IQR]		10 [0–89]	36 [10–134]	

^aOne hospital corporation included both academic and community hospital sites, which were analyzed separately

^bMann–Whitney *U* test

AHC = academic hospital corporation; CHC = community hospital corporation; ICU = intensive care unit; IQR = interquartile range; SD = standard deviation

Table 2 Adult COVID-19 intensive care unit admissions and intensive care unit days of COVID-19 care provided in community and academic intensive care units

	All	CHCs	AHCs	<i>P</i> value
COVID-19 ICU admissions, <i>n</i> /total <i>N</i> (%)	9,651/9,651 (100%)	6,902/9,651 (71.5%)	2,749/9,651 (28.5%)	
COVID-19 ICU admissions per baseline ICU bed, rate (95% CI)	5.3 (5.2 to 5.4)	6.9 (6.7 to 7.1)	3.4 (3.2 to 3.5)	< 0.001 ^a
ICU days of adult COVID-19 care, <i>n</i> /total <i>N</i> (%)	131,838/131,838 (100%)	88,571/131,838 (67.2%)	43,267/131,838 (32.8%)	
ICU days of adult COVID-19 care per baseline ICU bed, rate (95% CI)	72.4 (72.0 to 72.8)	88.4 (87.8 to 89.0)	52.9 (52.4 to 53.4)	< 0.001 ^a

^aChi square test

AHC = academic hospital corporation; CHC = community hospital corporation; CI = confidence interval; ICU = intensive care unit

AHCs ($P < 0.001$) (Table 2). Intensive care unit admissions varied between peak and trough periods, but the percentage of admissions in CHCs was consistently 60–80% (Fig. 1A). Two different types of ICU admissions were reported: “direct” admissions, originating from within the same hospital corporation, such as the emergency department or ward, and “transfer” admissions, originating from another hospital corporation. Direct admissions were more common than transfer admissions in both CHCs and AHCs; however, the percentage of transfer admissions in AHCs increased during peak periods, reaching nearly 50% in April 2021 (Fig. 1B).

There were 131,838 days of ICU care (ICU days) provided to adult patients with COVID-19 in Ontario. Of these, CHCs provided 88,571 (67.2%) ICU days and AHCs provided 43,267 (32.8%) ICU days, corresponding to 88.4 (95% CI, 87.8 to 89.0) ICU days per baseline ICU bed in CHCs and 52.9 (95% CI, 52.4 to 53.4) ICU days per baseline ICU bed in AHCs ($P < 0.001$) (Table 2).

Burden of COVID-19 intensive care unit care in individual hospital corporations

Individual hospital corporations provided from < 100 ICU days to > 10,000 ICU days of COVID-19 care (data not shown). As a result of this heterogeneity, 18/72 (25%) hospital corporations (11 CHCs and seven AHCs) provided > 70% of ICU COVID-19 care in the province. There was also significant variation in the number of ICU days of COVID-19 care relative to baseline ICU beds. Figure 2 shows the 20 hospital corporations with the highest number of ICU days per baseline ICU bed while Electronic Supplementary Material (ESM) eFigure shows all Ontario hospital corporations having at least one baseline adult ICU bed.

Notably, CHCs had both the highest and lowest number of patients with COVID-19 per baseline ICU bed. We therefore compared high and low occupancy CHCs with respect to baseline ICU bed numbers and noted that high occupancy CHCs had a higher mean (SD) number of baseline ICU beds than low occupancy CHCs (28 [21] vs 8 [4] beds; $P < 0.001$). We therefore subdivided CHCs into “large” and “small,” based on the median number of

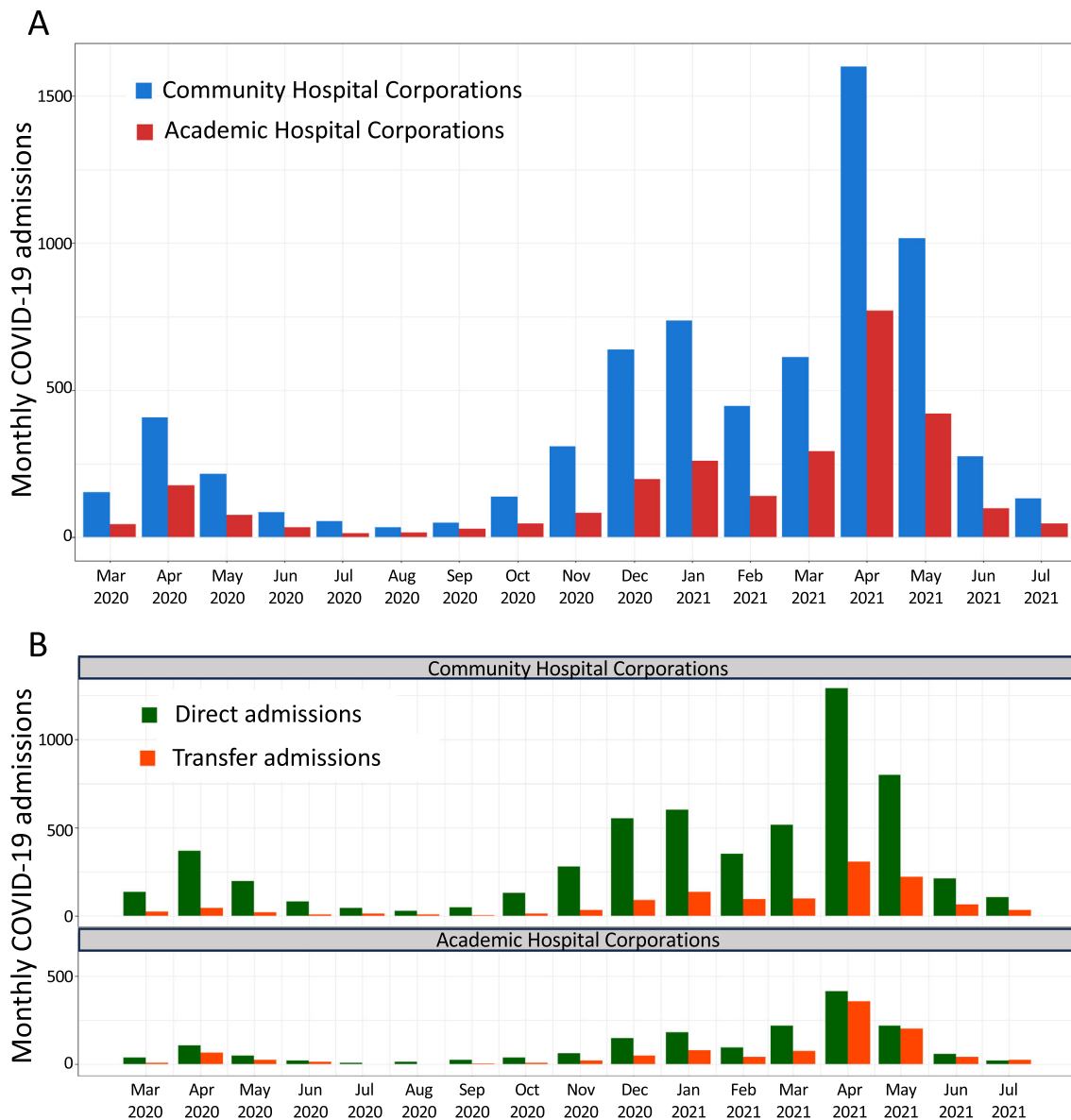


Fig. 1 Adult COVID-19 admissions in community hospital corporations and academic hospital corporations during the first three waves of the pandemic. (A) Monthly COVID-19 ICU admissions in CHCs and AHCs. Blue bars: CHC admissions. Red bars: AHC admissions. (B) Monthly direct admissions and transfer admissions in CHCs and AHCs. Green bars: direct admissions. Orange bars: transfer admissions.

AHC = academic hospital corporation; CHC = community hospital corporation; ICU = intensive care unit

baseline ICU beds. Large CHCs, with > 10 beds, provided a significantly higher median [IQR] number of ICU days of COVID-19 care per baseline ICU bed than both AHCs and small CHCs (73.7 [53.8–110.6] vs 42.2 [32.7–71.8] vs 21.4 [7.2–40.3] ICU days; $P < 0.001$) (Fig. 3).

Patient characteristics

Using patient-level data, we compared the demographic and clinical characteristics of ICU patients with COVID-19 in CHCs and AHCs (Table 2). We first compared patients

who were directly admitted, i.e., those admitted to the ICU from within the same hospital corporation. Out of 7,306 direct ICU admissions, 5,619 (76.9%) were in CHCs and 1,687 (23.1%) in AHCs (Table 3). Direct admissions to CHCs had higher mean (SD) MOD scores on admission (4.2 [2.6] vs 3.9 [2.6]; $P < 0.001$) and lower ratios of arterial oxygen partial pressure to fractional inspired oxygen concentration (P/F ratio) [189 (176) vs 267 (221); $P < 0.001$], indicating more severe hypoxemia. In addition, they were invasively ventilated on more days (47.4% vs 40.9% of ICU days; $P < 0.001$) and noninvasively

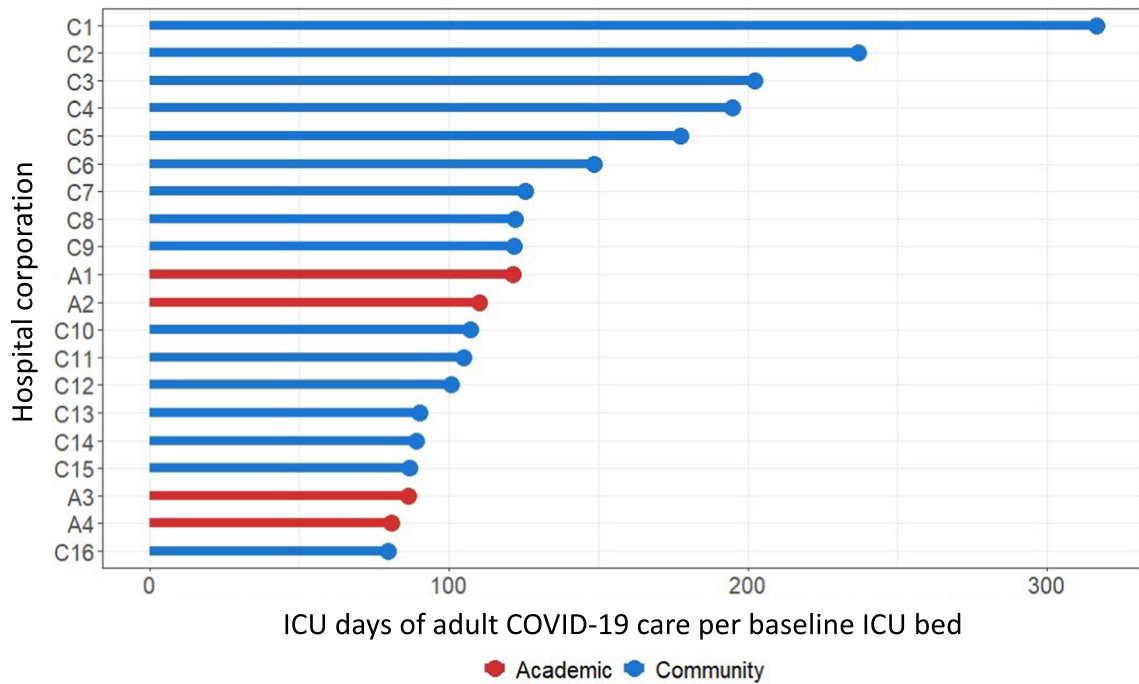


Fig. 2 Intensive care unit days of adult COVID-19 care per baseline intensive care unit bed. Shown are the 20 hospitals with the highest number of ICU days per baseline ICU bed. Blue: community hospital corporations. Red: academic hospital corporations.

ICU = intensive care unit

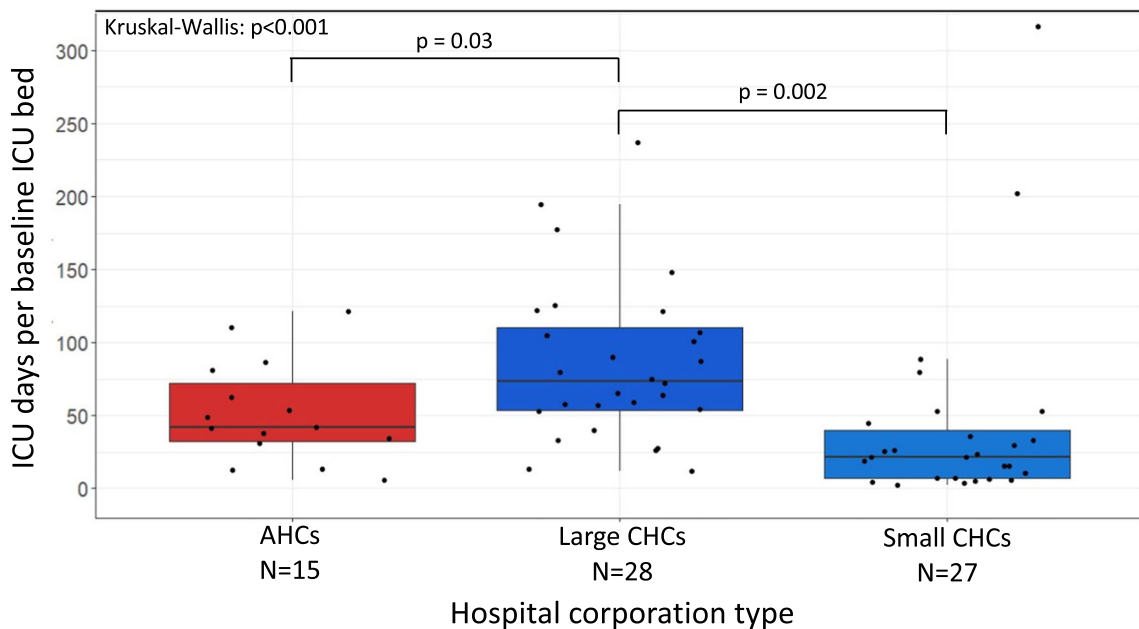


Fig. 3 Intensive care unit days of adult COVID-19 care per baseline intensive care unit bed, by hospital type. Shown are the top 20 hospital corporations.

CHC = community hospital corporation; AHC = academic hospital corporation; large CHC ≥ 10 baseline ICU beds; small CHC ≤ 10 baseline ICU beds; ICU = intensive care unit

ventilated on more days (25.0% vs 17.7% of ICU days; $P < 0.001$) (Table 3). Use of renal replacement therapy was similar. ECMO, which is only available in a small number

of AHCs, was used more frequently in AHC direct admissions (1.2% vs 0.1% of ICU days; $P < 0.001$) and the median [IQR] ICU length of stay was also slightly

Table 3 Characteristics of “direct” admission patients in community hospital corporations and academic hospital corporations

	CHCs <i>N</i> = 5,619	AHCs <i>N</i> = 1,687	<i>P</i> value
Age (yr), mean (SD)	62.9 (14.4)	62.9 (15.6)	0.38 ^a
Female patients, <i>n</i> /total <i>N</i> (%)	2,062/5,619 (36.7%)	667/1,687 (39.5%)	0.04^a
MOD score on admission, mean (SD)	4.6 (2.6)	3.9 (2.6)	< 0.001^a
P/F ratio on admission, mean (SD)	189 (176)	267 (221)	< 0.001^a
Invasive ventilation, % ICU days (SD)	47.4 (41.9)	40.9 (40.4)	< 0.001^a
Noninvasive ventilation, % ICU days (SD)	25.0 (32.4)	17.7 (29.5)	< 0.001^a
No ventilation, % ICU days (SD)	7.7 (20.2)	12.2 (26.1)	< 0.001^a
Renal replacement therapy, % ICU days (SD)	4.3 (15.5)	5.1 (17.3)	0.08 ^b
ECMO, % ICU days (SD)	0.1 (1.2)	1.2 (8.8)	< 0.001^b
ICU length of stay in days, median [IQR]	7.0 [3.2–14.5]	7.3 [3.4–16.6]	0.02^b

^aStudent's *t* test^bMann–Whitney *U* test*P* values in bold are below the significance threshold of *P* = 0.05

AHC = academic hospital corporation; CHC = community hospital corporation; ECMO = extracorporeal membrane oxygenation; ICU = intensive care unit; IQR = interquartile range; MOD = multiple organ dysfunction; P/F ratio = ratio of arterial oxygen partial pressure to fractional inspired oxygen concentration; SD = standard deviation

Table 4 Characteristics of “transfer” admission patients in community hospital corporations and academic hospital corporations

	CHCs <i>N</i> = 1,105	AHCs <i>N</i> = 966	<i>P</i> value
Age (yr), mean (SD)	62.6 (13.3)	55.7 (14.0)	< 0.001^a
Female patients, <i>n</i> /total <i>N</i> (%)	407/1,105 (36.8%)	336/966 (34.8%)	0.40 ^a
MOD score on admission, mean (SD)	5.6 (2.9)	6.3 (2.7)	< 0.001^a
P/F ratio on admission, mean (SD)	234 (184)	218 (183)	< 0.001^a
Invasive ventilation, % ICU days (SD)	69.0 (37.0)	80.3 (29.5)	< 0.001^a
Noninvasive ventilation, % ICU days (SD)	10.2 (20.4)	3.9 (12.5)	< 0.001^a
No ventilation, % ICU days (SD)	6.3 (17.9)	5.4 (17.1)	0.23 ^a
Renal replacement therapy, % ICU days (SD)	7.1 (19.2)	9.86 (22.1)	< 0.001^b
ECMO, % ICU days (SD)	0.0 (0.3)	12.5 (29.3)	< 0.001^b
ICU length of stay in days, median [IQR]	10.8 [5.0–21.5]	13.3 [6.2–25.1]	< 0.001^b

^aStudent's *t* test^bMann–Whitney *U* test*P* values in bold are below the significance threshold of *P* = 0.05

ECMO = extracorporeal membrane oxygenation; MOD = multiple organ dysfunction; P/F ratio = ratio of arterial oxygen partial pressure to fractional inspired oxygen concentration

longer among AHC patients (7.3 [3.4–16.6] days vs 7.0 [3.2–14.5] days; *P* = 0.02).

We next analyzed transfer ICU admissions, i.e., patients admitted to the ICU from another hospital corporation, often as a second ICU admission. Patients with transfer admissions in AHCs were younger than those in CHCs (55.6 vs 62.6 yr; *P* < 0.01) (Table 4). The mean (SD) MOD scores on admission were higher (6.3 [2.7] vs 5.6 [2.9]; *P* < 0.01)

and mean (SD) P/F ratios were lower (217 [183] vs 235 [184]; *P* < 0.001). In addition, transfer patients in AHCs were invasively ventilated on more days (80.3% vs 69.0% of ICU days; *P* < 0.01) although noninvasively ventilated on fewer days (3.9% vs 10.2% of ICU days; *P* < 0.01). Extracorporeal membrane oxygenation was significantly more common among AHC patients (12.5% vs 0.02% of ICU days; *P* < 0.001) and the median [IQR] ICU length of stay was

also longer (13.3 [6.2–25.1] days vs 10.8 [5.0–21.5] days; $P < 0.001$).

Discharge destinations

Discharge destinations were classified into four categories: 1) discharge from the ICU, 2) transfer to another ICU, 3) deceased/palliative, and 4) other (ESM eTable). Discharge from the ICU was more common among AHC patients (55.3% vs 51.6%; $P = 0.002$) while transfer to another ICU was more common among CHC patients (21.0% vs 16.1%; $P < 0.001$) (Table 5). The percentage of patients who were deceased/palliative was similar in CHCs and AHCs (27.0% vs 28.2%; $P = 0.26$); however, this did not account for the final outcomes of patients who were transferred to other ICUs on discharge.

Mortality

To account for patients who were transferred between ICUs, we used birthdate, sex, and date of transfer to match admission records corresponding to a single illness episode. This changed the discharge destination for 733 patients. Table 6 shows patient discharge destinations based on index hospital (hospital of first admission). Discharge from the ICU was more common among AHC patients (59.2% vs 56.3%; $P = 0.01$) while transfer to another ICU was equally common among CHC and AHC patients. Deceased/palliative was more common among CHC patients (30.4% vs 27.5%; $P = 0.009$).

We applied logistic regression to model the odds ratio (OR) for death based on index admission to a CHC or AHC. In a univariable model, the OR for mortality was lower for AHC patients (OR, 0.87; 95% CI, 0.78 to 0.97; $P < 0.001$) (Table 7). Nevertheless, in a multivariable model that included age, sex, and severity of illness at first ICU admission (MOD score), the adjusted OR for mortality was similar for AHC and CHC patients (Table 7).

Extracorporeal membrane oxygenation therapy

Extracorporeal membrane oxygenation is the most advanced therapy for patients with severe acute respiratory failure. In Ontario, it is only available in a small number of AHCs, so most patients are transferred to receive ECMO. We modelled the likelihood of receiving ECMO based on index hospital type. In a univariable model, the OR for ECMO was significantly higher among patients whose index admission was in an AHC (OR, 6.62; 95% CI, 5.10 to 8.67; $P < 0.001$) (Table 8). This effect persisted in a multivariable model that included age, sex, and severity of illness at first ICU admission (MOD score) (adjusted OR, 6.16; 95% CI, 4.72 to 8.11; $P < 0.001$).

Discussion

Ontario's community hospital ICUs played a vital role in caring for critically ill patients with COVID-19 during the first three waves of the pandemic. The results of the present retrospective cohort study show that community hospital corporations accounted for 55.4% of prepandemic ICU beds but received 77% of direct ICU admissions and provided 67.2% of all adult ICU COVID-19 care. Large CHCs played a particularly important role, providing significantly more ICU days of care per baseline ICU bed relative to AHCs and small CHCs. The reasons are likely geographical, given that many on Ontario's large CHCs are located in suburban neighbourhoods that were COVID-19 hotspots.³

Among patients who were directly admitted to the ICU, the severity of illness was higher in CHCs than in AHCs. In large CHCs that were experiencing high bed pressures, it is likely that only the most severely ill patients could be accommodated in the ICU while moderately ill patients had to be accommodated on the wards. In point of fact, the Ontario Science Table reported in 2021 that multiple hospitals were using high-flow nasal oxygen to treat patients with COVID-19 on the wards because of a lack

Table 5 Discharge destinations for patients admitted to community and academic intensive care units

	CHCs <i>N</i> = 6,777	AHCs <i>N</i> = 2,695	<i>P</i> value
Discharge from ICU, <i>n</i> /total <i>N</i> (%)	3,498/6,777 (51.6%)	1,489/2,695 (55.3%)	0.002^a
Transfer to another ICU, <i>n</i> /total <i>N</i> (%)	1,420/6,777 (21.0%)	434/2,695 (16.1%)	< 0.001^a
Deceased/palliative, <i>n</i> /total <i>N</i> (%)	1,832/6,777 (27.0%)	760/2,695 (28.2%)	0.26 ^a
Other, <i>n</i> /total <i>N</i> (%)	27/6,777 (0.4%)	12/2,695 (0.4%)	0.89 ^a

P values were calculated using the Chi square test. *P* values in bold are below the significance threshold of $P = 0.05$.

AHC = academic hospital corporation; CHC = community hospital corporation; ICU = intensive care unit

Table 6 Discharge destination for patients with index admission to a community or academic intensive care unit

	CHCs N = 6,420	AHCs N = 2,319	P value
Discharged, n/total N (%)	3,612/6,420 (56.3%)	1,374/6,420 (59.2%)	0.01
Transferred, n/total N (%)	835/6,420 (13.0%)	300/6,420 (12.9%)	0.96
Deceased/palliative, n/total N (%)	1,954/6,420 (30.4%)	638/6,420 (27.5%)	0.009
Other, n/total N (%)	19/6,420 (0.3%)	7/6,420 (0.3%)	1

P values were calculated using the Chi square test. P values in bold are below the significance threshold of $P = 0.05$.

AHC = academic hospital corporation; CHC = community hospital corporation

Table 7 Univariable and multivariable logistic regression models for mortality based on index hospital type

Variable	Model 1 (univariable)		Model 2 (multivariable)	
	OR (95% CI)	P value	OR (95% CI)	P value
Index hospital type: academic	0.87 (0.78 to 0.97)	< 0.001	0.97 (0.87 to 1.09)	0.62
Male sex			1.23 (1.11 to 1.37)	< 0.001
Age (per year)			1.05 (1.05 to 1.06)	< 0.001
MOD score on admission (per point)			1.21 (1.19 to 1.23)	< 0.001

Model performance characteristics are shown in ESM eTable

CI = confidence interval; MOD = multiple organ dysfunction; OR = odds ratio

Table 8 Univariable and multivariable logistic regression models for the likelihood of receiving extracorporeal membrane oxygenation

Variable	Model 1 (univariable)		Model 2 (multivariable)	
	OR (95% CI)	P value	OR (95% CI)	P value
Index hospital type: academic	6.62 (5.10 to 8.67)	< 0.001	6.16 (4.72 to 8.11)	< 0.001
Male sex			2.03 (1.52 to 2.75)	< 0.001
Age (per year)			0.95 (0.95 to 0.96)	< 0.001
MOD score on admission (per point)			1.19 (1.14 to 1.24)	< 0.001

CI = confidence interval; MOD = multiple organ dysfunction; OR = odds ratio

of ICU beds.²⁰ Unmeasured differences in patient populations, such as comorbidities and social determinants of health, may also have contributed to differences in illness severity, but data on these variables were not available for this cohort.¹⁰

Among patients who were transfer admissions, acuity was higher in AHCs than in CHCs. Intensive care unit transfers were used extensively to offload overwhelmed ICUs and to ensure that severely ill patients received appropriate support, irrespective of the hospital of first admission.²¹ Intubated patients were often selected for transport, as this was perceived to be “safer” than transporting patients who were unintubated.²² Thus, transfer admissions represented a severely ill cohort of ICU patients. While both CHCs and AHCs received

severely ill patients as transfer admissions, AHCs filled a vital role in caring for the most severely ill patients.

After adjustment for available risk factors (age, sex, severity of illness on admission), the OR for mortality was similar between patients whose index admission was to a CHC or AHC. This does not account for the final discharge destination of 13% of patients, who were transferred to another ICU on discharge and for whom we could not identify a subsequent ICU admission record. The absence of further ICU records suggests that their discharge destinations may have been outside the ICU; however, this cannot be confirmed. The similarity in mortality between CHCs and AHCs is encouraging as it suggests that quality of care was maintained, even in CHCs experiencing high bed pressures. It also speaks to the success of the

transfer system in ensuring that the sickest patients received appropriate care, irrespective of their hospital of first presentation.^{20,21}

Extracorporeal membrane oxygenation is a scarce resource that is offered in only a small number of AHCs. Unlike mortality, the likelihood of receiving ECMO was significantly higher among patients whose index admission was to an AHC. The reasons for this are likely multifactorial. First, patients whose index admission was to a hospital with ECMO may have been more likely to receive ECMO, since they were “on-site” and known to the clinical team. Second, patients with complex comorbidities, such as transplant recipients, may have presented preferentially to AHCs and may have been more likely to receive ECMO. Third, many community hospitals, particularly in rural areas, are located at a significant distance from ECMO centres, reducing the feasibility of being transferred for ECMO. Finally, community ICUs may have been less aware of the indications for ECMO and less likely to refer patients. Standardization of referral criteria could potentially alleviate some of the discrepancy in ECMO rates between CHC and AHC patients.

One of the key findings of this study is the high variability in the burden of COVID-19 ICU care between Ontario hospitals. Some hospitals, particularly large CHCs, shouldered heavy patient care loads, both in absolute terms and relative to their baseline ICU bed numbers. In this context, planning for future pandemics should include equipping large CHCs to handle future ICU surges. Many AHCs have specialized ICUs dedicated to cardiovascular surgery, neurosurgery or trauma, giving them additional ICU beds that can be repurposed when needed. Placing some of these specialized services in large CHCs could serve the dual purpose of improving health care access in suburban communities and simultaneously increasing local ICU capacity in the event of future emerging disease outbreaks. An efficient and robust patient transfer system is also essential to enable rapid decanting of patients from overwhelmed hospitals, as occurred during the third wave of the pandemic, and to match patient needs with resources. Interhospital transport, however, carries risks for patients; thus, strategies to redeploy ICU staff from ICUs with low patient numbers to those with high patient numbers should also be considered.

Finally, given that more than 75% of direct ICU admissions occurred in CHCs, embedding clinical research infrastructure into CHCs would improve recruitment in trials of early therapeutic interventions, leading to faster results and better generalizability, as well as offering improved access to novel therapeutics for high risk populations.^{7,23,24}

Strengths and limitations

Our study has limitations. They included a lack of data on comorbidities, medications, and ICU interventions and a reliance on manually entered clinical data. ICU bed numbers were based on prepandemic data, which did not include additional beds that may have opened during the pandemic. Final discharge destinations could not be confirmed for 13% of patients, despite matching of patient records by birthdate, sex and dates of admission/discharge. Finally, hospital mortality was not analyzed and some patients who were discharged from the ICU may have subsequently died in hospital. Nevertheless, this is a comprehensive study that includes all adult patients with COVID-19 admitted to Ontario ICUs between 1 March 2020 to 31 July 2021. Other strengths of the study include the completeness of the data set and the linkage of patients from first admission to final discharge destination.

Conclusions

During the pandemic, Ontario’s large CHCs cared for high numbers of critically ill patients with COVID-19 relative to their baseline ICU bed capacity. Pandemic preparedness should include equipping large CHCs to handle ICU surges in future emerging disease outbreaks.

Author contributions Alexandra Binnie, Jennifer Tsang, Erick Duan, and Divya Joshi designed the study. Alexandra Binnie, Daniel Pestana, Jennifer Tsang, and Robert Fowler analyzed and interpreted the data. Alexandra Binnie, Daniel Pestana, and Jennifer Tsang contributed to the writing of the manuscript.

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