Journal of Critical Care 71 (2022) 154089

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.journals.elsevier.com/journal-of-critical-care

Location and outcomes of rehospitalizations after critical illness in a single-payer healthcare system

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ARTICLE INFO

Keywords:
Intensive care unit
Patient readmission
Mortality

ABSTRACT

Purpose: Unplanned rehospitalization at a hospital other than the initial hospital may contribute to poor outcomes. We examined the location of rehospitalizations and assessed outcomes following critical illness in a single-payer healthcare system.

Materials and methods: Population-based retrospective cohort study using linked datasets (2012–2017) from Ontario, Canada including adults (≥18 years) with an unplanned rehospitalization within 30-days after an index hospitalization that included an ICU stay with mechanical ventilation. Outcomes were the percentage of 30-day rehospitalizations at non-index hospitals, mortality and costs. We employed logistic regression and generalized linear models to assess associations.

Results: There were 14,997 (16.4%) 30-day rehospitalizations. Of these 2765 (18.4%) occurred in a non-index hospital. Distance of home residence from the index hospital was the strongest predictor of a non-index rehospitalization (adjusted odds ratio (aOR) 8.40, 95%CI 7.05–10.01, highest vs. lowest distance quintile). Within 30-days of rehospitalization, deaths (aOR 0.91, 95%CI (0.80–1.04)) and total healthcare costs (adjusted relative risk 1.03 (1.00–1.06)), were similar for patients readmitted to the index or a non-index hospital.

Conclusion: Non-index rehospitalization within 30-days of initial discharge is common following critical illness. These rehospitalizations were not significantly associated with an increased risk of harm or higher costs in a single-payer healthcare system.

1. Introduction

Rehospitalization following critical illness is common [1-3], and is associated with significant morbidity, mortality and costs [1-4]. In particular, patients who require mechanical ventilation during an ICU stay are at high risk of readmission, with as many as one in four readmitted within 30-days of discharge, with attendant increased mortality and health care costs [5,6], and approximately 12% of these patients die during rehospitalization [7]. As a consequence, hospital readmission rate, in particular rehospitalizations within 30-days after discharge, is an important patient safety and hospital performance measure [8].

A previous estimate from the US suggests that as many as one-third of ICU survivors who are readmitted to a hospital within 30-days are readmitted to a different hospital than the hospital that provided the initial care (index hospital) [7]. Described as care fragmentation or poor continuity of care [9,10] non-index rehospitalizations may have important patient and health system consequences, including increased mortality, delayed access to medical information and therapies, and potentially increased health care costs due to duplication of efforts

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https://doi.org/10.1016/j.jcrc.2022.154089
0883-9441/

including repeated diagnostic tests and procedures [7]. Studies of surgical patients and critically ill patients in the US suggest worse outcomes and higher costs for these non-index rehospitalizations [7,9,10].

Unlike the US, Ontario has a single-payer healthcare system. By design and concentration of some tertiary and quaternary medical and surgical care, some patients receive ICU care in hospitals other than the closest hospital to their home, a practice supported by formal and informal referral and inter-hospital transfer and repatriation agreements and processes [11]. For patients, there are no strong financial incentives or disincentives to receive care in a particular hospital. For hospitals, tertiary and quaternary medical and surgical care is planned and reimbursed according to health system needs. If readmissions to hospitals do not require the same type of specialty care, it is possible that care at another, potentially closer hospital is a reasonable patient- and system-centered approach, despite a lack of universal access to patients' medical records, usually via an electronic health record (EHR), across hospitals [12-14]. An understanding of whether, and to what extent, a single-payer healthcare system approach to delivering ICU services impacts the rate of non-index rehospitalizations and subsequent outcomes for patients may provide valuable insights into efforts to support care transitions after critical illness and allow other systems and countries to determine whether such an approach warrants consideration. Therefore, the objectives of this study were to describe rates of 30-day rehospitalization to index versus non-index hospitals following critical illness, to examine factors associated with 30-day rehospitalization at a non-index hospital, and to assess whether there was an association between rehospitalization to a non-index hospital and mortality, length of stay and costs during the rehospitalization.

2. Methods

2.1. Study design, population and data source

We conducted a retrospective cohort study using population-level health administrative data from Ontario. Residents of Ontario, Canada's most populous province with over 14 million people, have access to universal health insurance which covers medically necessary care, including acute care and physician services. We identified patients aged 18 years and older who were discharged alive between April 1, 2012 and March 31, 2017 from a hospitalization that included an ICU stay with mechanical ventilation using the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD). Admission to ICU was determined using special care unit codes in the DAD, with a sensitivity of 97.2% and specificity of 99.9% [15] and receipt of mechanical ventilation using billing codes from the Ontario Health Insurance Plan (OHIP) physician database and procedure codes from the DAD, as previously described [16]. Demographic and vital status on eligible patients were ascertained from Ontario's Registered Persons Database and health care costs were derived using a validated algorithm [17] (see Table E1 in the Supplementary File for details of the study datasets). These datasets were linked using unique encoded identifiers and analyzed at ICES, an independent, non-profit research institute funded by an annual grant from the Government of Ontario. The data for this study was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a Research Ethics Board.

2.2. Patient selection

All patients discharged alive after a hospitalization with admission to an ICU and receipt of mechanical ventilation were eligible for inclusion. We excluded non-residents of Ontario and patients younger than 18 and older than 105 years, patients who received cardiac surgery during the hospitalization because such care is only provided at a few select hospitals, patients transferred from or to another acute care hospital (to minimize the impact of this prior care on outcomes and minimize counting transfers as a rehospitalization), and patients whose hospital length of stay was less than 2 days in order to identify a more critically ill cohort. In determining rehospitalizations that occurred within 30 days of discharge from the index admission, we further excluded patients who died within 30 days of hospital discharge and before rehospitalization, patients not rehospitalized within 30 days of discharge, and patients with a planned 30-day rehospitalization as identified from the admission category on the discharge record. For patients who over the study period had multiple eligible hospitalizations with a subsequent first rehospitalization within 30-days of discharge, we randomly selected one to minimize bias in our outcome assessments (see Fig. E1 in the Supplementary File for patient flowchart).

2.3. Outcomes

The primary outcome was the percentage of 30-day rehospitalizations to a non-index hospital. We classified hospitals operating within a multi-site facility (referred to as “sister hospitals”) during the study period as one hospital and deemed a rehospitalization to a sister hospital as the same as an index-hospital rehospitalization. Reasoning that these hospitals may have more opportunities for better care coordination, including potentially better access to shared electronic medical records. Secondary outcomes were (1) factors associated with a non-index 30-day rehospitalization, the main explanatory factor of interest being travel distance; (2) hospital mortality, length of stay, admission to ICU, and receipt of dialysis during the rehospitalization; and (3) mortality and costs within the 30-days after rehospitalization for all rehospitalized patients.

2.4. Other variables

Distance was calculated as the direct straight-line distance in kilometers between the patient's normal place of residence and the index hospital and was categorized based on the quintile distribution of the data. Other variables include patient age, sex, Charlson Comorbidity Index score [18] using a 2-year look-back period that included the index hospitalization, most responsible and admission diagnoses, medical or surgical status during the index admission, and socio-economic status variables including neighborhood income quintile and the Ontario Marginalization Index, a validated multidimensional measure of marginalization [19]. Admission diagnosis was identified using an algorithm developed at ICES, which classifies the ICD-10 diagnostic codes which are accompanied by a diagnosis type indicating presence on hospital admission (diagnosis type ‘M'(without appearing as type 2 on the same abstract),'1′,'5′,'W','X', or ‘Y'). Diagnosis type ‘M' represents the most responsible diagnosis, the condition contributing the most to a patient's hospital stay. A similar coding approach has been used previously [20].

2.5. Statistical analyses

Descriptive statistics for patient baseline characteristics were compared using Chi-squared statistics and Analysis of Variance or Kruskal-Wallis tests for groups defined by location of rehospitalization and distance. We used logistic regression to assess the factors associated with a non-index hospital rehospitalization. Putative risk factors were identified a priori, based on clinical relevance and/or identified from the literature as available in the administrative datasets. To examine the association between rehospitalization to a non-index hospital and each binary outcome (mortality, rehospitalization with intensive care and receipt of mechanical ventilation, tracheostomy and dialysis during rehospitalization), we performed using multivariable logistic regression accounting for patient's age, sex, neighborhood income, rural residence, Charlson comorbidity index, most responsible diagnosis, number of hospitalization in the year prior to rehospitalization, residence at time of readmission and the number of days between index hospital

discharge and readmission. We employed zero-truncated negative binomial regression and generalized linear modelling (with gamma distribution and log link function) to examine the association between a non-index rehospitalization and ICU and hospital length of stay and healthcare costs, respectively. In both approaches, we adjusted for the patient characteristics listed above. As a sensitivity analysis we repeated the multivariable models for each outcome, restricting to the subset of patients residing in the Greater Toronto Area, a large metropolitan area in the province of Ontario. This was done to mitigate the influence of distinct patterns of rehospitalization within more rural and remote communities, including confounding due to patient referrals to specialized urban centres [21]. Separately, we repeated these analyses defining rehospitalizations to a sister hospital as a non-index rehospitalization. Analyses were performed using SAS Enterprise Guide 7.12 SAS Institute, Cary NC.

3. Results

Of the 91,161 patients who survived to hospital discharge following an ICU stay with mechanical ventilation, 14,997 (16.4%) had an unplanned rehospitalization within 30 days, with 2765 (18.4%) of these rehospitalization occurring at a non-index hospital (eFig. 1). Patients readmitted to a non-index hospital vs index hospital were younger (mean (standard deviation, SD): 63.6 (16.4) vs 65.2 (15.7)), more likely to be admitted as a surgical case during the initial hospitalization (49.4% vs 42.0%) and resided further from the index hospital: median (interquartile range, IQR) 24 (6–71) kilometers versus 6 (3–17) kilometers (Table 1). Patients readmitted to non-index hospitals were also more likely to have been discharged from a hospital that was a teaching centre, located in an urban setting and admitted a higher annual volume of ICU patients (Table 1 and Table E2 in the Supplementary File). The proportion of non-index rehospitalizations was 21.2% in the analysis classifying rehospitalizations to a sister hospital as non-index, with similar differences noted between the two groups (Table E3 in the Supplementary File).

3.1. Distance to the hospital and rehospitalization to non-index hospitals

The proportion of patients with a non-index rehospitalization went up as the distance from normal place of residence to the index hospital increased (Figure 1). Those living the farthest away from the index hospital (quintile 5) had a higher risk of a non-index 30-day rehospitalization (40.1% vs 9.2% in the lowest distance quintile). In multivariable regression, distance from patient residence to the index hospital was the strongest predictor of rehospitalization at a non-index hospital, adjusted odds ratio (OR) 8.40 (95% Confidence Interval (CI) 7.05, 10.01) for highest distance quintile compared to the lowest quintile (Table 2). Other factors associated with an increased odds of rehospitalization at a non-index hospital included receipt of tracheostomy during the index admission and discharge to the community versus other settings (home care, rehabilitation or nursing/aged home or chronic care facilities). Notably, the effect of being a surgical patient was attenuated in the adjusted analysis. There was also no association between age, sex or Charlson comorbidity score and location of rehospitalization (Table 2). Similarly, after adjusting for covariates, socio-economic-status as described by the Ontario Marginalization Index was not associated with rehospitalization at a non-index hospital (Table E4 in the Supplementary File). Table E5 (in the Supplementary File) highlights the similar findings when rehospitalization to a sister hospital was analyzed as non-index.

3.2. Characteristics and outcomes during rehospitalization at non-index and index hospitals

Compared to index rehospitalization, a smaller proportion of patients readmitted to a non-index hospital had the same admission diagnosis as during the index hospitalization (18.4% vs 12.8%, $p < 0.0001$). The main admission diagnosis for patients readmitted to non-index hospitals was "heart failure" (7.9%), compared to "other chronic obstructive pulmonary disease" (9.0%) among patients readmitted to the index hospital (Table E6 in the Supplementary File). Patients readmitted at a non-index hospital had a similar rate of admission to an ICU during the rehospitalization: 27.7% vs 26.7% adjusted OR 1.10 (95% CI 1.00–1.21), and the rates of mechanical ventilation were similar (13.9% vs 16.7%, adjusted OR 0.89 (95% CI 0.79–1.01) (Table 3). ICU and hospital length of stay and hospital mortality during rehospitalization were also similar for patients readmitted to non-index and index hospitals.

3.3. Mortality and healthcare costs within 30-days from rehospitalization

A similar percentage of patients rehospitalized at non-index hospitals died within the 30-days after rehospitalization (11.6% vs 13.6%, adjusted OR 0.91 (95% CI 0.80–1.04). There were no differences in inpatient hospital costs for the 30 days from the date of rehospitalization. However, emergency department and physician services costs were higher among patients rehospitalized at a non-index hospital (Table 3). These observations were also similar in our sensitivity analyses restricted to patients residing in the Greater Toronto Area (Table E7 in the Supplementary File) and classifying rehospitalizations to a sister hospital as non-index (Table E8 in the Supplementary File).

4. Discussion

In this population-based study of rehospitalizations after critical illness in a single-payer healthcare system, one sixth of mechanically ventilated patients experienced an unplanned rehospitalization within 30 days of discharge, with almost 20% of these rehospitalizations occurring in a non-index hospital. Distance from normal residence to the index hospital was the strongest predictor of a non-index rehospitalization. Outcomes during rehospitalization were similar for patients irrespective of the hospital. These findings were robust to analyses restricted to a subset of patients residing in a geographically more homogeneous area with similar access to critical care resources. Overall, our findings are different from a study in the US where there were disparities in outcome associated with rehospitalization at a non-index hospital for mechanically ventilated patients. This differential result suggests that healthcare systems factors may be an important target to reduce such disparities in outcomes. Further work is needed to elucidate what aspects of a single-payer system may contribute most to ensuring similar outcomes for patients requiring rehospitalization.

Our findings are notable for the relatively similar rate of rehospitalizations at 30 days compared with other critically ill populations. In New York state, the rate of rehospitalizations for those who received mechanical ventilation was almost identical: 16.2% [3]. Similarly, in a network of 17 ICUs in the US, the rehospitalization rate at 30 days (in 2012) was 15% [22] and in a randomized trial of an ICU recovery pilot program, the rates of rehospitalization within 30 days were 14.4% and 21.5% for the intervention and control arms respectively [23]. However, none of these studies addressed the question of location of rehospitalization, and some studies, such as by Bloom et al., only tracked patients rehospitalized at the same site [23].

The frequency of rehospitalizations at a different hospital was lower (18.4%) than in the one comparable study in the US (31.3%) [7]. The reasons for this difference are unclear. However, it is notable that a key factor associated with rehospitalization at a different hospital in Ontario was closer distance from home, which was not meaningfully different in the New York data, where different geographical distribution of hospitals relative to the population may be a factor. A second aspect that may help explain the difference was a high rate of discharge to skilled nursing facilities in the US data, which may have an intake from a wide catchment, but then use certain hospitals for routine rehospitalizations.

Table 1
Patient characteristics during index admission, for all patients with a rehospitalization within 30 days and stratified by location of rehospitalization*

	All Rehospitalizations ($N = 14,997$)	Index rehospitalizations ($N = 12,232$)	Non-index rehospitalization ($N = 2765$)	Standardized Difference
Age, yrs				
Mean (SD)	64.9 (15.8)	65.2 (15.7)	63.6 (16.4)	0.1
Median (IQR)	67 (56–77)	67 (56–77)	66 (54–75)	0.09
Age group, yrs n (%)				
18–44	1641 (10.9)	1287 (10.5)	354 (12.8)	0.07
45–64	4984 (33.2)	4036 (33.0)	948 (34.3)	0.03
65–74	3890 (25.9)	3195 (26.1)	695 (25.1)	0.02
75–84	3172 (21.2)	2618 (21.4)	554 (20.0)	0.03
≥ 85	1310 (8.7)	1096 (9.0)	214 (7.7)	0.04
Male, n (%)	8090 (53.9)	6526 (53.4)	1564 (56.6)	0.06
Charlson comorbidity score, n (%)				
0	2151 (14.3)	1746 (14.3)	405 (14.6)	0.01
1–2	5210 (34.7)	4258 (34.8)	952 (34.4)	0.01
≥ 3	7636 (50.9)	6228 (50.9)	1408 (50.9)	0
Surgical patient, n (%)	6502 (43.4)	5135 (42.0)	1367 (49.4)	0.15
Duration IMV, median (IQR)	3 (1–6)	3 (1–6)	3 (1–5)	0.03
Tracheostomy, n (%)	899 (6.0)	695 (5.7)	204 (7.4)	0.07
Pulmonary artery catheter, n (%)	509 (3.4)	378 (3.1)	131 (4.7)	0.09
Dialysis, n (%)	1312 (8.7)	1047 (8.6)	265 (9.6)	0.04
Distance from residence to the index hospital				
Mean (SD)	30.2 (79.7)	23.3 (68.6)	59.9 (111.4)	0.4
Median (IQR)	7 (3–24)	6 (3–17)	24 (6–71)	0.73
Distance quintile, n (%)				
1	2641 (17.6)	2397 (19.6)	244 (8.8)	0.31
2	2757 (18.4)	2510 (20.5)	247 (8.9)	0.33
3	2814 (18.8)	2421 (19.8)	393 (14.2)	0.15
4	2854 (19.0)	2285 (18.7)	569 (20.6)	0.05
5	2909 (19.4)	1742 (14.2)	1167 (42.2)	0.65
Missing	1022 (6.8)	877 (7.2)	145 (5.2)	0.08
Income quintile (%)				
1	4223 (28.2)	3514 (28.7)	709 (25.6)	0.07
2	3267 (21.8)	2650 (21.7)	617 (22.3)	0.02
3	2788 (18.6)	2261 (18.5)	527 (19.1)	0.01
4	2456 (16.4)	2003 (16.4)	453 (16.4)	0
5	2205 (14.7)	1760 (14.4)	445 (16.1)	0.05
Missing	58 (0.4)	44 (0.4)	14 (0.5)	0.02
Rural residence, n (%)	1528 (10.2)	1049 (8.6)	479 (17.3)	0.26
Missing	31 (0.2)	23 (0.2)	8 (0.3)	0.02
Planned index admission, n (%)	2149 (14.3)	1534 (12.5)	615 (22.2)	0.26
Hospitalization prior to index admission, n (%)				
Within 30 days	3222 (21.5)	2656 (21.7)	566 (20.5)	0.03
Within 1-year	8286 (55.3)	6850 (56.0)	1436 (51.9)	0.08
Index hospital characteristics				
Type, n (%)				0.24
Teaching	6755 (45.0)	5237 (42.8)	1518 (54.9)	
Non-teaching	8242 (55.0)	6995 (57.2)	1247 (45.1)	
Location, n (%)				
Rural	1105 (7.4)	946 (7.7)	159 (5.8)	0.08
Suburban	1293 (8.6)	1159 (9.5)	134 (4.8)	0.18
Urban	12,599 (84.0)	10,127 (82.8)	2472 (89.4)	0.19
Acute care beds, Median (IQR)	325 (204–418)	318 (200–416)	352 (232–436)	0.18
ICU beds, Median (IQR)	26 (16–65)	25 (15–65)	30 (21–69)	0.23
ICU annual patient volume, median (IQR)	1972 (1324-4823)	1916 (1257-4588)	2100 (1560-5044)	0.27
ICU LOS, median (IQR)	6 (3−10)	6 (3–10)	6 (3–10)	0.02
Hospital LOS, median (IQR)	15 (9–29)	15 (9–29)	15 (9–30)	0.01
Discharge disposition, n (%)				
Community	5142 (34.3)	4042 (33.0)	1100 (39.8)	0.14
Home care program	6016 (40.1)	4981 (40.7)	1035 (37.4)	0.07
Rehab hospital	1727 (11.5)	1400 (11.4)	327 (11.8)	0.01
Nursing/aged home	1149 (7.7)	984 (8.0)	165 (6.0)	0.08
Chronic care hospital	726 (4.8)	632 (5.2)	94 (3.4)	0.09
Other	237 (1.6)	193 (1.6)	44 (1.6)	0
Time to 30-day readmission (days)				
Mean (SD)	12.2 (8.5)	12.1 (8.5)	12.7 (8.6)	0.07
Median (IQR)	11 (5–19)	10 (5–19)	11 (5–19)	0.07

IMV = invasive mechanical ventilation.
* See Table E2 for full details of demographic variables.

The lack of any signal for harm associated with rehospitalization at a different hospital in Ontario, is an important finding. It suggests that receipt of care at a different hospital is not, inherently, associated with worse outcomes or increased costs [7]. It is possible that our findings are attributable, in part, to greater access to better health information exchange across hospitals, as lack of access may contribute to care fragmentation due to the need for repetition of diagnostic tests and less prompt delivery of appropriate care [24]. However, it is notable that for the duration of this study, the majority of hospitals in Ontario did not have a shared EHR system. Some areas, such as much of the Greater

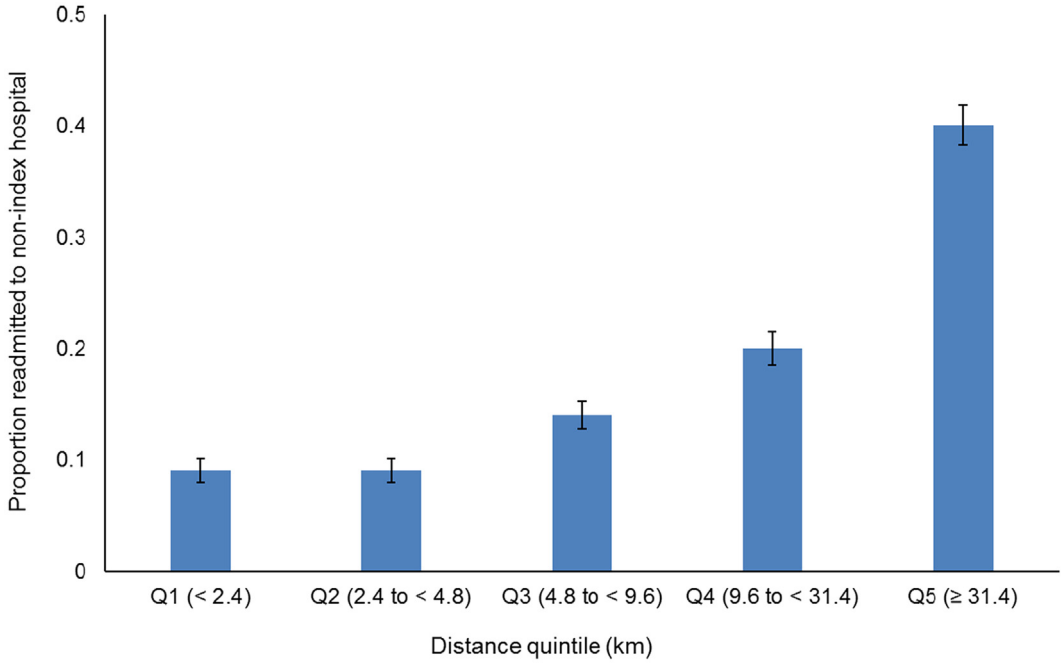

Fig. 1. Proportion of rehospitalizations at non-index hospitals by travel distance from normal residence to index hospital.
Data are for the proportion of non-index rehospitalization in each quintile of travel distance from patient's normal residence to the index hospital; Q1 = quintile 1 (lowest); Q2 = quintile 2; Q3 = quintile 3; Q4 = quintile 4; Q5 = quintile 5 (highest).

Toronto region, had a limited system for sharing labs, study results and medical notes; but, the system was not comprehensive and not province-wide until just after this study was completed [25]. One, older, survey, of oncologists found that only 22% reported having access to other organizations EHRs [12]. However, these networks may still be more extensive than in the US. While the majority of hospitals in the US do have some form of EHR [26], in the New York context, there may be more limited exchange of patient information between hospitals than in Ontario, due to technological challenges, as well as economic disincentives. Another possibility for the reason for a mitigation in the signal for harm may be due to access to follow-up clinic care. For example, in a randomized controlled trial of an ICU recovery pilot program for survivors of critical illness, the overall rate of rehospitalization was reduced to 14.4% compared with 21.5% in the control arm [23], although there were no differences in outcomes at 30 days. Differences in discharge planning, discharge location, and follow-up practices across regions and countries warrants future research.

In multivariable analysis, risk factors associated with non-index rehospitalization included receipt of tracheostomy during the initial hospitalization, discharge to the community and distance travelled from a normal residence to the index hospital, the latter having the largest influence on non-index rehospitalization. This finding regarding residential distance from hospitals is consistent with previous studies [9,27], underscoring that while the vast majority of Ontarians reside in urban settings, approximately 14% reside in more widely dispersed rural and remote northern communities, necessitating traveling long distances to access specialized care, such as ICU services. Other studies suggest that care closer to home is associated with lower out-of-pocket costs for patients and families and may better align with their preferences, including reducing the burden of traveling long distances to hospital [28-31]. Our data also demonstrated that outcomes are no worse for patients readmitted to closer-to-home non-index hospitals following critical illness suggesting this practice may be appropriate for select patients and more acceptable to patients and caregivers. Future work aimed at understanding the patient, family and health system factors required to support such a practice is also warranted as care closer to home may represent an important patient-centered outcome.

Table 2
Multivariable model of factors associated with 30-day rehospitalization to a non-index hospital*

Characteristics	N (%)	Odds Ratio (95% CI)
Distance to index hospital quintile		
1 (< 2.4 km)	2641 (17.6)	Reference
2 (2.4 to <4.8 km)	2757 (18.4)	0.91 (0.75,1.10)
3 (4.8 to <9.6 km)	2814 (18.8)	1.52 (1.27,1.81)
4 (9.6 to <31.4 km)	2854 (19.0)	2.67 (2.24,3.17)
5 (≥ 31.4 km)	2909 (19.4)	8.40 (7.05,10.01)
Missing	1022 (6.8)	1.80 (0.93,3.46)
Age group		
18–44	1641 (10.9)	Reference
45–64	4984 (33.2)	0.97 (0.83,1.13)
65–74	3890 (25.9)	1.02 (0.87,1.20)
75–84	3172 (21.2)	1.16 (0.98,1.38)
≥ 85	1310 (8.7)	1.24 (1.00,1.54)
Male	8090 (53.9)	1.09 (0.99,1.19)
Income quintile		
1	4223 (28.3)	Reference
2	3267 (21.9)	1.12 (0.97,1.30)
3	2788 (18.7)	0.99 (0.83,1.18)
4	2456 (16.4)	0.95 (0.78,1.15)
5	2205 (14.8)	1.14 (0.91,1.41)
Interventions during index admission		
Tracheostomy	899 (6.0)	1.30 (1.06,1.56)
Dialysis	1312 (8.7)	0.89 (0.76,1.05)
Charlson comorbidity score		
0	2151 (14.3)	Reference
1–2	5210 (34.7)	0.99 (0.86,1.14)
≥ 3	7636 (50.9)	1.04 (0.91,1.20)
Surgical patient	6502 (43.4)	0.94 (0.85,1.03)
Discharge location		
Community	5142 (34.3)	Reference
Home care	6016 (40.1)	0.74 (0.67,0.82)
Rehab hospital	1727 (11.5)	0.75 (0.64,0.87)
Nursing/aged home	1149 (7.7)	0.69 (0.57,0.84)
Chronic care hospital	726 (4.8)	0.49 (0.38,0.63)
Other	237 (1.6)	1.02 (0.71,1.46)
Teaching hospital	6755 (45.0)	1.04 (0.91,1.20)
Index hospital location		
Rural	1105 (7.4)	Reference
Suburban	1293 (8.6)	0.67 (0.35,1.27)
Urban	12,599 (84.0)	1.17 (0.63,2.18)

* See Table E4 for all variables included in the model.

Table 3
Outcomes during rehospitalization and at 30-days after rehospitalization.

	Rehospitalization			
	Index (N = 12,232)	Non-index (N = 2765)	Absolute difference (95% CI)	Adjusted Odds Ratio/Relative Risk (95% CI) (Reference = index)
Outcomes during rehospitalization				
ICU admission				
Any	3261 (26.7)	766 (27.7)	1.04 (1.02, 1.07)	1.10 (1.00, 1.21)
With IMV	2038 (16.7)	385 (13.9)	2.74 (2.72, 2.75)	0.89 (0.79, 1.01)
With tracheostomy	149 (1.2)	32 (1.2)	0.06 (0.06, 0.07)	1.06 (0.72, 1.58)
With dialysis	316 (2.6)	71 (2.6)	0.02 (0.01, 0.02)	0.99 (0.76, 1.30)
Any dialysis	761 (6.2)	156 (5.6)	0.58 (0.57, 0.59)	0.87 (0.72, 1.05)
ICU LOS				
Mean ± SD	10.1 (27.2)	9.5 (27.9)	0.60 (0.57, 0.62)	1.02 (0.91, 1.15)
Median (IQR)	5 (3–9)	4 (3–8)		
Hospital LOS (days)				
Mean ± SD	14.3 (28.7)	13.7 (28.7)	0.52 (0.51, 0.54)	1.00 (0.95, 1.06)
Median (IQR)	7 (4–14)	7 (4–13)		
Mortality	1443 (11.8)	278 (10.1)	1.74 (1.73, 1.76)	0.91 (0.79, 1.04)
Outcomes 30 days from date of rehospitalization				
Mortality	1660 (13.6)	320 (11.6)	2.00 (1.98, 2.01)	0.91 (0.80, 1.04)
			Health care costs	
Inpatient				
Mean ± SD	14,893 (15,805)	14,703 (15,599)	189.9 (182.5, 197.4)	1.01 (0.97, 1.04)
Median (IQR)	9553 (5237-18,587)	9147 (5035-18,676)		
ED costs				
Mean ± SD	613 (524)	690 (601)	76.69 (76.42, 76.96)	1.06 (1.03, 1.08)
Median (IQR)	592 (0–851)	610 (400–917)		
Physician				
Mean ± SD	2709 (2479)	2876 (2556)	167.1 (165.9, 168.3)	1.06 (1.03, 1.10),
Median (IQR)	1998 (1163-3352)	2125 (1234-3629)		
Total cost				
Mean ± SD	22,286 (18,419)	22,613 (18,480)	326.7 (317.9, 335.5)	1.03 (1.00, 1.06)
Median (IQR)	17,239 (9895-28,482)	17,662 (9668-29,717)		

IMV = invasive mechanical ventilation; LOS – length of stay; ED – emergency department.
All models adjusted for the following variables at Rehospitalization: age, sex, neighborhood income, rural residence, Charlson comorbidity index, most responsible diagnosis, number of hospitalizations in the year prior to readmission, residence at time of readmission, hospital-free days (number of days between index hospital discharge and readmission).

We found no association between patient socioeconomic variables and risk of rehospitalization at a non-index hospital, suggesting that income and other social inequities likely have minimal influence. This finding is similar to the work by Hua et al. which found little difference in rates of rehospitalization at same vs different hospitals based on race, or insurance status [7] and prior research in the Toronto area found no association with sociodemographic factors [32]. However, race and insurance status in the US have been previously associated with overall risk of rehospitalization, which itself is associated with poorer outcomes [3,33-35], suggesting that socioeconomic and racial disparities remain an important area for future research.

Our study has a number of limitations. First, use of administrative data limited the amount of clinical information available regarding both the index hospitalization and the rehospitalization. In particular, we lacked detailed data regarding severity of illness during the initial hospitalization, including organ support, which may influence both the timing of rehospitalization and where patients are rehospitalized. While admission to ICU is well validated with regard to coding [15], identification of mechanical ventilation using billing codes has not been studied. Several studies have applied the same definition of mechanical ventilation used in our work [36,37] to identify our cohort, but it is plausible that this approach may lead to misclassification of some patients. However, there is no evidence to suggest that there would be differential misclassification between patients rehospitalized in the index versus a non-index hospital. We also had limited information on potential reasons for the choice of a specific hospital; while we were able to demonstrate that distance from a normal residence appears to be a driver of this choice, we lacked any data on patient preferences for care, and did not assess relationships with physicians, clinics or other specific resources at hospitals that may influence choice. Although we assessed socioeconomics of patients using income quintiles, we did not include race in our assessment, due to concerns that this variable is not accurately coded [38,39]. However, prior work in the US has not shown that race is strongly associated with outcomes in index versus non-index hospitals [7]. Residual confounding remains a concern, as suggested elsewhere, even with a finding of no difference between groups [21,40,41]. Additionally, we had no specific information on hospitals and systems in Ontario that have shared EHRs. We did do a sensitivity analysis restricted to the area of the country where partial access to patients' EHR data exists (Greater Toronto), but future work is needed to elucidate how this access, or lack of access, acts as a facilitator (or barrier) of care across hospitals. We did not prespecify any adjustment for multiple comparisons in this analysis [42]. However, few differences between the groups were noted, and our main finding of an association between distance to hospital and rehospitalization at an index hospital showed a large association that would be unlikely to be impacted by any adjustment.

Although Ontario includes approximately 40% of the Canadian population, each Province has a separate healthcare funding model; therefore, our findings may not be fully representative within Canada. However, all Provinces do provide universal coverage. Finally, we limited our assessment to patients who did not undergo multiple transfers of care between acute care hospitals, as it would become impossible to adjudicate which hospital to label as the index hospital. Given that there is some regionalization of services, such as trauma and neurosurgery, we have likely excluded some patients who required specialized services, limiting generalizability to these populations.

5. Conclusion

For critically ill patients within the context of a single-payer healthcare system, overall rehospitalizations are as frequent as in the US. However, non-index rehospitalization is less frequent and the factor most strongly associated with a non-index hospitalization was a hospital closer to an individual's residence, suggesting that ability to access care near home may represent an important patient-centered component of care. Such care was not associated with an increased risk of harm, suggesting that even for complex critically ill patients, follow-up care can be safely delivered in other hospitals besides where the critical illness occurred. Future studies are needed to determine what aspects of a single-payer healthcare system, such as lack of insurance concerns, access across hospitals to EHR information, better availability of follow-up clinic appointments, or other factors, may allow for non-differential outcomes across hospitals for critically ill patients.

Funding

This work was supported by the Canadian Institutes of Health Research Operating Grant (grant number 136933) to Dr. Hannah Wunsch; and the National Institute of Health (grant number K08 AG051184) to Dr. May Hua.

Financial disclosures

Hannah Wunsch is supported by a Canada Research Chair [Tier 2] in Critical Care Organization and Outcomes and by a Merit Award from the Department of Anesthesiology and Pain Medicine at the University of Toronto.

Author contributions

Conceptualization: H.W., M.H., D.C.S. and R.A.F. *Acquisition or interpretation of the data:* all authors. *Statistical analyses:* L.F., H.W. and A.D.H. *Drafting of the manuscript*: A.D.H. *Review and revision of the manuscript for intellectual content:* all authors. *Obtained funding:* H.W., M.H., D.C.S., and R.A.F.

L.F. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analyses.

Declaration of Competing Interest

None.

Acknowledgments

This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health (MOH) and the Ministry of Long-*Term Care (MLTC)*. Parts of this material are based on data and information compiled and provided by the Canadian Institute for Health Information (CIHI). The opinions, analyses, results and conclusions reported in this paper are those of the authors and are independent from the funding or data sources. No endorsement by ICES, the MOH, MLTC or CIHI is intended or should be inferred. We thank IQVIA Solutions Canada Inc. for use of their Drug Information Database.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcrc.2022.154089.

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