Variation in Critical Care Unit Admission Rates and Outcomes for Patients With Acute Coronary Syndromes or Heart Failure Among High- and Low-Volume Cardiac Hospitals

Sean van Diepen, MSc, MD; Jeffrey A. Bakal, PhD; Meng Lin, MSc; Padma Kaul, PhD; Finlay A. McAlister, MSc, MD; Justin A. Ezekowitz, MSc, MBBCh

***Background*—**Little is known about cross-hospital differences in critical care units admission rates and related resource utilization and outcomes among patients hospitalized with acute coronary syndromes (ACS) or heart failure (HF).

***Methods and Results*—**Using a population-based sample of 16 078 patients admitted to a critical care unit with a primary diagnosis of ACS (n=14 610) or HF (n=1467) between April 1, 2003 and March 31, 2013 in Alberta, Canada, we stratified hospitals into high (>250), medium (200 to 250), or low (<200) volume based on their annual volume of all ACS and HF hospitalization. The percentage of hospitalized patients admitted to critical care units varied across low, medium, and high-volume hospitals for both ACS and HF as follows: 77.9%, 81.3%, and 76.3% ($P<0.001$), and 18.0%, 16.3%, and 13.0% ($P<0.001$), respectively. Compared to low-volume units, critical care patients with ACS and HF admitted to high-volume hospitals had shorter mean critical care stays (56.6 versus 95.6 hours, $P<0.001$), more critical care procedures (1.9 versus 1.2 per patient, <0.001), and higher resource-intensive weighting (2.8 versus 1.5, $P<0.001$). No differences in in-hospital mortality (5.5% versus 6.2%, adjusted odds ratio 0.93; 95% CI, 0.61 to 1.41) were observed between high- and low-volume hospitals; however, 30-day cardiovascular readmissions (4.6% versus 6.8%, odds ratio 0.77; 95% CI, 0.60 to 0.99) and cardiovascular emergency-room visits (6.6% versus 9.5%, odds ratio 0.80; 95% CI, 0.69 to 0.94) were lower in high-volume compared to low-volume hospitals. Outcomes stratified by ACS or HF admission diagnosis were similar.

***Conclusions*—**Cardiac patients hospitalized in low-volume hospitals were more frequently admitted to critical care units and had longer hospitals stays despite lower resource-intensive weighting. These findings may provide opportunities to standardize critical care utilization for ACS and HF patients across high- and low-volume hospitals. **(*J Am Heart Assoc*. 2015;4: e001708 doi: 10.1161/JAHA.114.001708)**

Key Words: critical care • heart failure • acute coronary syndrome • hospital variation

Acute coronary syndromes (ACS) and decompensated heart failure (HF) are common hospital admission diagnoses, with 50% to 79% of ACS patients and 10% to 51% of HF patients being admitted to critical care units (CCU).[1–4] CCU beds comprise 5% to 10% of h.ospital beds in North America, but account for 20% to 35% of hospital costs.[5–7] A recent publication reported a wide variation between hospitals in the percentage of patients with HF who were triaged to the CCU in the United States.[8] Patients admitted to hospitals with the highest CCU admission rates were less likely to require critical care therapies (such as mechanical ventilation and intravenous vasoactive therapies), but there was no difference in in-hospital mortality. The authors hypothesized that in a for-profit healthcare system, the observed differences may have been due to economic considerations rather than patient considerations. However, an alternate hypothesis is that hospital expertise influences the decision to admit patients to critical-care areas. The lack of randomized trials supporting either individual interventions or management strategies that would require a CCU may contribute to considerable variation in clinical practice.

Canada has a single-payer not-for-profit healthcare system in which institutional economic considerations do not factor

From the Divisions of Cardiology (P.K., J.A.E.) and General Internal Medicine (F.A.M.), Department of Medicine, and Divisions of Critical Care and Cardiology (S.D.), and Canadian Vigour Center (S.D., J.A.B., M.L., P.K., F.A.M., J.A.E.), University of Alberta, Edmonton, Canada.

The interpretation and conclusions contained herein are those of the researchers and do not necessarily represent the views of the Government of Alberta. Neither the Government of Alberta nor the Alberta Health express any opinion in relation to this study.

Accompanying Figures S1 and S2 and Tables S1 through S5 are available at http://jaha.ahajournals.org/content/4/3/e001708/suppl/DC1

Correspondence to: Sean van Diepen, MSc, MD, 2C2 Cardiology Walter MacKenzie Center, University of Alberta Hospital, 8440-11 St. Edmonton, Alberta, Canada, T6G 2B7. E-mail: sv9@ualberta.ca

Received December 16, 2014; accepted February 5, 2015.

into critical-care admission decisions. We evaluated CCU admission rates for the 2 most common cardiac admission diagnoses (ACS and HF) in high, medium, and low-volume hospitals. Furthermore, we compared the differential utilization of critical-care-specific therapies, length of stay, and resource utilization, and explored risk-adjusted clinical outcomes across hospital groups.

Methods

Study Design and Data Sources

Using linked administrative databases, we created a population-based cohort of patients hospitalized with an ACS or HF and examined measures of in-hospital resource utilization and clinical outcomes. The data set, as described previously,[9] was created by linking 5 administrative databases in the province of Alberta, Canada using anonymized individual patient identifiers: (1) the Alberta Inpatient Discharge Abstract Database, which records information for all admissions to acute-care facilities, including the primary diagnosis, up to 24 secondary diagnoses, inpatient surgical procedures, and CCU admissions; (2) the Ambulatory Care Classification System, which records all emergency department (ED) and hospital-based clinic data and up to 10 primary and secondary diagnoses; (3) the Admission Discharge and Transfer database, which codes for the timing of transfers between units in the same hospital for individual patients from the time of admission until hospital discharge; (4) the Alberta Health Care Practitioner Claims database, which codes physician claims for all inpatient, outpatient, and diagnostic services, including nonsurgical procedures and up to 3 diagnoses per encounter; and (5) the Alberta Health Care Insurance Registry, which tracks the demographics and vital status of all Albertans. The University of Alberta Health Research Ethics Board (Pro00037567) approved this study.

Patient Population

All patients aged ≥20 years admitted to an Alberta hospital with a CCU between April 1, 2003 and March 31, 2013 with a primary diagnosis of an ACS (International Classification of Diseases, 9th revision, clinical modification [ICD-9-CM] code 410 or 411 and International Classification of Diseases, 10th revision [ICD-10] code I20 to 21) or HF (ICD-9-CM 428, ICD-10) were included in the study. Given the recognized association between hospital readmission and adverse outcomes, only the first hospitalization during the study period was included, and patients with any hospitalization 30 days prior to the index ACS or HF hospitalization were excluded (see Figure S1 for flowchart).[10] To avoid potential referral biases, only patients with an ED visit at the same institution at the time of the index admission were included; thus, all patients transferred between institutions and direct emergency medical services to cardiac catheterization lab admissions were excluded from the analysis. In this database, the ACS and HF coding have a specificity of ≥99.4% and ≥98.7%, respectively.[11,12] Patient comorbidities were identified using all inpatient, ED, and outpatient ICD-9-CM and ICD-10 administrative codes in the year prior to the index admission. Rural patients were defined on the basis of their home residence using previous methodology.[13]

Among 100 acute-care hospitals in Alberta, only hospitals with a CCU (defined as a coronary intensive care unit or a medical/surgical intensive care unit) were included in the study. The average number of annual ACS and/or HF admissions (critical care and non–critical care) through the ED during the study period was used to classify hospitals as high (3, >250 admissions), medium (3, 200 to 250 admissions), or low (7, <200 admissions) volume hospitals (Figure S2). In-hospital critical-care therapies (such as mechanical ventilation or intra-arterial monitoring; see Table S1 for complete list) were identified using the Alberta Health Care Practitioner Claims database and Canadian Classification of Health Interventions codes for procedures from 2003 to 2013.

A limitation of the full data set analysis is that while it provides exact duration of admission and critical care–related therapies, it does not provide the timing of the critical care stay during the hospital admission from 2003 to 2007. In an a priori–specified sensitivity analysis, outcomes were analyzed in patients admitted directly to a CCU from the ED using the Admission Discharge and Transfer database (April 1, 2007 to March 31, 2013), which captures the timing of hospital unit stays throughout the hospital admission.

Outcomes

The primary resource utilization outcome was the percentage of all hospitalized ACS and/or HF patients admitted to a CCU. The outcomes of interest for patients with a CCU admission included length of critical care stay, length of hospital stay, use of critical care therapies (see Table S1), and resource-intensive weight (RIW) for each admission.[14] RIW provides a factor that relates a given hospitalization to a typical hospitalization for a patient with similar diagnosis-related group and comorbidity profile, accounting for both resource use and length of stay. For example, a hospitalization with an RIW of 1.5 suggests that this hospitalization required 50% more resources either through interventions (procedures, equipment requirements) or time (length of stay). The primary clinical outcome was in-hospital all-cause mortality among patients with a CCU stay. Secondary outcomes of interest included (1) all-cause mortality 30 days from hospital admission, (2) all-cause and cardiovascular 30-day postdischarge rehospitalization, and (3) all-cause and cardiovascular 30-day ED visit. All outcomes were evaluated separately in ACS and HF admissions and compared between the high-, medium-, and low-volume hospitals.

Statistical Methods

Categorical data were summarized as percentages and differences tested using the χ^2 test, and continuous variables were summarized as medians and interquartile ranges and tested using a Wilcoxon rank sum test. To adjust for differences in patients' baseline characteristics, a series of multivariable logistic regression models were developed to generate adjusted results using age, sex, socioeconomic status, and associated comorbidities (listed in Table 1) between hospital volume strata. To account for hospital effects, all models used robust estimates of variance clustered by every hospital to account for within-hospital correlations. Statistical significance was set at P=0.05 and all statistical tests were 2-sided. All analyses were conducted in SAS 9.3 (SAS Institute Inc., Cary, NC).

Results

Between April 1, 2003 and March 31, 2013, a total of 62 846 patients presented to an ED and were admitted to 13 hospitals with a CCU with a primary diagnosis of an ACS or HF. The final study population included 28 088 patients (16 078 critical care and 12 010 ward patients; Figure S1). Patient follow-up was 95.5% over a median of 54 (interquartile range 25 to 90) months, and patients with missing follow-up information were excluded. Patients admitted to low-volume hospitals were more likely to be older, female, have a rural address, have a lower income, and have more cardiac and noncardiac comorbidities (Table 1); these patterns persisted when admissions to CCU versus hospital ward were examined separately (Table 1) or when critical care admissions for ACS were examined separately (Table 2). Patients admitted to CCUs with HF in low-volume hospitals were less likely to have a history of hypertension, diabetes, dyslipidemia, myocardial infarction, and HF.

Resource Utilization and Critical Care Procedures

The percentage of hospitalized patients admitted to CCUs varied across low-, medium-, and high-volume hospitals for both ACS (77.9%, 81.3%, and 76.3%, P<0.001) and HF (18.0%, 16.3%, and 13.0%, P<0.001) patients (Figure 1). The combined percentage of hospitalized ACS and HF patients admitted to CCUs also varied across low (53.6%), medium (56.6%), and high (59.9%) volume hospitals (P<0.001). The paradoxically higher combined CCU admission rate in high-volume centers was driven by a higher proportion of ACS:HF admissions in high- versus low-volume centers. Overall, annual hospital ACS and HF volume was highly correlated with annual CCU volume (r=0.71, P=0.006).

Critical care resource utilization and procedural information by hospital volume is presented in Table 3. Compared to patients in high volume CCUs, CCU patients in low volume hospitals had longer median critical care stays (85.3 versus 45.1 hours, P<0.001 across groups), higher median total CCU:hospital length-of-stay ratios (96% versus 41%, P<0.001 across groups), and lower RIW (1.5 versus 2.3, P<0.001 across groups). High-volume hospitals had the highest per-patient use of critical care–related procedures and therapies including invasive or noninvasive mechanical ventilation, resuscitation, arterial or central lines, intra-aortic balloon pumps, and percutaneous or surgical coronary interventions. These patterns were similar when ACS and HF admissions were evaluated individually (Table 3). In low-volume hospitals, the median critical care, total CCU:hospital length-of-stay ratios, and hospital stays were longer for ACS admissions; HF patients in low-volume hospitals had longer median CCU stays, higher CCU:hospital length-of-stay ratios, but fewer hospitals days. Results were similar in the sensitivity analysis limited to patients admitted directly to a CCU from the ED (Table S2) and in a sensitivity analysis limited to hospitals with telemetry wards.

Outcomes

The outcomes among patients admitted to CCUs stratified by annual hospital volume are presented in Figure 2 and Table 4. After multivariable adjustment, no significant differences were observed in the rates of in-hospital death, 30-day death from admission, or 30-day all-cause rehospitalization after discharge in patients who had been treated in the CCU, with either ACS or HF as their most responsible diagnosis across hospital volume strata. Compared to low-volume hospitals, high-volume hospitals had lower rates of 30-day cardiovascular readmission after hospital discharge (4.6% versus 6.8%, adjusted odds ratio 0.77; 95% CI, 0.60 to 0.99), 30-day all-cause ED visits after discharge (16.6% versus 20.8%, adjusted odds ratio 0.85; 95% CI, 0.77 to 0.93), and 30-day cardiovascular ED visits after discharge (6.6% versus 9.5%, adjusted odds ratio 0.80; 95% CI, 0.69 to 0.94). Results were similar in the a priori sensitivity analysis limited to those patients admitted directly to a CCU from the ED (Table S3). Outcome patterns were similar between high-volume and low-volume hospitals for ACS and/or HF patients. Compared to patients admitted to hospital wards only, ACS and HF patients

Table 1. Baseline Characteristics of Critical Care Unit and Hospital Ward Acute Coronary Syndrome and Heart Failure Admissions by Annual Average Hospital Volume

	All Admissions				Critical Care Unit Admission				Hospital Ward Admission			
	Low (n=8100)	Medium (n=7121)	High (n=12 867)	*P* Value	Low (n=4344)	Medium (n=4031)	High (n=7701)	*P* Value	Low (n=3756)	Medium (n=3088)	High (n=5166)	*P* Value
Demographics												
Age, median (IQR), y	69.8 (14.2)	69.0 (14.0)	66.8 (13.9)	<0.001	65.3 (13.9)	64.8 (13.4)	63.2 (13.0)	<0.001	75.0 (12.7)	74.4 (12.8)	72.1 (13.6)	<0.001
Male, %	61.1	60.9	66.9	<0.001	66.8	67.2	72.9	<0.001	54.6	52.7	57.9	<0.001
Rural residence, %	7.2	2.3	3.6	<0.001	6.4	2.4	3.4	<0.001	8.0	2.3	3.7	<0.001
Neighborhood income, %				<0.001				<0.001				<0.001
Missing	8.2	9.5	9.4		8.4	9.4	10.5		8.0	9.5	7.8	
Lowest quartile	33.4	21.6	28.6		28.8	18.5	25.0		38.8	25.6	33.8	
Second quartile	22.3	24.5	20.1		22.4	23.4	20.1		22.1	25.9	20.1	
Third quartile	20.4	23.3	20.3		22.7	24.5	20.7		17.8	21.8	19.7	
Highest quartile	15.7	21.2	21.7		17.7	24.2	23.7		13.3	17.2	18.6	
Comorbidities, %												
Hypertension	56.1	56.8	59.3	<0.001	55.0	56.8	54.9	0.13	57.5	56.8	66.0	<0.001
Diabetes	27.5	28.9	26.0	<0.001	23.4	24.5	20.6	0.057	32.2	34.7	34.0	0.071
Dyslipidemia	31.4	33.7	44.3	<0.001	39.7	44.5	47.5	<0.001	21.8	19.7	39.5	<0.001
Myocardial infarction	12.7	11.1	12.5	<0.001	11.6	12.4	10.7	0.022	14.0	9.4	15.2	<0.001
PCI*	2.0	1.8	2.3	0.033	2.0	1.8	2.0	0.82	1.9	1.8	2.8	0.003
Coronary artery bypass*	0.6	0.5	0.8	0.051	0.5	0.4	0.6	0.66	0.8	0.7	1.2	0.029
Prior heart failure	22.2	20.7	19.2	<0.001	10.5	8.5	7.2	<0.001	35.8	36.7	37.1	0.44
Atrial fibrillation	16.7	15.2	13.5	<0.001	8.2	7.2	5.9	<0.001	26.4	25.7	24.9	0.25
Cerebrovascular disease	4.9	4.0	4.4	0.015	3.4	2.6	3.3	0.060	6.7	5.7	6.0	0.22
Peripheral vascular disease	7.1	5.8	4.8	<0.001	5.5	4.4	4.2	0.005	9.0	7.7	5.8	<0.001
COPD	19.2	15.8	13.9	<0.001	13.6	10.3	8.5	<0.001	25.5	23.0	22.0	<0.001
Chronic kidney disease	12.1	10.3	11.1	0.002	8.0	6.3	6.5	0.003	16.8	15.4	18.0	0.011
Dementia	3.8	3.0	2.3	<0.001	1.5	1.2	1.0	0.050	6.6	5.2	4.4	<0.001
Anemia	11.7	10.2	9.7	<0.001	6.4	5.1	5.2	0.008	17.8	16.7	16.5	0.27
Cancer	5.1	3.6	3.6	<0.001	3.7	2.8	2.5	<0.001	6.8	4.7	5.3	<0.001

COPD indicates chronic obstructive pulmonary disease; IQR, interquartile range; PCI, percutaneous coronary intervention.
*Within 1 year of index admission.

Table 2. Baseline Characteristics Among Critical Care Admissions Stratified by Annual Acute Coronary Syndrome and/or Heart Failure Hospital Volume

	Critical Care Unit ACS and HF Admissions				Critical Care ACS Admissions				Critical Care HF Admissions			
	Low (n=4344)	Medium (n=4031)	High (n=7701)	*P* Value	Low (n=3753)	Medium (n=3592)	High (n=7265)	*P* Value	Low (n=591)	Medium (n=441)	High (n=436)	*P* Value
Demographics												
Age, median (IQR), y	65.3 (13.9)	64.8 (13.4)	63.2 (13.0)	<0.001	64.5 (13.9)	64.1 (13.4)	62.8 (12.9)	<0.001	70.6 (12.7)	69.9 (12.2)	69.4 (13.0)	0.47
Male, %	66.8	67.2	72.9	<0.001	68.2	67.8	73.5	0.002	57.7	61.5	62.8	0.21
Rural residence, %	6.4	2.4	3.4	<0.001	6.0	2.2	3.4	<0.001	8.9	3.6	4.0	<0.001
Neighborhood income, %				<0.001				<0.001				<0.001
Missing	8.4	9.4	10.5		8.3	9.2	10.6		9.1	11.3	9.6	
Lowest quartile	28.8	18.5	25.0		27.9	18.4	24.7		34.5	19.7	30.3	
Second quartile	22.4	23.4	20.1		22.3	23.3	20.0		23.4	24.5	21.3	
Third quartile	22.7	24.5	20.7		22.8	24.7	20.7		21.7	22.7	21.6	
Highest quartile	17.7	24.2	23.7		18.9	24.5	24.1		11.3	21.8	17.2	
Comorbidities, %												
Hypertension	55.0	56.8	54.9	0.13	55.3	57.3	54.7	0.04	53.5	52.6	58.3	0.19
Diabetes	23.4	24.5	20.6	0.057	21.7	22.8	19.4	<0.001	33.8	38.0	40.4	0.09
Dyslipidemia	39.7	44.5	47.5	<0.001	42.4	46.6	48.4	<0.001	22.3	26.8	32.3	0.002
Myocardial infarction	11.6	12.4	10.7	0.022	11.3	12.4	10.3	0.004	13.4	12.5	17.9	0.047
PCI*	2.0	1.8	2.0	0.82	2.0	2.0	1.9	0.99	2.2	0.9	3.0	0.09
Coronary artery bypass*	0.5	0.4	0.6	0.66	0.4	0.3	0.5	0.52	1.0	1.1	1.6	0.68
Prior heart failure	10.5	8.5	7.2	<0.001	5.9	4.3	4.9	0.005	39.4	42.2	46.7	0.07
Atrial fibrillation	8.2	7.2	5.9	<0.001	5.5	5.2	5.0	0.42	25.2	23.1	22.3	0.51
Cerebrovascular disease	3.4	2.6	3.3	0.060	3.2	2.4	3.2	0.06	4.7	4.3	6.2	0.40
Peripheral vascular disease	5.5	4.4	4.2	0.005	4.8	3.9	3.8	0.03	9.5	8.4	10.1	0.68
COPD	13.6	10.3	8.5	<0.001	11.9	9.1	7.6	<0.001	24.9	19.7	23.9	0.13
Chronic kidney disease	8.0	6.3	6.5	0.003	6.4	5.1	5.4	0.03	17.9	16.3	24.5	0.004
Dementia	1.5	1.2	1.0	0.050	1.2	1.2	0.9	0.18	2.9	1.1	1.8	0.14
Anemia	6.4	5.1	5.2	0.008	5.2	4.4	4.3	0.09	14.0	11.3	19.3	0.003
Cancer	3.7	2.8	2.5	<0.001	3.5	2.7	2.3	0.001	5.1	3.0	5.3	0.17

ACS indicates acute coronary syndrome; COPD, chronic obstructive pulmonary disease; HF, heart failure; IQR, interquartile range; PCI, percutaneous coronary intervention.
*Within 1 year of index hospitalization.

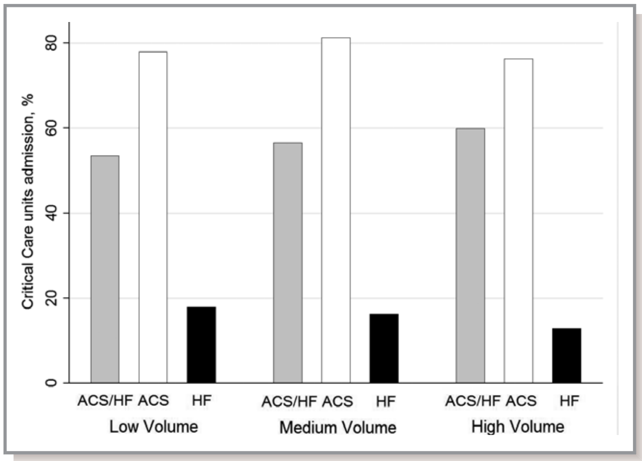

Figure 1. Percentage of acute coronary syndrome (ACS) and/or heart failure (HF) patients admitted to critical care units, stratified by hospital cardiac volume.

admitted to a CCU had significantly higher adjusted in-hospital and 30-day mortality, though this was largely driven by higher mortality among HF patients (Tables S4 and S5). Outcomes were similar in a sensitivity analysis limited to hospitals with telemetry wards.

Discussion

In a contemporary population-based cohort of patients admitted to the hospital with ACS or HF in a single-payer, not-for-profit healthcare system, several novel findings emerge. First, compared to lower volume hospitals, higher volume hospitals were less likely to admit ACS and HF patients to CCUs. Second, CCU patients in higher volume hospitals were more likely to receive critical care procedures and therapies, and thus had higher RIW. Third, no differences in in-hospital or 30-day mortality were observed, but patients treated in lower volume hospitals were more likely to have a cardiovascular hospital readmission or an ED visit within 30 days of discharge.

The CCU, originally developed for specialized arrhythmia monitoring and treatment, has been an important advancement in the care of ACS.[15,16] In the contemporary era, the proportion of CCU patients admitted with HF and critical illness has grown in tertiary hospitals.[17,18] The reported percentage of patients hospitalized with an ACS or HF admitted to CCUs has varied widely between and within countries. A previous report from the US Premier Perspective database found that in the United States, hospitals with the highest CCU admission rates were more likely to be smaller centers and patients were less likely to require CCU-specific therapies.[4] In a single-payer healthcare system, we found that lower volume cardiac hospitals were significantly more likely to admit ACS and HF patients to CCUs rather than a ward. Moreover, patients admitted to CCUs in higher volume hospitals had a higher RIW, as they required more critical care–related therapies and procedures than those admitted to CCUs in lower volume hospitals, suggesting higher clinical acuity. Although Safavi and colleagues suggest that in a for-profit healthcare system, economic considerations may factor into CCU admission decisions, our findings in a not-for-profit healthcare system provide an alternate explanation that annual clinical volume may be an equally important determinate in ward versus CCU triage decisions. We hypothesize that annual hospital volume may be a surrogate for individual physician and institutional ACS and HF expertise, wherein clinicians in low-volume centers may be less comfortable admitting lower acuity cardiac patients to hospital wards.

The association between clinical volumes, either hospital-wide or physician-based, and outcomes is well reported in both the cardiovascular and critical care literature, but little is known about outcomes in CCUs.[19–24] The lack of an observed mortality difference between low- and high-volume hospitals among ACS and HF patients in this analysis is consistent with a previous analysis of critical care HF hospitalization in the United States.[4] Moreover, our findings build on previous reports by including ACS and postdischarge outcomes in a province-wide data set that does not rely on voluntary hospital participation. We observed that patients discharged from high-volume hospitals were less likely to require hospital readmission or an ED visit within 30 days of discharge whether they had been treated in a CCU or not. The reasons underpinning hospital readmission are complex and likely reflect individual medical risks, adherence to evidence-based therapy, systems of care, social and community supports, length of hospital stay, continuity of care, and provider experience.[25–31] Importantly, previous registry data in the United States have demonstrated that a bias may exist wherein community hospitals without diagnostic catheterization were more likely to transfer lower risk patients.[32] This potential bias was mitigated by including all patients who underwent cardiac procedures at another institution (a common practice in this regionalized single-payer system of cardiac care). Our findings present future opportunities to evaluate the reasons underlying hospital readmission and potential treatment disparities with the goal of bridging care gaps and improving the care in lower volume cardiac hospitals.

The findings of this analysis could potentially direct future studies to evaluate the appropriateness and cost effectiveness of critical care utilization for ACS and HF patients. Up to 21% of hospitalized patients in the United States require a critical care stay at an estimated 2.5- to 4.5-fold higher per-day cost.[33,34] In the intensive-care literature, there is a recognition that low-acuity admissions account for up to 69% of admissions and length of stay has been shown to account 85% to 90% of the

Table 3. Resource Utilization Among Critical Care Admissions by Average Annual Cardiac Volume

	Acute Coronary Syndrome or Heart Failure Most Responsible Diagnosis				Acute Coronary Syndrome Most Responsible Diagnosis				Heart Failure Most Responsible Diagnosis			
	Low (n=4344)	Medium (n=4031)	High (n=7701)	*P* Value	Low (n=3753)	Medium (n=3592)	High (n=7265)	*P* Value	Low (n=591)	Medium (n=441)	High (n=436)	*P* Value
Critical care hours, mean (SD)	95.9 (64.1)	78.3 (57.8)	56.6 (51.0)	<0.001	94.9 (60.2)	76.8 (53.1)	54.7 (45.6)	<0.001	102.2 (84.4)	91.0 (86.1)	87.7 (101.8)	<0.001
Critical care hours, median (IQR)	85.3 (60.6)	66.5 (56.6)	45.1 (39)	<0.001	85.6 (57.2)	66.7 (53.5)	44.6 (37.6)	<0.001	83.7 (93.7)	66.2 (95.1)	60.3 (78.4)	<0.001
Hospital days, mean (SD)	7 (8)	6 (8)	7 (10)	<0.001	6 (5)	5 (5)	6 (9)	<0.001	12 (16)	12 (18)	16 (21)	<0.001
Hospital days, median (IQR)	5 (5)	5 (4)	5 (4)	<0.001	5 (4)	4 (3)	4 (4)	<0.001	8 (10)	9 (12)	11 (12)	<0.001
Mean CCU/total LOS ratio,% (SD)	76 (31)	67 (34)	46 (27)	<0.001	79 (29)	70 (32)	47 (27)	<0.001	54 (35)	45 (35)	33 (27)	<0.001
Median CCU/total LOS ratio,% (IQR)	96 (49)	81 (64)	41 (36)	<0.001	97 (41)	85 (60)	42 (36)	<0.001	51 (73)	36 (67)	26 (34)	<0.001
Resource-intensive weighting (RIW), mean (SD)	1.5 (1.5)	1.4 (1.4)	2.3 (2.8)	<0.001	1.4 (0.9)	1.3 (1.0)	2.3 (2.5)	<0.001	2.2 (3.1)	2.2 (3.3)	3.9 (5.8)	<0.001
Critical care–related therapies and procedures*												
Total procedures (mean procedures per person)	5271 (1.2)	4088 (1.0)	14 847 (1.9)	<0.001	4274 (1.1)	3357 (0.9)	13 145 (1.8)	<0.001	997 (1.7)	731 (1.7)	1702 (3.9)	<0.001
Any procedure, %	52.7	49.2	82.3	<0.001	54.0	50.8	83.7	<0.001	44.7	36.3	59.4	<0.001
Percutaneous coronary intervention, %	34.2	34.1	72.0	<0.001	39.5	38.1	75.8	<0.001	0.5	1.6	8.9	<0.001
Coronary artery bypass grafting†, %	0	0	2.1	<0.001	0	0	2.2	<0.001	0	0	0.7	0.03
Invasive or noninvasive mechanical ventilation, %	5.4	3.1	9.0	<0.001	3.0	1.8	7.9	<0.001	20.6	13.8	27.3	<0.001
Intubation, %	0.07	0.05	0.18	0.08	0.03	0.06	0.17	0.06	0.3	0	0.5	0.48
Dialysis, %	0.8	1.0	1.7	<0.001	0.4	0.7	1.4	<0.001	3.6	3.6	7.3	0.008
Cardiac arrest or resuscitation, %	13.4	7.9	12.6	<0.001	12.8	7.2	12.0	<0.001	17.3	13.4	23.6	<0.001
Arterial/central/hemodialysis line, %	11.9	9.7	8.7	<0.001	12.2	9.4	7.9	<0.001	9.6	12.5	21.3	<0.001
Right heart catheter, %	0.4	0.4	1.5	<0.001	0.1	0.2	1.0	<0.001	2.0	1.8	9.9	<0.001
Temporary pacemaker, %	0.4	0.7	1.2	<0.001	0.4	0.7	1.2	<0.001	0.9	0.5	1.4	0.34
Cardioversion, %	1.5	1.7	2.7	<0.001	1.1	0.9	2.5	<0.001	4.2	8.2	6.7	0.029
Pericardiocentesis, %	0.02	0.02	0.2	0.007	0.03	0.03	0.2	0.014	0	0	0.02	0.30
Intra-aortic balloon pump, %	0	0.05	2.9	<0.001	0	0.06	3.0	<0.001	0	0	1.2	0.002

CCU indicates critical care unit; IQR, interquartile range; LOS, length of stay; RIW, resource-intensive weighting.
*First occurrence only.
†Only 2 hospitals in the province of Alberta have cardiac surgical services; thus, coronary bypass was not included in RIW or total procedure calculations.

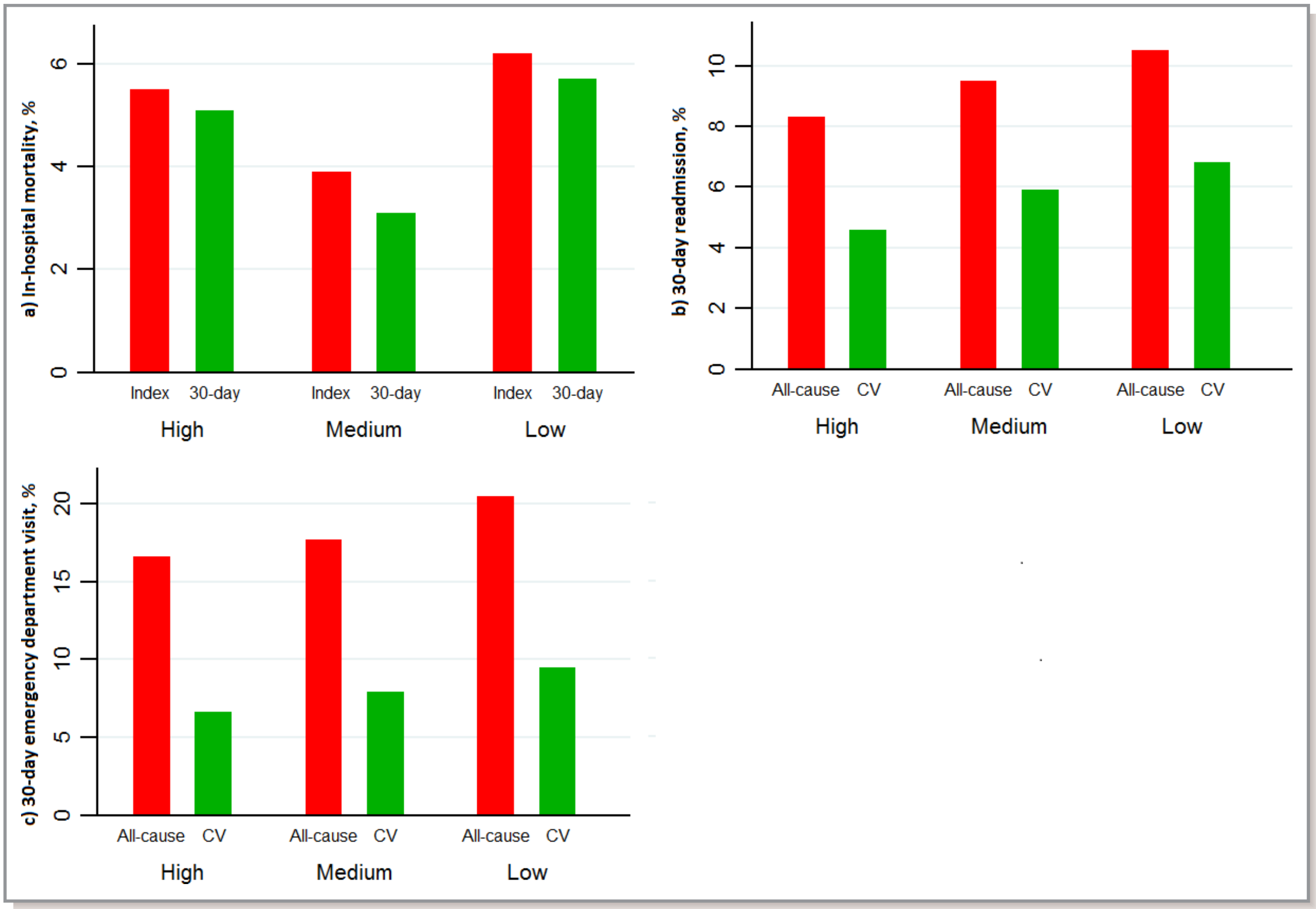

Figure 2. Cardiovascular (CV) clinical outcomes among acute coronary syndrome and/or heart failure patients admitted to critical care units, stratified by hospital cardiac volume.

interpatient variability in cost.[34,35] Our paradoxical observation that patients in low-volume hospitals were less likely to require critical care–related therapies (suggesting lower patient acuity) but had longer critical care stays presents potential opportunities to develop and implement evidenced-based critical care admission criteria and discharge pathways that could potentially lead to substantial cost savings.

Limitations

Although we were able to capture data on all encounters with the healthcare system in a defined geographic region (an entire Canadian province) and thereby examine a population-based sample of patients with ACS and/or HF, this analysis has several limitations. First, no information on in-hospital pharmacological therapy was available, and practice patterns may differ in other healthcare systems. Second, physiologic, laboratory, and goals of care information were not available in this administrative data set; thus, risk adjustment was performed using demographic and medical history data only. Third, 74% of acute care hospitals in Alberta reported having access to ward telemetry capabilities outside of CCUs, but information on the capacity and availability of individual hospital ward telemetry availability on the day admission for each patient was not available. Fourth, information on individual hospital unit nurse-to-patient ratios was not available in this data set. Finally, the critical care–related therapies and procedures coded in this analysis were provided during the index hospital admission. We acknowledge that they may be delivered in other units, though this is less likely given the clinical patient population and practice patterns in the region studied.

Conclusions

In a large population-based cohort of patients admitted with an ACS or HF, we observed that patients admitted to lower volume hospitals were older, had more comorbidities, and were more likely to be admitted to CCUs; however, the lower volume hospital patients had longer mean critical care stays despite lower resource utilization and use of critical

Table 4. Acute Coronary Syndrome and Heart Failure Critical Care Unit Admission Outcomes by Average Annual Hospital Volume

	Acute Coronary Syndromes or Heart Failure Most Responsible Diagnosis			Acute Coronary Syndrome Most Responsible Diagnosis			Heart Failure Most Responsible Diagnosis		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Index hospitalization death*, %	6.2	3.9	5.5	4.4	3.0	4.5	17.4	11.8	21.6
Adjusted OR‡ (95% CI)	Ref	0.71 (0.50, 1.02)	0.93 (0.61, 1.41)	Ref	0.75 (0.56, 1.02)	1.06 (0.64, 1.74)	Ref	0.67 (0.40, 1.10)	1.11 (0.67, 1.85)
30-day death from admission, %	5.7	3.7	5.1	4.4	3.1	4.5	14.4	8.8	16.7
Adjusted OR‡ (95% CI)	Ref	0.73 (0.50, 1.08)	1.05 (0.68, 1.62)	Ref	0.81 (0.55, 1.19)	1.16 (0.69, 1.95)	Ref	0.60 (0.34, 1.06)	1.24 (0.76, 2.04)
30-day all-cause readmission†, %	10.5	9.5	8.3	9.5	8.8	7.8	17.8	15.4	18.4
Adjusted OR§ (95% CI)	Ref	0.96 (0.64, 1.44)	0.84 (0.62, 1.15)	Ref	0.98 (0.65, 1.47)	0.86 (0.64, 1.14)	Ref	0.92 (0.51, 1.67)	0.98 (0.49, 1.95)
30-day cardiovascular readmission*, %	6.8	5.9	4.6	6.2	5.4	4.3	11.5	11.1	12.3
Adjusted OR‖ (95% CI)	Ref	0.92 (0.65, 1.31)	0.77 (0.60, 0.99)	Ref	0.92 (0.61, 1.36)	0.74 (0.56, 0.97)	Ref	1.02 (0.58, 1.83)	1.09 (0.54, 2.21)
30-day all-cause ED visit*, %	20.5	17.7	16.6	19.6	17.3	16.2	26.8	21.6	23.7
Adjusted OR¶ (95% CI)	Ref	0.90 (0.z77, 1.05)	0.85 (0.77, 0.93)	Ref	0.91 (0.80, 1.02)	0.85 (0.75, 0.96)	Ref	0.82 (0.47, 1.44)	0.85 (0.55, 1.30)
30-day cardiovascular ED visit*, %	9.5	7.9	6.6	8.4	7.2	6.2	17.4	14.1	14.9
Adjusted OR# (95% CI)	Ref	0.89 (0.73, 1.09)	0.80 (0.69, 0.94)	Ref	0.91 (0.71, 1.17)	0.79 (0.68, 0.93)	Ref	0.80 (0.40, 1.58)	0.88 (0.51, 1.54)

CABG indicates coronary artery bypass grafting; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; ED, emergency department; OR, odds ratio; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; RIW, resource-intensive weighting.

*Includes hospitalizations >30 days.

†From hospital discharge.

Variables included in each of the multivariate models are as follows: ‡Age, gender, rural residence, neighborhood income, any procedure use, RIW, hypertension, anemia, CHF, CVD, dementia, COPD, chronic kidney disease, cancer, diabetes, prior PCI, dyslipidemia. §Age, gender, rural residence, neighborhood income, CABG, RIW, atrial fibrillation, anemia, CHF, PVD, chronic kidney disease, cancer, diabetes, dyslipidemia. ‖Age, gender, rural residence, neighborhood income, any procedure use, CABG, RIW, atrial fibrillation, CHF, chronic kidney disease, cancer, diabetes. ¶Age, gender, rural residence, neighborhood income, CABG, hypertension, atrial fibrillation, anemia, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer. #Age, gender, rural residence, neighborhood income, any procedure use, CABG, atrial fibrillation, CHF, PVD, COPD, chronic kidney disease, cancer, diabetes.

care–related therapies. Patients discharged from lower volume hospitals were more likely to have cardiovascular readmissions and ED visits within 30 days of discharge. These findings suggest an opportunity to evaluate and standardize the appropriateness of critical care utilization for ACS and HF patients across high- and low-volume hospitals.

Acknowledgments

This study is based in part on data provided by Alberta Health.

Sources of Funding

Dr McAlister is supported by Alberta Innovates—Health Solutions and the University of Alberta Chair in Cardiovascular Outcomes. Dr Ezekowitz is supported by a salary award from Alberta Innovates—Health Solutions.

Disclosures

None.

References

1. Hasdai D, Behar S, Wallentin L, Danchin N, Gitt AK, Boersma E, Fioretti PM, Simoons ML, Battler A. A prospective survey of the characteristics, treatments and outcomes of patients with acute coronary syndromes in Europe and the Mediterranean basin. *Eur Heart J*. 2002;23:1190–1201.
2. Nieminen MS, Brutsaert D, Dickstein K, Drexler H, Follath F, Harjola V-P, Hochadel M, Komajda M, Lassus J, Lopez-Sendon JL, Ponikowski P, Tavazzi L. EuroHeart Failure Survey II (EHFS II): a survey on hospitalized acute heart failure patients: description of population. *Eur Heart J*. 2006;27:2725–2736.
3. Hugli O, Braun JE, Kim S, Pelletier AJ, Camargo CA Jr. United States emergency department visits for acute decompensated heart failure, 1992 to 2001. *Am J Cardiol*. 2005;96:1537–1542.
4. Safavi KC, Dharmarajan K, Kim N, Strait KM, Li SX, Chen SI, Lagu T, Krumholz HM. Variation exists in rates of admission to intensive care units for heart failure patients across hospitals in the United States. *Circulation*. 2013;127:923–929.
5. Chalfin DB. Cost-effectiveness analysis in health care. *Hosp Cost Manag Account*. 1995;7:1–8.
6. Chalfin DB, Cohen IL, Lambrinos J. The economics and cost-effectiveness of critical care medicine. *Intensive Care Med*. 1995;21:952–961.
7. Halpern NA, Bettes L, Greenstein R. Federal and nationwide intensive care units and healthcare costs: 1986–1992. *Crit Care Med*. 1994;22:2001–2007.
8. Safavi KC, Dharmarajan K, Kim N, Strait KM, Li S-X, Chen SII, Lagu T, Krumholz HM. Variation exists in rates of admission to intensive care units for heart failure patients across hospitals in the United States. *Circulation*. 2013;127:923–929.
9. van Diepen S, Youngson E, Ezekowitz JA, McAlister FA. Which risk score best predicts perioperative outcomes in nonvalvular atrial fibrillation patients undergoing noncardiac surgery? *Am Heart J*. 2014;168:60–67.
10. Solomon SD, Dobson J, Pocock S, Skali H, McMurray JJV, Granger CB, Yusuf S, Swedberg K, Young JB, Michelson EL, Pfeffer MA. Influence of nonfatal hospitalization for heart failure on subsequent mortality in patients with chronic heart failure. *Circulation*. 2007;116:1482–1487.
11. Quan H, Li B, Duncan Saunders L, Parsons GA, Nilsson CI, Alibhai A, Ghali WA. Assessing validity of ICD-9-CM and ICD-10 administrative data in recording clinical conditions in a unique dually coded database. *Health Serv Res*. 2008;43:1424–1441.
12. Quan H, Parsons GA, Ghali WA. Validity of information on comorbidity derived from ICD-9-CCM administrative data. *Med Care*. 2002;40:675–685.
13. Plessis V, Beshiri R, Bollman R, Clemenson H. Definitions of rural. *Rural and Small Town Canada Analysis Bulletin*. 2001;3:0006–XI.
14. Sarnecki L, Gordon L. Analysis of acuity trends using resource intensity weights via the CIHI portal. *Stud Health Technol Inform*. 2009;143:42–46.
15. Julian DG. Treatment of cardiac arrest in acute myocardial ischaemia and infarction. *Lancet*. 1961;2:840–844.
16. Killip T, Kimball JT. Treatment of myocardial infarction in a coronary care unit: a two year experience with 250 patients. *Am J Cardiol*. 1967;20:457–464.
17. Katz JN, Turer AT, Becker RC. Cardiology and the critical care crisis: a perspective. *J Am Coll Cardiol*. 2007;49:1279–1282.
18. Katz JN, Shah BR, Volz EM, Horton JR, Shaw LK, Newby LK, Granger CB, Mark DB, Califf RM, Becker RC. Evolution of the coronary care unit: clinical characteristics and temporal trends in healthcare delivery and outcomes. *Crit Care Med*. 2010;38:375–381.
19. Walkey AJ, Wiener RS. Hospital case volume and outcomes among patients hospitalized with severe sepsis. *Am J Resp Crit Care Med*. 2014;189:548–555.
20. Kahn JM, Goss CH, Heagerty PJ, Kramer AA, O'Brien CR, Rubenfeld GD. Hospital volume and the outcomes of mechanical ventilation. *N Engl J Med*. 2006;355:41–50.
21. Casale PN, Jones JL, Wolf FE, Pei Y, Eby LM. Patients treated by cardiologists have a lower in-hospital mortality for acute myocardial infarction. *J Am Coll Cardiol*. 1998;32:885–889.
22. Joynt KE, Orav EJ, Jha AK. Physician volume, specialty, and outcomes of care for patients with heart failure. *Circ Heart Fail*. 2013;6:890–897.
23. Shin D-H, Kim J-S, Kim B-K, Ko Y-G, Choi D, Hong M-K, Jang Y. The relationship between hospital volumes and mortality rates after myocardial infarction (abstract). *J Am Coll Cardiol*. 2012;59:E381.
24. Srinivas VS, Hailpern SM, Koss E, Monrad ES, Alderman MH. Effect of physician volume on the relationship between hospital volume and mortality during primary angioplasty. *J Am Coll Cardiol*. 2009;53:574–579.
25. Eastwood CA, Howlett JG, King-Shier KM, McAlister FA, Ezekowitz JA, Quan H. Determinants of early readmission after hospitalization for heart failure. *Can J Cardiol*. 2014;30:612–618.
26. McAlister FA, Au AG, Majumdar SR, Youngson E, Padwal RS. Postdischarge outcomes in heart failure are better for teaching hospitals and weekday discharges. *Circ Heart Fail*. 2013;6:922–929.
27. Sidhu RS, Youngson E, McAlister FA. Physician continuity improves outcomes for heart failure patients treated and released from the emergency department. *JACC Heart Fail*. 2014;2:368–376.
28. Hernandez AF, Greiner MA, Fonarow GC, Hammill BG, Heidenreich PA, Yancy CW, Peterson ED, Curtis LH. Relationship between early physician follow-up and 30-day readmission among Medicare beneficiaries hospitalized for heart failure. *JAMA*. 2010;303:1716–1722.
29. Penning-van Beest FJA, Termorshuizen F, Goettsch WG, Klungel OH, Kastelein JJP, Herings RMC. Adherence to evidence-based statin guidelines reduces the risk of hospitalizations for acute myocardial infarction by 40%: a cohort study. *Eur Heart J*. 2007;28:154–159.
30. Eapen ZJ, Reed SD, Li Y, Kociol RD, Armstrong PW, Starling RC, McMurray JJ, Massie BM, Swedberg K, Ezekowitz JA, Fonarow GC, Teerlink JR, Metra M, Whellan DJ, O'Connor CM, Califf RM, Hernandez AF. Do countries or hospitals with longer hospital stays for acute heart failure have lower readmission rates? Findings from ASCEND-HF. *Circ Heart Fail*. 2013;6:727–732.
31. McAlister FA, Youngson E, Bakal JA, Kaul P, Ezekowitz J, van Walraven C. Impact of physician continuity on death or urgent readmission after discharge among patients with heart failure. *CMAJ*. 2013;185:e681–e689.
32. Roe MT, Chen AY, Delong ER, Boden WE, Calvin JE, Cairns CB, Sidney SC, Pollack CV, Brindis RG, Califf RM, Gibler B, Ohman EM, Peterson ED. Patterns of transfer for patients with non-ST-segment elevation acute coronary syndrome from community to tertiary care hospitals. *Am Heart J*. 2008;156:185–192.
33. Cooper LM, Linde-Zwirble WT. Medicare intensive care unit use: analysis of incidence, cost, and payment. *Crit Care Med*. 2004;32:2247–2253.
34. Rapoport J, Teres D, Zhao Y, Lemeshow S. Length of stay data as a guide to hospital economic performance for ICU patients. *Med Care*. 2003;41:386–397.
35. Dahl D, Wojtal GG, Breslow MJ, Holl R, Huguez D, Stone D, Korpi G. The high cost of low-acuity ICU outliers. *J Healthc Manag*. 2012;57:421–433.