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, MB BCH

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 hours, P < 0.001), more critical care procedures (1.9 versus 1.2 per patient, P < 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 hospital 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

A cute 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 hospital 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...
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, 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 I21) or HF (ICD-9-CM 428, ICD-10) 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. 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 chi-square 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

<table>
<thead>
<tr>
<th></th>
<th>All Admissions</th>
<th>Critical Care Unit Admission</th>
<th>Hospital Ward Admission</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (n=8100)</td>
<td>Medium (n=7121)</td>
<td>High (n=12 867)</td>
<td></td>
</tr>
<tr>
<td>Age, median (IQR), y</td>
<td>69.8 (14.2)</td>
<td>69.0 (14.0)</td>
<td>66.8 (13.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male, %</td>
<td>61.1</td>
<td>60.9</td>
<td>66.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rural residence, %</td>
<td>7.2</td>
<td>2.3</td>
<td>3.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Neighborhood income, %</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Missing</td>
<td>8.2</td>
<td>9.5</td>
<td>9.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lowest quartile</td>
<td>33.4</td>
<td>21.6</td>
<td>28.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Second quartile</td>
<td>22.3</td>
<td>24.5</td>
<td>20.1</td>
<td></td>
</tr>
<tr>
<td>Third quartile</td>
<td>20.4</td>
<td>23.3</td>
<td>20.3</td>
<td></td>
</tr>
<tr>
<td>Highest quartile</td>
<td>15.7</td>
<td>21.2</td>
<td>21.7</td>
<td></td>
</tr>
<tr>
<td>Comorbidities, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>56.1</td>
<td>56.8</td>
<td>59.3</td>
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<tr>
<td>Diabetes</td>
<td>27.5</td>
<td>28.9</td>
<td>26.0</td>
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</tr>
<tr>
<td>Dyslipidemia</td>
<td>31.4</td>
<td>33.7</td>
<td>44.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>12.7</td>
<td>11.1</td>
<td>12.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PCI*</td>
<td>2.0</td>
<td>1.8</td>
<td>2.3</td>
<td>0.033</td>
</tr>
<tr>
<td>Coronary artery bypass*</td>
<td>0.6</td>
<td>0.5</td>
<td>0.8</td>
<td>0.051</td>
</tr>
<tr>
<td>Prior heart failure</td>
<td>22.2</td>
<td>20.7</td>
<td>19.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>16.7</td>
<td>15.2</td>
<td>13.5</td>
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<tr>
<td>Cerebrovascular disease</td>
<td>4.9</td>
<td>4.0</td>
<td>4.4</td>
<td>0.015</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>7.1</td>
<td>5.8</td>
<td>4.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>COPD</td>
<td>19.2</td>
<td>15.8</td>
<td>13.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chronic kidney disease</td>
<td>12.1</td>
<td>10.3</td>
<td>11.1</td>
<td>0.002</td>
</tr>
<tr>
<td>Dementia</td>
<td>3.8</td>
<td>3.0</td>
<td>2.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Anemia</td>
<td>11.7</td>
<td>10.2</td>
<td>9.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cancer</td>
<td>5.1</td>
<td>3.6</td>
<td>3.6</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Critical Care Unit ACS and HF Admissions</th>
<th>Critical Care ACS Admissions</th>
<th>Critical Care HF Admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (n=4321)</td>
<td>Medium (n=4031)</td>
<td>High (n=7701)</td>
</tr>
<tr>
<td>Age, median (IQR), y</td>
<td>65.3 (13.9)</td>
<td>64.8 (13.4)</td>
<td>63.2 (13.0)</td>
</tr>
<tr>
<td>Male, %</td>
<td>66.8</td>
<td>67.2</td>
<td>72.9</td>
</tr>
<tr>
<td>Rural residence, %</td>
<td>6.4</td>
<td>2.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Neighborhood income, %</td>
<td>8.4</td>
<td>9.4</td>
<td>10.5</td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest quartile</td>
<td>28.8</td>
<td>18.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Second quartile</td>
<td>22.4</td>
<td>23.4</td>
<td>20.1</td>
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<td>Third quartile</td>
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<td>20.7</td>
</tr>
<tr>
<td>Highest quartile</td>
<td>17.7</td>
<td>24.2</td>
<td>23.7</td>
</tr>
<tr>
<td>Comorbidities, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>55.0</td>
<td>56.8</td>
<td>54.9</td>
</tr>
<tr>
<td>Diabetes</td>
<td>23.4</td>
<td>24.5</td>
<td>20.6</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>39.7</td>
<td>44.5</td>
<td>47.5</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>11.6</td>
<td>12.4</td>
<td>10.7</td>
</tr>
<tr>
<td>PCI*</td>
<td>2.0</td>
<td>1.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Coronary artery bypass*</td>
<td>0.5</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Prior heart failure</td>
<td>10.5</td>
<td>8.5</td>
<td>7.2</td>
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<tr>
<td>Atrial fibrillation</td>
<td>8.2</td>
<td>7.2</td>
<td>5.9</td>
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<tr>
<td>Cerebrovascular disease</td>
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<td>2.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
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<td>4.2</td>
</tr>
<tr>
<td>COPD</td>
<td>13.6</td>
<td>10.3</td>
<td>8.5</td>
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<tr>
<td>Chronic kidney disease</td>
<td>8.0</td>
<td>6.3</td>
<td>6.5</td>
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<tr>
<td>Dementia</td>
<td>1.5</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Anemia</td>
<td>6.4</td>
<td>5.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Cancer</td>
<td>3.7</td>
<td>2.8</td>
<td>2.5</td>
</tr>
</tbody>
</table>

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.
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. In the contemporary era, the proportion of CCU patients admitted with HF and critical illness has grown in tertiary hospitals. 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. 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 determinant 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. 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. 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. 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. 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. 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

<table>
<thead>
<tr>
<th></th>
<th>Acute Coronary Syndrome or Heart Failure Most Responsible Diagnosis</th>
<th>Acute Coronary Syndrome Most Responsible Diagnosis</th>
<th>Heart Failure Most Responsible Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (n=4344)</td>
<td>Medium (n=4031)</td>
<td>High (n=7701)</td>
</tr>
<tr>
<td>Critical care hours, mean (SD)</td>
<td>95.9 (64.1)</td>
<td>78.3 (57.8)</td>
<td>56.6 (51.0)</td>
</tr>
<tr>
<td>Critical care hours, median (IQR)</td>
<td>85.3 (60.6)</td>
<td>66.5 (56.6)</td>
<td>45.1 (39)</td>
</tr>
<tr>
<td>Hospital days, mean (SD)</td>
<td>7 (8)</td>
<td>6 (8)</td>
<td>7 (10)</td>
</tr>
<tr>
<td>Hospital days, median (IQR)</td>
<td>5 (5)</td>
<td>5 (4)</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Mean CCU/total LOS ratio, % (SD)</td>
<td>76 (31)</td>
<td>67 (34)</td>
<td>46 (27)</td>
</tr>
<tr>
<td>Median CCU/total LOS ratio, % (IQR)</td>
<td>96 (49)</td>
<td>81 (64)</td>
<td>41 (36)</td>
</tr>
<tr>
<td>Resource-intensive weighting (RIW), mean (SD)</td>
<td>1.5 (1.5)</td>
<td>1.4 (1.4)</td>
<td>2.3 (2.8)</td>
</tr>
</tbody>
</table>

Critical care–related therapies and procedures:

<table>
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<tr>
<th></th>
<th>Low (n=591)</th>
<th>Medium (n=441)</th>
<th>High (n=436)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total procedures</td>
<td>5271 (1.2)</td>
<td>4088 (1.0)</td>
<td>14 847 (1.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Any procedure, %</td>
<td>52.7</td>
<td>49.2</td>
<td>82.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Percutaneous coronary intervention, %</td>
<td>34.2</td>
<td>34.1</td>
<td>72.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Coronary artery bypass grafting†, %</td>
<td>0</td>
<td>0</td>
<td>2.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Invasive or noninvasive mechanical ventilation, %</td>
<td>5.4</td>
<td>3.1</td>
<td>9.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Intubation, %</td>
<td>0.07</td>
<td>0.05</td>
<td>0.18</td>
<td>0.08</td>
</tr>
<tr>
<td>Dialysis, %</td>
<td>0.8</td>
<td>1.0</td>
<td>1.7</td>
<td>0.01</td>
</tr>
<tr>
<td>Cardiac arrest or resuscitation, %</td>
<td>13.4</td>
<td>7.9</td>
<td>12.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Arterial/central/hemodialysis line, %</td>
<td>11.9</td>
<td>9.7</td>
<td>8.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Right heart catheter, %</td>
<td>0.4</td>
<td>0.4</td>
<td>1.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Temporary pacemaker, %</td>
<td>0.4</td>
<td>0.7</td>
<td>1.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cardioversion, %</td>
<td>1.5</td>
<td>1.7</td>
<td>2.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pericardiocentesis, %</td>
<td>0.02</td>
<td>0.02</td>
<td>0.2</td>
<td>0.07</td>
</tr>
<tr>
<td>Intra-aortic balloon pump, %</td>
<td>0</td>
<td>0.05</td>
<td>2.9</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

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.
interpatient variability in cost.\textsuperscript{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

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

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: 1Age, gender, rural residence, neighborhood income, any procedure use, RIW, hypertension, anemia, CHF, CVD, dementia, COPD, chronic kidney disease, cancer, diabetes, prior PCI, dyslipidemia. 2Age, gender, rural residence, neighborhood income, CABG, RIW, atrial fibrillation, anemia, CHF, PVD, chronic kidney disease, cancer, diabetes, dyslipidemia. 3Age, gender, rural residence, neighborhood income, any procedure use, CABG, RIW, atrial fibrillation, CHF, chronic kidney disease, cancer, diabetes. 4Age, gender, rural residence, neighborhood income, CABG, hypertension, atrial fibrillation, anemia, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer. 5Age, 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 and the University of Alberta Chair in Cardiovascular Solutions and the University of Alberta Chair in Cardiovascular

Disclosures

None.

References


SUPPLEMENTAL MATERIAL

Figure S1: Study cohort flowchart

ED Patients at 13 hospitals with ICU/CCU and main diagnosis of ACS/HF between April 01, 2003 and March 31, 2013
N=62,846

Patients not admitted to the same hospital as ED
N=25,762

Patients admitted to the same hospital as ED
N=37,804

First ACS/HF hospitalization in time frame
N=29,850

Patients aged<20
N=29

Patients with a previous hospitalization in the previous 30 days
N=1,733

ACS/HF Cohort
N=28,088
Figure S2: Histogram of annual hospital acute coronary syndrome and heart failure admissions
Table S1: Physician Claims and Canadian Classification of Health Interventions for in-hospital procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Physician claims codes</th>
<th>Canadian Classification of Health Interventions codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive or non-invasive mechanical ventilation</td>
<td>13.62A</td>
<td>1.GZ.31.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.GZ.31.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.GZ.31.^^</td>
</tr>
<tr>
<td>Percutaneous Coronary Intervention</td>
<td>36.01 or 36.02 or 36.05</td>
<td>1.IJ.26.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.IJ.50.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.IJ.57.^^</td>
</tr>
<tr>
<td>Coronary Artery Bypass</td>
<td>36.1</td>
<td>1.IJ.76.^^</td>
</tr>
<tr>
<td>Cardiac Arrest or Resuscitation</td>
<td>13.99E</td>
<td>1.GZ.30.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.HZ.30.^^</td>
</tr>
<tr>
<td>Intubation</td>
<td>01.03</td>
<td></td>
</tr>
<tr>
<td>Arterial, central, or hemodialysis Line</td>
<td>50.91A</td>
<td>1.KV.53.^^</td>
</tr>
<tr>
<td></td>
<td>50.94D</td>
<td>1.JT.53.^^</td>
</tr>
<tr>
<td></td>
<td>50.93A</td>
<td>1.JQ.53.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.KX.53.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.LZ.28.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.KR.53.^^</td>
</tr>
<tr>
<td>Intraaortic balloon pump</td>
<td>49.61B</td>
<td>1.HP.53.^^</td>
</tr>
<tr>
<td>Swan Ganz Catheter</td>
<td>50.95A</td>
<td>2.IM.28.^^</td>
</tr>
<tr>
<td>Chest tube</td>
<td>46.04B or 46.04A</td>
<td>1.GV.52.^^</td>
</tr>
<tr>
<td>Bronchoscopy</td>
<td>01.09</td>
<td>2.GM.70.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.GM.71.^^</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.GT.71.^^</td>
</tr>
<tr>
<td>Temporary Pacemaker</td>
<td>49.73A or 49.82B</td>
<td>1.HZ.38.^^</td>
</tr>
<tr>
<td>Cardioversion</td>
<td>13.72A</td>
<td>1.HZ.09.^^</td>
</tr>
<tr>
<td>Pericardiocentesis</td>
<td>49.0</td>
<td>1.HA.52.^^</td>
</tr>
<tr>
<td>Pharmacologic Manipulation*</td>
<td>49.98B</td>
<td></td>
</tr>
</tbody>
</table>

* Pharmacologic manipulation is a physician billing intended for intravenous vasoactive therapies and could include inotropes, vasopressors, and/or vasodilators
Table S2: Resource utilization among critical care admission by average annual cardiac volume among patients admitted direction to a critical care unit from the emergency department

<table>
<thead>
<tr>
<th>Resource Utilization</th>
<th>Acute Coronary Syndrome or Heart Failure Most Responsible Diagnosis</th>
<th>Acute Coronary Syndrome Most Responsible Diagnosis</th>
<th>Heart Failure Most Responsible Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (n=2219)</td>
<td>Medium (n=1928)</td>
<td>High (n=3913)</td>
</tr>
<tr>
<td>Critical care hours, mean (SD)</td>
<td>92.4(57.5)</td>
<td>84.2(57.1)</td>
<td>55.7(42.4)</td>
</tr>
<tr>
<td>Critical care hours, median (IQR)</td>
<td>80.4(55.4)</td>
<td>70.0(57.9)</td>
<td>45.7(35.6)</td>
</tr>
<tr>
<td>Hospital days, mean (SD)</td>
<td>6 (7)</td>
<td>5 (5)</td>
<td>6 (11)</td>
</tr>
<tr>
<td>Hospital days, median (IQR)</td>
<td>6 (4)</td>
<td>4 (3)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Mean CCU/total LOS ratio, % (SD)</td>
<td>78(29)</td>
<td>76(29)</td>
<td>50(28)</td>
</tr>
<tr>
<td>Median CCU/total LOS ratio, % (IQR)</td>
<td>96(42)</td>
<td>94(43)</td>
<td>45(38)</td>
</tr>
<tr>
<td>Resource intensive weighting (RIW), mean (SD)</td>
<td>1.4 (1.2)</td>
<td>1.4 (0.9)</td>
<td>2.3 (2.7)</td>
</tr>
</tbody>
</table>

Critical care related therapies and procedures

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Acute Coronary Syndrome or Heart Failure Most Responsible Diagnosis</th>
<th>Acute Coronary Syndrome Most Responsible Diagnosis</th>
<th>Heart Failure Most Responsible Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total procedures (mean procedures per person)</td>
<td>3474 (1.6)</td>
<td>2298 (1.2)</td>
<td>8194 (2.1)</td>
</tr>
<tr>
<td>Any procedure, %</td>
<td>64.0</td>
<td>59.0</td>
<td>85.1</td>
</tr>
<tr>
<td>Percutaneous coronary intervention, %</td>
<td>42.6</td>
<td>41.2</td>
<td>75.9</td>
</tr>
<tr>
<td>Coronary artery bypass grafting, %</td>
<td>0</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>Invasive or non-invasive mechanical ventilation, %</td>
<td>4.2</td>
<td>2.3</td>
<td>8.0</td>
</tr>
<tr>
<td>Intubation, %</td>
<td>0.05</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>Dialysis, %</td>
<td>0.8</td>
<td>0.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Cardiac arrest or resuscitation, %</td>
<td>17.9</td>
<td>10.8</td>
<td>15.6</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Arterial/ central/ hemodialysis</td>
<td>19.1</td>
<td>16.2</td>
<td>12.5</td>
</tr>
<tr>
<td>Swan Ganz catheter, %</td>
<td>0.5</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Temporary pacemaker, %</td>
<td>0.4</td>
<td>0.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Cardioversion, %</td>
<td>1.5</td>
<td>1.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Pericardiocentesis, %</td>
<td>0.05</td>
<td>0</td>
<td>0.13</td>
</tr>
<tr>
<td>Intraaortic balloon pump, %</td>
<td>0</td>
<td>0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

*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.
**Table S3:** Acute coronary syndrome and heart failure admission outcomes by average annual hospital volume among patients admitted directly to a critical care unit from the emergency department

<table>
<thead>
<tr>
<th></th>
<th>Acute Coronary Syndrome or Heart Failure</th>
<th>Acute Coronary Syndrome Most Responsible Diagnosis</th>
<th>Heart Failure Most Responsible Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Index hospitalization death</strong>, %</td>
<td>3.7</td>
<td>2.3</td>
<td>4.8</td>
</tr>
<tr>
<td>Adjusted OR$^#$ (95% CI)</td>
<td>Ref</td>
<td>0.72 (0.50, 1.05)</td>
<td>1.34 (0.96, 1.86)</td>
</tr>
<tr>
<td><strong>30-day death from admission</strong>, %</td>
<td>3.5</td>
<td>2.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Adjusted OR$^#$ (95% CI)</td>
<td>Ref</td>
<td>0.75 (0.45, 1.25)</td>
<td>1.45 (0.93, 2.23)</td>
</tr>
<tr>
<td><strong>30-day all-cause readmission</strong>, %</td>
<td>9.0</td>
<td>8.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Adjusted OR$^#$ (95% CI)</td>
<td>Ref</td>
<td>0.95 (0.63, 1.42)</td>
<td>0.93 (0.71, 1.22)</td>
</tr>
<tr>
<td><strong>30-day cardiovascular readmission</strong>, %</td>
<td>5.7</td>
<td>4.9</td>
<td>4.4</td>
</tr>
<tr>
<td>Adjusted OR$^#$ (95% CI)</td>
<td>Ref</td>
<td>0.92 (0.65, 1.31)</td>
<td>0.77 (0.60, 0.99)</td>
</tr>
<tr>
<td><strong>30-day all-cause ED visit</strong>, %</td>
<td>18.5</td>
<td>17.7</td>
<td>15.2</td>
</tr>
<tr>
<td>Adjusted OR$^#$ (95% CI)</td>
<td>Ref</td>
<td>0.90 (0.77, 1.05)</td>
<td>0.85 (0.77, 0.93)</td>
</tr>
<tr>
<td><strong>30-day cardiovascular ED visit</strong>, %</td>
<td>7.8</td>
<td>6.9</td>
<td>5.4</td>
</tr>
<tr>
<td>Adjusted OR$^#$ (95% CI)</td>
<td>Ref</td>
<td>0.89 (0.73, 1.09)</td>
<td>0.80 (0.69, 0.94)</td>
</tr>
</tbody>
</table>

*Includes hospitalizations > 30 days; †From hospital discharge;
Abbreviations: CI, confidence interval; ED, emergency department; OR, odds ratio
Variables included in each of the multivariate models are as follows:

$^#$Age, gender, rural residence, neighbourhood income, any procedure usage, RIW, hypertension, anemia, CHF, CVD, dementia, COPD, chronic kidney disease, cancer, diabetes, prior PCI, dyslipidemia

$^*$Age, gender, rural residence, neighbourhood income, CABG, RIW, atrial fibrillation, anemia, CHF, PVD, chronic kidney disease, cancer, diabetes, dyslipidemia

$^\dagger$Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, RIW, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer, diabetes

$^\ddagger$Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, hypertension, atrial fibrillation, anemia, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer
### Table S4: Outcomes in critical care unit and hospital ward acute coronary syndrome and heart failure admissions by annual average hospital volume

<table>
<thead>
<tr>
<th></th>
<th>All Admissions</th>
<th>Critical Care Unit Admission</th>
<th>Hospital Ward Admission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (n=8100)</td>
<td>Medium (n=7121)</td>
<td>High (n=12867)</td>
</tr>
<tr>
<td></td>
<td>Low (n=4344)</td>
<td>Medium (n=4031)</td>
<td>High (n=7701)</td>
</tr>
<tr>
<td></td>
<td>Low (n=3756)</td>
<td>Medium (n=3088)</td>
<td>High (n=5166)</td>
</tr>
<tr>
<td><strong>Index hospitalization death</strong>, %</td>
<td>8.1 6.5 6.3</td>
<td>6.2 3.9 5.5</td>
<td>10.3 9.9 7.6</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref 0.88 (0.66, 1.17) 0.85 (0.63, 1.15)</td>
<td>Ref 0.71 (0.50, 1.02) 0.93 (0.61, 1.41)</td>
<td>Ref 1.04 (0.60, 1.80) 0.87 (0.54, 1.40)</td>
</tr>
<tr>
<td><strong>30-day death from admission</strong>, %</td>
<td>7.3 5.7 5.8</td>
<td>5.7 3.7 5.1</td>
<td>9.0 8.2 6.7</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref 0.84 (0.62, 1.14) 0.95 (0.73, 1.25)</td>
<td>Ref 0.73 (0.50, 1.08) 1.05 (0.68, 1.62)</td>
<td>Ref 0.95 (0.55, 1.66) 0.86 (0.60, 1.23)</td>
</tr>
<tr>
<td><strong>30-day all-cause readmission</strong>, %</td>
<td>13.1 11.5 10.2</td>
<td>10.5 9.5 8.3</td>
<td>16.2 14.2 13.1</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref 0.94 (0.75, 1.18) 0.85 (0.69, 1.03)</td>
<td>Ref 0.96 (0.64, 1.44) 0.84 (0.62, 1.15)</td>
<td>Ref 0.91 (0.78, 1.06) 0.83 (0.69, 0.99)</td>
</tr>
<tr>
<td><strong>30-day cardiovascular readmission</strong>, %</td>
<td>8.0 7.1 5.8</td>
<td>6.8 5.9 4.6</td>
<td>9.4 8.6 7.7</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref 0.95 (0.77, 1.17) 0.81 (0.68, 0.97)</td>
<td>Ref 0.92 (0.65, 1.31) 0.77 (0.60, 0.99)</td>
<td>Ref 0.95 (0.80, 1.14) 0.84 (0.71, 0.99)</td>
</tr>
<tr>
<td><strong>30-day all-cause ED visit</strong>, %</td>
<td>22.7 18.9 18.0</td>
<td>20.5 17.7 16.6</td>
<td>25.4 20.7 20.2</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref 0.86 (0.72, 1.02) 0.81 (0.73, 0.90)</td>
<td>Ref 0.90 (0.77, 1.05) 0.85 (0.77, 0.93)</td>
<td>Ref 0.82 (0.66, 1.02) 0.79 (0.66, 0.94)</td>
</tr>
<tr>
<td><strong>30-day cardiovascular ED visit</strong>, %</td>
<td>10.9 9.2 7.8</td>
<td>9.5 7.9 6.6</td>
<td>12.7 11.0 9.7</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref 0.89 (0.71, 1.11) 0.77 (0.66, 0.90)</td>
<td>Ref 0.89 (0.73, 1.09) 0.80 (0.69, 0.94)</td>
<td>Ref 0.88 (0.65, 1.20) 0.77 (0.63, 0.94)</td>
</tr>
</tbody>
</table>

*Includes hospitalizations > 30 days; †From hospital discharge; Note: Among all ward and CCU patients 30-day death from admission was n=1732 (6.2%) and Index hospitalization mortality n=1935 (6.9%, ACS=874, HF=1061). Among index hospitalization deaths, n=1641 (84.8%) were within 30 days and n=294 (15.2%) were > 30 days (n=234, had HF and n=60 had an ACS)

Abbreviations: CI, confidence interval; ED, emergency department; OR, odds ratio

Variables included in each of the multivariate models are as follows:

# Age, gender, rural residence, neighbourhood income, any procedure usage, RIW, hypertension, anemia, CHF, CVD, dementia, COPD, chronic kidney disease, cancer, diabetes, prior PCI, dyslipidemia

5 Age, gender, rural residence, neighbourhood income, CABG, RIW, atrial fibrillation, anemia, CHF, PVD, chronic kidney disease, cancer, diabetes, dyslipidemia

8 Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, RIW, atrial fibrillation, CHF, chronic kidney disease, cancer, diabetes

5 Age, gender, rural residence, neighbourhood income, CABG, hypertension, atrial fibrillation, anemia, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer

8 Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, atrial fibrillation, CHF, PVD, COPD, chronic kidney disease, cancer
**Table S5:** Unadjusted and adjusted outcomes in acute coronary syndrome and heart failure patients admitted critical care units versus hospital wards

<table>
<thead>
<tr>
<th></th>
<th>All Admissions</th>
<th>Acute Coronary Syndrome</th>
<th>Heart Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hospital Ward Admission (n=12010)</td>
<td>Critical Care Unit Admission (n=16078)</td>
<td>Hospital Ward Admission (n=4150)</td>
</tr>
<tr>
<td></td>
<td>Hospital Ward Admission (n=7860)</td>
<td>Critical Care Unit Admission (n=14610)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hospital Ward Admission (n=7860)</td>
<td>Critical Care Unit Admission (n=14610)</td>
<td></td>
</tr>
<tr>
<td><strong>Index hospitalization death</strong>, %</td>
<td>9.0</td>
<td>6.6</td>
<td>10.3</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.56 (0.38, 0.82)</td>
<td>0.61 (0.41, 0.93)</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>1.42 (1.11, 1.82)</td>
<td>1.03 (0.76, 1.39)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day death from admission, %</td>
<td>7.8</td>
<td>6.3</td>
<td>8.6</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>0.62 (0.43, 0.88)</td>
<td>0.64 (0.42, 0.96)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>1.46 (1.16, 1.85)</td>
<td>1.09 (0.79, 1.50)</td>
<td>Ref</td>
</tr>
<tr>
<td><strong>30-day all-cause readmission</strong>, %</td>
<td>14.3</td>
<td>10.9</td>
<td>16.2</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.60 (0.51, 0.72)</td>
<td>0.75 (0.61, 0.94)</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>0.95 (0.83, 1.07)</td>
<td>0.95 (0.80, 1.13)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day cardiovascular readmission**, %</td>
<td>8.4</td>
<td>6.9</td>
<td>9.3</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>0.64 (0.52, 0.78)</td>
<td>0.72 (0.55, 0.94)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>1.00 (0.86, 1.16)</td>
<td>0.91 (0.74, 1.14)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day all-cause ED visit**, %</td>
<td>21.9</td>
<td>17.9</td>
<td>17.3</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>0.78 (0.71, 0.84)</td>
<td>0.95 (0.83, 1.08)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>1.08 (0.99, 1.16)</td>
<td>1.14 (1.02, 1.28)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day cardiovascular ED visit**, %</td>
<td>11.0</td>
<td>8.3</td>
<td>7.0</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>0.68 (0.59, 0.77)</td>
<td>0.83 (0.71, 0.97)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>1.09 (1.01, 1.17)</td>
<td>1.09 (0.98, 1.20)</td>
<td>Ref</td>
</tr>
</tbody>
</table>

*Includes hospitalizations > 30 days; †From hospital discharge;
Abbreviations: CI, confidence interval; ED, emergency department; OR, odds ratio
Variables included in each of the multivariate models are as follows:
Age, gender, rural residence, neighbourhood income, any procedure usage, RIW, hypertension, anemia, CHF, CVD, dementia, COPD, chronic kidney disease, cancer, diabetes, prior PCI, dyslipidemia

Age, gender, rural residence, neighbourhood income, CABG, RIW, atrial fibrillation, anemia, CHF, PVD, chronic kidney disease, cancer, diabetes, dyslipidemia

Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, RIW, atrial fibrillation, CHF, chronic kidney disease, cancer, diabetes
§ Age, gender, rural residence, neighbourhood income, CABG, hypertension, atrial fibrillation, anemia, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer
¥ Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, atrial fibrillation, CHF, PVD, COPD, chronic kidney disease, cancer, diabetes
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, Jeffrey A. Bakal, Meng Lin, Padma Kaul, Finlay A. McAlister and Justin A. Ezekowitz

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SUPPLEMENTAL MATERIAL

Figure S1: Study cohort flowchart

ED Patients at 13 hospitals with ICU/CCU and main diagnosis of ACS/HF between April 01, 2003 and March 31, 2013
N=62,846

Patients admitted to the same hospital as ED
N=37,804

First ACS/HF hospitalization in time frame
N=29,850

Patients not admitted to the same hospital as ED
N=25,762

Patients aged<20
N=29

Patients with a previous hospitalization in the previous 30 days
N=1,733

ACS/HF Cohort
N=28,088
Figure S2: Histogram of annual hospital acute coronary syndrome and heart failure admissions
**Table S1**: Physician Claims and Canadian Classification of Health Interventions for in-hospital procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Physician claims codes</th>
<th>Canadian Classification of Health Interventions codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percutaneous Coronary Intervention</td>
<td>36.01 or 36.02 or 36.05</td>
<td>1.IJ.26.^^ 1.IJ.50.^^ 1.IJ.57.^^</td>
</tr>
<tr>
<td>Coronary Artery Bypass</td>
<td>36.1</td>
<td>1.IJ.76.^^</td>
</tr>
<tr>
<td>Cardiac Arrest or Resuscitation</td>
<td>13.99E</td>
<td>1.GZ.30.^^ 1.HZ.30.^^</td>
</tr>
<tr>
<td>Intubation</td>
<td>01.03</td>
<td></td>
</tr>
<tr>
<td>Arterial, central, or hemodialysis Line</td>
<td>50.91A 50.94D 50.93A</td>
<td>1.KV.53.^^ 1.JT.53.^^ 1.JQ.53.^^ 1.KX.53.^^ 2.LZ.28.^^ 1.KR.53.^^</td>
</tr>
<tr>
<td>Intraaortic balloon pump</td>
<td>49.61B</td>
<td>1.HP.53.^^</td>
</tr>
<tr>
<td>Swan Ganz Catheter</td>
<td>50.95A</td>
<td>2.IM.28.^^</td>
</tr>
<tr>
<td>Chest tube</td>
<td>46.04B or 46.04A</td>
<td>1.GV.52.^^</td>
</tr>
<tr>
<td>Bronchoscopy</td>
<td>01.09</td>
<td>2.GM.70.^^ 2.GM.71.^^ 2.GT.71.^^</td>
</tr>
<tr>
<td>Temporary Pacemaker</td>
<td>49.73A or 49.82B</td>
<td>1.HZ.38.^^</td>
</tr>
<tr>
<td>Cardioversion</td>
<td>13.72A</td>
<td>1.HZ.09.^^</td>
</tr>
<tr>
<td>Pericardiocentesis</td>
<td>49.0</td>
<td>1.HA.52.^^</td>
</tr>
<tr>
<td>Pharmacologic Manipulation*</td>
<td>49.98B</td>
<td></td>
</tr>
</tbody>
</table>

* Pharmacologic manipulation is a physician billing intended for intravenous vasoactive therapies and could include inotropes, vasopressors, and/or vasodilators
Table S2: Resource utilization among critical care admission by average annual cardiac volume among patients admitted direction to a critical care unit from the emergency department

<table>
<thead>
<tr>
<th></th>
<th>Acute Coronary Syndrome or Heart Failure Most Responsible Diagnosis</th>
<th>Acute Coronary Syndrome Most Responsible Diagnosis</th>
<th>Heart Failure Most Responsible Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (n=2219)</td>
<td>Medium (n=1928)</td>
<td>High (n=3913)</td>
</tr>
<tr>
<td>Critical care hours, mean (SD)</td>
<td>92.4(57.5)</td>
<td>84.2(57.1)</td>
<td>55.7(42.4)</td>
</tr>
<tr>
<td>Critical care hours, median (IQR)</td>
<td>80.4(55.4)</td>
<td>70.0(57.9)</td>
<td>45.7(35.6)</td>
</tr>
<tr>
<td>Hospital days, mean (SD)</td>
<td>6 (7)</td>
<td>5 (5)</td>
<td>6 (11)</td>
</tr>
<tr>
<td>Hospital days, median (IQR)</td>
<td>4(4)</td>
<td>4(3)</td>
<td>4(3)</td>
</tr>
<tr>
<td>Mean CCU/total LOS ratio, % (SD)</td>
<td>78(29)</td>
<td>76(29)</td>
<td>50(28)</td>
</tr>
<tr>
<td>Median CCU/total LOS ratio, % (IQR)</td>
<td>96(42)</td>
<td>94(43)</td>
<td>45(38)</td>
</tr>
<tr>
<td>Resource intensive weighting (RIW), mean (SD)</td>
<td>1.4 (1.2)</td>
<td>1.4 (0.9)</td>
<td>2.3 (2.7)</td>
</tr>
</tbody>
</table>

Critical care related therapies and procedures

<table>
<thead>
<tr>
<th></th>
<th>Total procedures (mean procedures per person)</th>
<th>Any procedure, %</th>
<th>Percutaneous coronary intervention, %</th>
<th>Coronary artery bypass grafting†, %</th>
<th>Invasive or non-invasive mechanical ventilation, %</th>
<th>Intubation, %</th>
<th>Dialysis, %</th>
<th>Cardiac arrest or resuscitation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3474 (1.6)</td>
<td>64.0</td>
<td>42.6</td>
<td>0</td>
<td>4.2</td>
<td>0.05</td>
<td>0.8</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>2298 (1.2)</td>
<td>59.0</td>
<td>41.2</td>
<td>0</td>
<td>2.3</td>
<td>0.05</td>
<td>0.6</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>8194 (2.1)</td>
<td>85.1</td>
<td>75.9</td>
<td>1.1</td>
<td>8.0</td>
<td>0.08</td>
<td>1.4</td>
<td>15.6</td>
</tr>
<tr>
<td></td>
<td>3067 (1.5)</td>
<td>65.2</td>
<td>47.7</td>
<td>0</td>
<td>2.5</td>
<td>0</td>
<td>0.6</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>2068 (1.2)</td>
<td>61.1</td>
<td>45.0</td>
<td>0</td>
<td>1.4</td>
<td>0</td>
<td>0.4</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>7549 (2.0)</td>
<td>86.4</td>
<td>78.9</td>
<td>1.2</td>
<td>7.3</td>
<td>0.08</td>
<td>1.2</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>407 (1.7)</td>
<td>53.8</td>
<td>4.4</td>
<td>0</td>
<td>18.5</td>
<td>0.42</td>
<td>2.1</td>
<td>21.9</td>
</tr>
<tr>
<td></td>
<td>230 (1.4)</td>
<td>37.3</td>
<td>1.8</td>
<td>0</td>
<td>11.2</td>
<td>0</td>
<td>2.4</td>
<td>17.8</td>
</tr>
<tr>
<td></td>
<td>645 (4.0)</td>
<td>54.6</td>
<td>6.1</td>
<td>0</td>
<td>23.3</td>
<td>0</td>
<td>6.8</td>
<td>25.2</td>
</tr>
</tbody>
</table>

* p-value < 0.001

† p-value = 0.29

$ p-value = 0.015$
<table>
<thead>
<tr>
<th>Procedure</th>
<th>19.1</th>
<th>16.2</th>
<th>12.5</th>
<th>&lt;0.001</th>
<th>20.1</th>
<th>16.7</th>
<th>11.9</th>
<th>&lt;0.001</th>
<th>10.9</th>
<th>11.8</th>
<th>25.2</th>
<th>&lt;0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial/ central/ hemodialysis line, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swan Ganz catheter, %</td>
<td>0.5</td>
<td>0.1</td>
<td>0.9</td>
<td>&lt;0.001</td>
<td>0.2</td>
<td>0.1</td>
<td>0.6</td>
<td>0.003</td>
<td>2.9</td>
<td>0</td>
<td>8.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Temporary pacemaker, %</td>
<td>0.4</td>
<td>0.8</td>
<td>1.4</td>
<td>&lt;0.001</td>
<td>0.4</td>
<td>0.7</td>
<td>1.4</td>
<td>&lt;0.001</td>
<td>0.4</td>
<td>1.2</td>
<td>0.6</td>
<td>0.82</td>
</tr>
<tr>
<td>Cardioversion, %</td>
<td>1.5</td>
<td>1.2</td>
<td>2.9</td>
<td>&lt;0.001</td>
<td>1.0</td>
<td>0.9</td>
<td>2.8</td>
<td>&lt;0.001</td>
<td>5.5</td>
<td>4.1</td>
<td>5.5</td>
<td>0.80</td>
</tr>
<tr>
<td>Pericardiocentesis, %</td>
<td>0.05</td>
<td>0</td>
<td>0.13</td>
<td>0.22</td>
<td>0.05</td>
<td>0</td>
<td>0.13</td>
<td>0.25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td>Intraaortic balloon pump, %</td>
<td>0</td>
<td>0</td>
<td>3.0</td>
<td>&lt;0.001</td>
<td>0</td>
<td>0</td>
<td>3.1</td>
<td>&lt;0.001</td>
<td>0</td>
<td>0</td>
<td>1.8</td>
<td>0.023</td>
</tr>
</tbody>
</table>

*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.*
Table S3: Acute coronary syndrome and heart failure admission outcomes by average annual hospital volume among patients admitted directly to a critical care unit from the emergency department

<table>
<thead>
<tr>
<th></th>
<th>Acute Coronary Syndrome or Heart Failure Most Responsible Diagnosis</th>
<th>Acute Coronary Syndrome Most Responsible Diagnosis</th>
<th>Heart Failure Most Responsible Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Index hospitalization death*, %</td>
<td>3.7</td>
<td>2.3</td>
<td>4.8</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.72 (0.50, 1.05)</td>
<td>1.34 (0.96, 1.86)</td>
</tr>
<tr>
<td>30-day death from admission, %</td>
<td>3.5</td>
<td>2.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.75 (0.45, 1.25)</td>
<td>1.45 (0.93, 2.23)</td>
</tr>
<tr>
<td>30-day all-cause readmission*, %</td>
<td>9.0</td>
<td>8.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.95 (0.63, 1.42)</td>
<td>0.93 (0.71, 1.22)</td>
</tr>
<tr>
<td>30-day cardiovascular readmission*, %</td>
<td>5.7</td>
<td>4.9</td>
<td>4.4</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.92 (0.65, 1.31)</td>
<td>0.77 (0.60, 0.99)</td>
</tr>
<tr>
<td>30-day all-cause ED visit*, %</td>
<td>18.5</td>
<td>17.7</td>
<td>15.2</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.90 (0.77, 1.05)</td>
<td>0.85 (0.77, 0.93)</td>
</tr>
<tr>
<td>30-day cardiovascular ED visit*, %</td>
<td>7.8</td>
<td>6.9</td>
<td>5.4</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.89 (0.73, 1.09)</td>
<td>0.80 (0.69, 0.94)</td>
</tr>
</tbody>
</table>

*aIncludes hospitalizations > 30 days; †From hospital discharge;
Abbreviations: CI, confidence interval; ED, emergency department; OR, odds ratio
Variables included in each of the multivariate models are as follows:
#Age, gender, rural residence, neighbourhood income, any procedure usage, RIW, hypertension, anemia, CHF, CVD, dementia, COPD, chronic kidney disease, cancer, diabetes, prior PCI, dyslipidemia
$Age, gender, rural residence, neighbourhood income, CABG, RIW, atrial fibrillation, anemia, CHF, PVD, chronic kidney disease, cancer, diabetes, dyslipidemia
&Age, gender, rural residence, neighbourhood income, CABG, RIW, atrial fibrillation, CHF, chronic kidney disease, cancer, diabetes
§Age, gender, rural residence, neighbourhood income, CABG, hypertension, atrial fibrillation, anemia, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer
¥Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, atrial fibrillation, CHF, PVD, COPD, chronic kidney disease, cancer, diabetes
Table S4: Outcomes in critical care unit and hospital ward acute coronary syndrome and heart failure admissions by annual average hospital volume

<table>
<thead>
<tr>
<th></th>
<th>All Admissions</th>
<th>Critical Care Unit Admission</th>
<th>Hospital Ward Admission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (n=8100)</td>
<td>Medium (n=7121)</td>
<td>High (n=12867)</td>
</tr>
<tr>
<td>Index hospitalization death*, %</td>
<td>8.1</td>
<td>6.5</td>
<td>6.3</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.88 (0.66, 1.17)</td>
<td>0.85 (0.63, 1.15)</td>
</tr>
<tr>
<td>30-day death from admission, %</td>
<td>7.3</td>
<td>5.7</td>
<td>5.8</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.84 (0.62, 1.14)</td>
<td>0.95 (0.73, 1.25)</td>
</tr>
<tr>
<td>30-day all-cause readmission*, %</td>
<td>13.1</td>
<td>11.5</td>
<td>10.2</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.94 (0.75, 1.18)</td>
<td>0.85 (0.69, 1.03)</td>
</tr>
<tr>
<td>30-day cardiovascular readmission*, %</td>
<td>8.0</td>
<td>7.1</td>
<td>5.8</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.95 (0.77, 1.17)</td>
<td>0.81 (0.68, 0.97)</td>
</tr>
<tr>
<td>30-day all-cause ED visit*, %</td>
<td>22.7</td>
<td>18.9</td>
<td>18.0</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.86 (0.72, 1.02)</td>
<td>0.81 (0.73, 0.90)</td>
</tr>
<tr>
<td>30-day cardiovascular ED visit*, %</td>
<td>10.9</td>
<td>9.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.89 (0.71, 1.11)</td>
<td>0.77 (0.66, 0.90)</td>
</tr>
</tbody>
</table>

*Includes hospitalizations > 30 days; † From hospital discharge; Note: Among all ward and CCU patients 30-day death from admission was n=1732 (6.2%) and Index hospitalization mortality n=1935 (6.9%, ACS=874, HF=1061). Among index hospitalization deaths, n=1641(84.8%) were within 30 days and n=294 (15.2%) were > 30 days (n=234, had HF and n=60 had an ACS)

Abbreviations: CI, confidence interval; ED, emergency department; OR, odds ratio

Variables included in each of the multivariate models are as follows:

# Age, gender, rural residence, neighbourhood income, any procedure usage, RIW, hypertension, anemia, CHF, CVD, dementia, COPD, chronic kidney disease, cancer, diabetes, prior PCI, dyslipidemia

$ Age, gender, rural residence, neighbourhood income, CABG, RIW, atrial fibrillation, anemia, CHF, PVD, chronic kidney disease, cancer, diabetes, dyslipidemia

& Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, RIW, atrial fibrillation, CHF, chronic kidney disease, cancer, diabetes

€ Age, gender, rural residence, neighbourhood income, CABG, hypertension, atrial fibrillation, anemia, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer

$ Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, atrial fibrillation, CHF, PVD, COPD, chronic kidney disease, cancer, diabetes
Table S5: Unadjusted and adjusted outcomes in acute coronary syndrome and heart failure patients admitted critical care units versus hospital wards

<table>
<thead>
<tr>
<th></th>
<th>All Admissions</th>
<th>Acute Coronary Syndrome</th>
<th>Heart Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hospital Ward Admission (n=12010)</td>
<td>Critical Care Unit Admission (n=16078)</td>
<td>Hospital Ward Admission (n=4150)</td>
</tr>
<tr>
<td>Index hospitalization death*, %</td>
<td>9.0</td>
<td>5.3</td>
<td>6.6</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.56 (0.38, 0.82)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR^ (95% CI)</td>
<td>Ref</td>
<td>1.42 (1.11, 1.82)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day death from admission, %</td>
<td>7.8</td>
<td>5.0</td>
<td>6.3</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.62 (0.43, 0.88)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR^ (95% CI)</td>
<td>Ref</td>
<td>1.46 (1.16, 1.85)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day all-cause readmission*, %</td>
<td>14.3</td>
<td>9.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.60 (0.51, 0.72)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR^ (95% CI)</td>
<td>Ref</td>
<td>0.95 (0.83, 1.07)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day cardiovascular readmission*, %</td>
<td>8.4</td>
<td>5.5</td>
<td>6.9</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.64 (0.52, 0.78)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR^ (95% CI)</td>
<td>Ref</td>
<td>1.00 (0.86, 1.16)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day all-cause ED visit^, %</td>
<td>21.9</td>
<td>17.9</td>
<td>18.1</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.78 (0.71, 0.84)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR^ (95% CI)</td>
<td>Ref</td>
<td>1.08 (0.99, 1.16)</td>
<td>Ref</td>
</tr>
<tr>
<td>30-day cardiovascular ED visit^, %</td>
<td>11.0</td>
<td>7.7</td>
<td>8.3</td>
</tr>
<tr>
<td>Unadjusted OR (95% CI)</td>
<td>Ref</td>
<td>0.68 (0.59, 0.77)</td>
<td>Ref</td>
</tr>
<tr>
<td>Adjusted OR^ (95% CI)</td>
<td>Ref</td>
<td>1.09 (1.01, 1.17)</td>
<td>Ref</td>
</tr>
</tbody>
</table>

*Includes hospitalizations > 30 days; †From hospital discharge;
Abbreviations: CI, confidence interval; ED, emergency department; OR, odds ratio
Variables included in each of the multivariate models are as follows:
^Age, gender, rural residence, neighbourhood income, any procedure usage, RIW, hypertension, anemia, CHF, CVD, dementia, COPD, chronic kidney disease, cancer, diabetes, prior PCI, dyslipidemia
§Age, gender, rural residence, neighbourhood income, CABG, RIW, atrial fibrillation, anemia, CHF, PVD, chronic kidney disease, cancer, diabetes, dyslipidemia
^Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, RIW, atrial fibrillation, CHF, chronic kidney disease, cancer, diabetes
§ Age, gender, rural residence, neighbourhood income, CABG, hypertension, atrial fibrillation, anemia, atrial fibrillation, CHF, COPD, chronic kidney disease, cancer

¥ Age, gender, rural residence, neighbourhood income, any procedure usage, CABG, atrial fibrillation, CHF, PVD, COPD, chronic kidney disease, cancer, diabetes