ORIGINAL RESEARCH

Care Setting Intensity and Outcomes After Emergency Department Presentation Among Patients With Acute Heart Failure

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***Background*—**Patients with heart failure (HF) presenting to the emergency department (ED) can be admitted to care settings of different intensity, where the intensive care unit (ICU) is the highest intensity, ward admission is intermediate intensity, and those discharged home are of lowest intensity. Despite the costs associated with higher-intensity care, little is known about disposition decisions and outcomes of HF patients treated in different care settings.

***Methods and Results*—**We identified predictors of ICU or ward admission and determined whether survival differs in patients admitted to higher-intensity versus lower-intensity care settings (ie, ICU vs ward, or ward vs ED-discharged). Among 9054 patients (median, 78 years; 51% men) presenting to an ED in Ontario, Canada, 1163 were ICU-admitted, 5240 ward-admitted, and 2651 were ED-discharged. Predictors of ICU (vs ward) admission included: use of noninvasive positive pressure ventilation (adjusted odds ratio [OR], 2.01; 95% CI, 1.36–2.98), higher respiratory rate (OR, 1.10 per 5 breaths/min; 95% CI, 1.05–1.15), and lower oxygen saturation (OR, 0.90 per 5%; 95% CI, 0.86–0.94; all $P<0.001$). Predictors of ward-admitted versus ED-discharged were similar. Propensity-matched analysis comparing lower-risk ICU to ward-admitted patients demonstrated a nonsignificant trend at 100 days (relative risk [RR], 0.69; 95% CI, 0.43–1.10; $P=0.148$). At 1 year, however, survival was higher among those initially admitted to ICU (RR, 0.68; 95% CI, 0.49–0.94; $P=0.022$). There was no survival difference among low-risk ward-admitted versus ED-discharged patients.

***Conclusions*—**Respiratory factors were associated with admission to higher-intensity settings. There was no difference in early survival between some lower-risk patients admitted to higher-intensity units compared to those treated in lower-intensity settings.
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Key Words: acute heart failure • critical care • emergency department • heart failure • hospital disposition • intensive care • mortality • processes of care • quality of care • risk prediction

Emergency department (ED) visits and hospitalizations recur frequently among heart failure (HF) patients and contribute significantly to the costs of HF, now estimated to exceed $108 billion per year globally.[1] Acute care decisions in the ED are important because the subsequent setting of care is determined.[2] The potential options include care in the intensive care unit (ICU; the highest-intensity setting), hospital ward (intermediate intensity), or outpatient care after discharge home from the ED (low intensity). Decisions pertaining to the care setting are also important because costs differ substantially when patients are admitted to the ICU. Care in the ICU is valuable, but it is a high-cost setting for care provision, accounting for ≈20% to 35% of hospital costs and ≈0.5% to 1% of the gross domestic product of the United States.[3,4]

Past studies have raised questions about the effectiveness of decisions regarding the care setting for the HF patient and

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Accompanying Data S1 and Tables S1 through S4 are available at http://jaha.ahajournals.org/content/5/7/e003232/DC1/embed/inline-supplementary-material-1.pdf

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the resultant impact on outcomes. Substantial variation in admission of HF patients to the hospital and admission to the high-intensity ICU care setting have been previously demonstrated.[5,6] Whereas past studies found that hospital characteristics were associated with higher rates of hospital and ICU admission, the contributions of patient characteristics to higher-intensity care have not been determined.[7,8] Furthermore, 30-day survival of HF patients admitted to hospitals with the highest rates of ICU utilization were not significantly better than those with lower ICU admission.[6] These past studies were ecological in nature and examined short-term outcomes. Further examination at the patient level with longer-term time horizon may provide additional insights, given that acute care decisions in the ED have impacts on survival up to 1-year follow-up.[9]

We aimed to examine whether patient characteristics contributed to the setting where HF care was provided in a population-based study, by identifying predictors of higher-intensity care. Specifically, we examined factors associated with ICU (vs ward) admission for those who were hospitalized and ward admission versus ED discharge for those who were not admitted to ICU. We also sought to further explore the association of care setting intensity and survival at early and later time horizons. Specifically, we compared survival up to 1-year follow-up of lower-risk HF patients who were initially admitted to: (1) ICU versus hospital ward and (2) ward versus discharge from the ED.

Methods

Study Cohorts

The study population was comprised of patients who visited any of 86 acute care hospital EDs in Ontario between January 1, 2004 and March 31, 2007, with a primary diagnosis of acute decompensated HF (International Classification of Diseases, Tenth Revision code I50), who also met the Framingham HF criteria. Hospitalized HF patients were identified in the Enhanced Feedback For Effective Cardiac Treatment (EFFECT) database, and patients discharged from the ED were identified from the Emergency Heart failure Mortality Risk Grade (EHMRG) study.[10,11] Participating hospitals included teaching and large or small community hospitals, located in both rural and urban regions of the province.

Exclusion criteria were: development of HF after admission, age <18 or >105 years of age, nonresidents of Ontario, invalid health card number, dialysis-dependent end-stage renal disease, and having been deemed palliative and assigned a do not resuscitate (DNR) order before ED arrival. Patients who were transferred from another acute care facility or transferred out of the ED were also excluded. In those with multiple ED visits during the study period, the first episode was selected as the index acute HF presentation. Chart abstraction strategies and data reliability are detailed in previously published reports.[10,11]

Data Sources

Mortality was determined using the Registered Persons Database, which provides basic demographic data and vital status of all Ontario residents who are eligible for provincial health insurance and the Canadian Institute for Health Information Discharge Abstract Database, which provided information on in-hospital deaths. These administrative databases were linked to the EFFECT and EHMRG databases using encoded versions of the patients' unique, encrypted health card number. In-hospital processes of care were identified in the EFFECT clinical database.

Characteristics Associated With Ward or ICU Admission Versus Discharge Home

The sample was divided into 3 groups according to ED disposition: patients discharged from ED, admitted to ward, or admitted to ICU (either intensive care or coronary care unit [CCU]). We examined factors associated with ED disposition, by constructing two multivariable models comparing those admitted to: (1) ward versus discharge home or (2) ICU versus ward. We did not examine the 3 groups simultaneously because of the limited equipoise in comparison of ED-discharged versus ICU-admitted patients in the same model. Variables considered for entry into the multiple regression model are shown in Data S1. For both multivariable models, candidate variables were selected based on clinical and statistical significance ($P<0.05$ in the multivariable model). The models were estimated using generalized estimating equation methods to account for the clustering of patients within EDs and were adjusted for hospital type (teaching, large community, or small hospital).

Mortality Outcomes According to Care Setting

We used the EHMRG30-ST 30-day mortality model for initial risk stratification because it can be applied broadly to all patients presenting to the ED.[12] It builds upon the EHMRG 7-day mortality model by the addition of ST-depression on the 12-lead electrocardiogram (ECG), providing estimated probabilities of 30-day death using presenting clinical features (c-statistic >0.8).[10,12] To confirm the ability of the EHMRG30-ST to stratify mortality risk in different care settings (ie, ICU, ward, and discharge home), we examined the distribution of the score and the odds ratios (ORs) for death stratified by ED disposition setting.

Statistical Analysis

Propensity-score–matched analyses were used to estimate the mortality effect of hospital disposition in lower-risk patients (EHMRG30-ST risk estimate ≤ median).[13,14] We constructed 2 comparisons matched on the propensity score: (1) lower-risk patients admitted to ward were compared to those discharged from the ED, and (2) lower-risk patients admitted to ICU were compared to those admitted to ward. The propensity score model to predict ED disposition included ≈40 variables pertaining to demographics (age, sex, nursing home [NH] or long-term care resident), clinical presentation (vital signs, transported into ED by ambulance, chest pain symptoms, and the Canadian Triage Acuity Scale [CTAS] score), comorbidities (past myocardial infarction [MI], diabetes mellituus, hypertension, smoking, cerebrovascular disease, peripheral artery disease, chronic pulmonary disease, dementia, and active cancer), laboratory tests (hemoglobin, white blood cell count, sodium concentration, potassium concentration, creatinine concentration, abnormal troponin value, and ECG abnormalities), use of noninvasive positive pressure ventilation (NPPV) in the ED, complicating cardiovascular events before ED disposition (requirement for inotropes, intubation or respiratory arrest, cardiac arrest, ventricular tachycardia, or cardiogenic shock in the ED), and hospital type (teaching, large community, or small hospital). Vital signs were determined upon ED triage and included systolic blood pressure, heart rate, respiratory rate, and oxygen saturation. The CTAS score is a routinely assigned score performed at ED triage, which allows health care providers to evaluate patients' acuity and the need for more-urgent or emergent care.[15] An abnormal troponin was defined by a value exceeding the upper limit of the normal range, not necessarily indicative of acute MI. Twelve-lead ECG parameters included QRS duration and ECG abnormalities, which were defined as presence of atrial fibrillation or flutter, presence of Q-waves, or ST-segment abnormalities. Variables included in the propensity score model also included presence of an implanted device (implantable cardioverter defibrillator [ICD] or cardiac resynchronization therapy [CRT]) and prehospital medications (angiotensin-converting enzyme [ACE] inhibitor or angiotensin II receptor blocker [ARB], beta-adrenoreceptor antagonist, digoxin, furosemide, and metolazone). Greedy nearest neighbor matching was used to match higher-acuity-disposition and lower-acuity-disposition patients based on the logit of the propensity score using a caliper of 0.2 SDs of the logit of the propensity score.[16,17] Standardized differences were computed to assess balance between propensity-matched treated and untreated groups.[18] Selected 1-way interactions between variables were included in the propensity-matched model to improve balance, if needed. Relative risks for 7- and 30-day mortality were estimated for both propensity-matched cohorts using the method described by Agresti and Min.[19] In sensitivity analyses, we examined the propensity-matched results when patients were selected based on probability of 30-day death <5%, instead of based on the EHMRG30-ST risk estimate ≤ versus > the median.

Survival functions over the duration of 1 year of follow-up were estimated in each group using the Kaplan–Meier method and were compared between exposure groups using the stratified log-rank test. We chose to examine survival to 1-year follow-up because past studies have demonstrated that acute HF processes of care can affect this outcome.[9] Time to death was calculated from the date of index ED presentation. Continuous variables were expressed as medians (25th, 75th percentile) and compared between groups using the Kruskal–Wallis test. Categorical variables, reported as absolute number and percentages, were compared between groups using the χ^2 statistic. A 2-sided $P<0.05$ was considered statistically significant. All study data were stored in a secure database at the Institute for Clinical Evaluative Sciences and analyzed using SAS software (version 9.3; SAS Institute Inc., Cary, NC).

Ethical Considerations

This study was approved by the research ethics board of Sunnybrook Health Sciences Center (Toronto, Ontario, Canada), and ethical approval for data collection was also obtained from each study hospital.

Results

Study Population

From among 13 568 patients meeting Framingham criteria for HF, 4514 were excluded, resulting in a final study cohort of 9054 patients (see Figure 1 for flow diagram and exclusions). Approximately one third of the study population was discharged from the ED. Among those admitted to the hospital, 18.1% were admitted to the ICU. The clinical characteristics of the cohort according to ED disposition are shown in Table 1. Overall, median age was 78 years (69, 84) and 4441 (49.1%) were women. Patients admitted to higher-intensity units (ICU > ward > discharge) demonstrated worse physiological severity, with higher heart rate and respiratory rate and lower oxygen saturation. Cardiovascular disease risk factors and coronary artery disease were more prevalent with increasing care intensity setting. Evidence-based HF medication profile before presentation was similar among allocation groups, except for the use of diuretics, which was highest among those discharged from the ED.

As shown in Table 2, there were small, but statistically significant, differences in laboratory features between groups. The largest difference was presence of troponin higher than

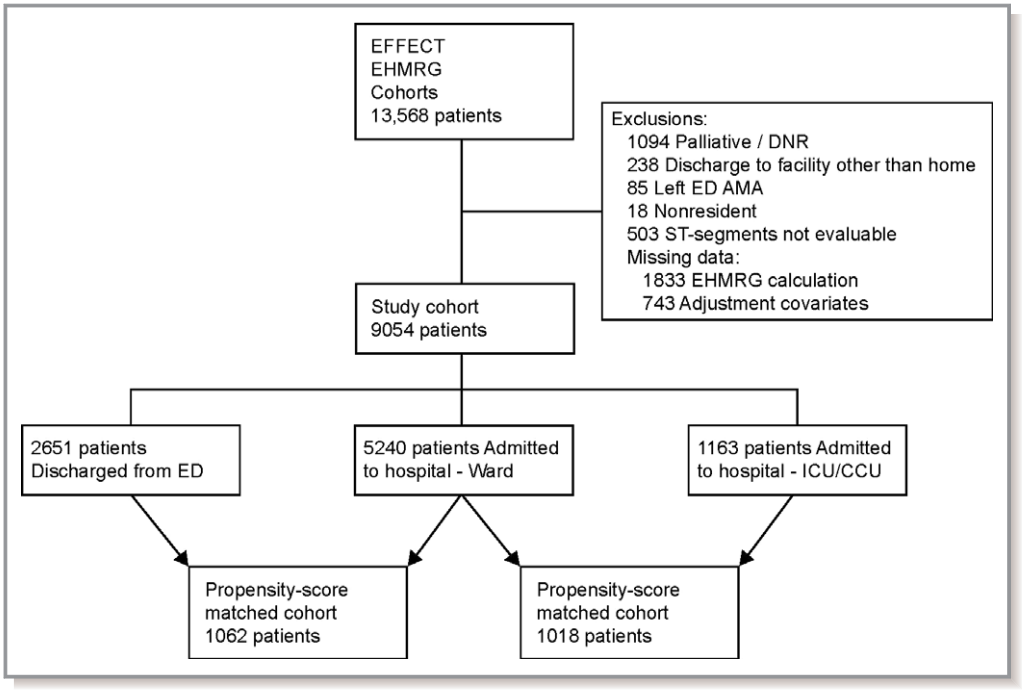

Figure 1. Flow diagram of the study cohort. AMA indicates against medical advice; CCU, coronary care unit; DNR, do not resuscitate; ED, emergency department; EFFECT, Enhanced Feedback For Effective Cardiac Treatment; EHMRG, Emergency Heart failure Mortality Risk Grade; ICU, intensive care unit.

the upper limit of normal, which was most prevalent among the ICU cohort. However, there were also smaller differences between groups in the presence of Q-waves or ST-depression. The distribution of EHMRG30-ST predicted probabilities of 30-day death are shown in Figure 2. The median predicted probabilities (25th, 75th percentiles) of 30-day death based on the EHMRG30-ST were 3% (2%, 7%) for ED-discharged, 5% (2%, 9%) for ward-admitted, and 6% (3%, 11%) for ICU-admitted patients ($P<0.001$).

Comparison of Ward-Admitted and ED-Discharged Patients

Figure 3 illustrates the characteristics associated with increased odds of admission to hospital ward versus discharge home after accounting for clustering within hospitals in a multivariable regression model (c-statistic=0.742). Factors associated with ward admission (adjusted OR >1) included several respiratory variables, including higher respiratory rate, lower oxygen saturation, and need for NPPV (OR, 5.75; 95% CI, 1.08, 30.76; $P=0.041$). Presentation to a teaching hospital was associated with lower odds (OR, 0.40; 95% CI, 0.22, 0.71; $P=0.002$), whereas small hospitals exhibited a nonsignificant trend to higher odds (OR, 2.65; 95% CI, 0.42, 16.59) of ward admission, controlling for all other significant covariates. Other prominent factors associated with ward admission (vs ED discharge) were elevated leukocyte count, abnormal troponin, and higher heart rate. Occurrence of a cardiovascular complication in the ED (OR, 10.14; 95% CI, 1.43, 71.93; $P=0.021$) was associated with ward admission (vs discharge), but the OR and upper confidence limits exceeded the *x*-axis scale and are not displayed in Figure 3.

Comparison of ICU- and Ward-Admitted Patients

Among patients who were admitted, several patient characteristics were associated with ICU rather than ward admission. Multivariable predictors of admission to the ICU (vs ward) are shown in Figure 4 (c-statistic=0.770). Accounting for clustering within hospitals, factors that were associated with ICU admission (adjusted OR >1) included previous MI, higher heart rate, higher creatinine concentration, and wider QRS duration. Respiratory factors (higher respiratory rate, lower oxygen saturation, and use of NPPV) were also associated with ICU admission. The presence of ST-depression on ECG and serum sodium concentration were not associated with ICU (vs ward) admission. Interestingly, higher SBP was associated with ICU admission, although SBP <90 mm Hg exhibited a nonsignificant trend, with an adjusted OR of 1.45 (95% CI, 0.82, 2.57). Occurrence of a complication in the ED was associated with higher odds of ICU compared to ward admission (OR, 5.92; 95% CI, 4.19, 8.35; $P<0.001$). Presentation at a teaching hospital was associated with lower odds of ICU admission than community hospitals after multivariable adjustment.

Table 1. Demographic and Clinical Characteristics of the Study Cohort According to Disposition Following ED Visit for HF

	Discharged From ED	Admitted to Ward	Admitted to ICU	*P* Value
N	2651	5240	1163	
Demographics				
Age, y (IQR)	78 (70, 84)	78 (70, 84)	74 (64, 81)	<0.001
Sex male, n (%)	1287 (48.5)	2505 (47.8)	649 (55.8)	<0.001
Long-term care resident, n (%)	319 (12.0)	453 (8.6)	61 (5.2)	<0.001
Transported by EMS, n (%)	888 (33.5)	2350 (44.8)	636 (54.7)	<0.001
Hospital type—teaching, n (%)	819 (30.9)	1388 (26.5)	236 (20.3)	<0.001
Hospital type—community, n (%)	1818 (68.6)	3760 (71.8)	896 (77.0)	
Hospital type—small, n (%)	14 (0.5)	92 (1.8)	31 (2.7)	
Comorbidities, n (%)				
Diabetes mellitus	916 (34.7)	1891 (36.2)	471 (40.7)	0.002
Hypertension	1573 (60.9)	3472 (66.8)	770 (66.8)	<0.001
Current smoking	183 (7.8)	639 (14.3)	222 (22.2)	<0.001
Previous myocardial infarction	940 (36.3)	1810 (35.3)	478 (41.9)	<0.001
Previous PCI	186 (7.5)	353 (6.8)	116 (10.2)	<0.001
Previous CABG	454 (17.2)	715 (13.7)	169 (14.6)	<0.001
Peripheral arterial disease	210 (8.0)	617 (11.8)	145 (12.5)	<0.001
Cerebrovascular disease	417 (15.9)	906 (17.4)	175 (15.2)	0.085
Cirrhosis	65 (2.5)	72 (4.9)	7 (2.8)	<0.001
Chronic lung disease	499 (19.0)	1227 (23.7)	280 (24.4)	<0.001
Dementia	187 (7.1)	442 (8.5)	53 (4.6)	<0.001
Active cancer	152 (5.7)	482 (9.2)	95 (8.2)	<0.001
Implanted device	274 (10.4)	488 (9.3)	73 (6.3)	<0.001
Clinical presentation, median (IQR)				
Systolic blood pressure, mm Hg	144 (126, 164)	145 (126, 167)	152 (130, 178)	<0.001
Heart rate, beats/min	81 (70, 97)	90 (74, 108)	105 (85, 123)	<0.001
Respiratory rate, breaths/min	20 (18, 24)	22 (20, 28)	26 (20, 32)	<0.001
Oxygen saturation, %	96 (94, 98)	95 (90, 97)	93 (85, 97)	<0.001
Pre-admission medications, n (%)				
ACE inhibitor or ARB	1581 (59.6)	3014 (57.5)	669 (57.5)	0.178
Beta blocker	1232 (46.5)	2306 (44.0)	499 (42.9)	0.053
Digoxin	544 (20.5)	981 (18.7)	178 (15.3)	<0.001
Spironolactone	212 (8.0)	387 (7.4)	85 (7.3)	0.589
Loop diuretic	1403 (52.9)	2518 (48.1)	468 (40.2)	<0.001
Thiazide diuretic	222 (8.4)	594 (11.3)	137 (11.8)	<0.001
Anticoagulant	844 (31.8)	1484 (28.3)	253 (21.8)	<0.001

ACE indicates angiotensin-converting enzyme; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass graft; ED, emergency department; EMS, emergency medical services; HF, heart failure; ICU, intensive or coronary care unit; IQR, interquartile range; PCI, percutaneous coronary intervention.

Mortality by Care Setting

At 30 days, there were 495 deaths (6.5%) with mortality rates of 2.9% for discharged, 6.0% for ward-admitted, and 8.7% for ICU patients. Prediction of 30-day mortality was robust when analysis was stratified by admission care setting intensity: either ICU- or ward-admitted patients or those discharged from the ED (Table 3).

Table 2. Demographic and Clinical Characteristics of the Study Cohort According to Disposition Following ED Visit for HF

	Discharged From ED	Admitted to Ward	Admitted to ICU	*P* Value
N	2651	5240	1163	
Laboratory, median (IQR)				
Hemoglobin, g/L	125 (112, 137)	124 (112, 138)	132 (116, 145)	<0.001
Leukocyte count, $\times 10^9$ cells/L	7.9 (6.5, 9.6)	8.6 (7.0, 10.9)	10.4 (8.1, 13.7)	<0.001
Sodium, mmol/L	139 (137, 141)	139 (136, 141)	139 (136, 141)	<0.001
Sodium <136 mEq/L, n (%)	410 (15.5)	1130 (21.6)	231 (19.9)	<0.001
Potassium, mmol/L	4.1 (3.8, 4.5)	4.2 (3.8, 4.5)	4.2 (3.8, 4.6)	0.007
Creatinine, μmol/L	97 (79, 120)	99 (79, 121)	103 (85, 126)	<0.001
Creatinine, mg/dL	1.1 (0.9, 1.4)	1.1 (0.9, 1.4)	1.2 (1.0, 1.4)	<0.001
Abnormal troponin, n (%)	154 (5.8)	653 (12.5)	368 (31.6)	<0.001
LVEF ≤40%, n (%)	1291 (49.5)	2329 (45.0)	648 (56.3)	<0.001
Electrocardiographic features, n (%)				
Atrial fibrillation or flutter	844 (31.8)	1781 (34.0)	323 (27.8)	<0.001
ST depression	686 (25.9)	1119 (21.4)	322 (27.7)	<0.001
Q-waves	486 (18.3)	908 (17.3)	234 (20.1)	0.069
QRS duration, ms	96 (84, 119)	98 (86, 122)	100 (89, 125)	<0.001

ED indicates emergency department; ICU, intensive or coronary care unit; IQR, interquartile range; LVEF, left ventricular ejection fraction.

Propensity-Score–Matched Analysis: Ward Admission Versus ED Discharge

A total of 531 pairs of 1:1 propensity-matched patients who were admitted to the ward or discharged from the ED were examined. Lower-risk patients admitted to the ward with lower-than-median predicted probability of 30-day mortality (EHMRG30-ST ≤ median) were well matched to ED-discharged patients for all covariates, with standardized differences shown in Table S1. Characteristics of the matched cohort are shown in Table S2. The ward- and ED-discharged groups were also well matched on the composite EHMRG 7-day risk score, with a standardized difference of 0.02 after propensity score matching. In propensity-matched analyses, there were no differences in 30-day or 1-year mortality among lower-risk patients initially admitted to ward versus patients discharged from the ED (Table 4, top). As shown in Figure 5, survival curves for the propensity-matched cohorts were similar over time.

Propensity-Score–Matched Analysis: ICU Versus Ward Admission

A total of 509 pairs of 1:1 propensity-matched patients, who were admitted to the ICU or the ward, were examined. Lower-risk ICU patients with lower-than-median predicted probability of 30-day mortality (EHMRG30-ST ≤ median) were well-matched for all covariates to ward patients, with standardized differences shown in Table S3. The characteristics of the matched cohort are shown in Table S4. Compared to the ICU-admitted population, matched patients tended to be younger and less often presented to hospital by ambulance. The ward- and ICU-admitted patients were also well matched on the composite EHMRG 7-day risk score, with standardized difference 0.03 after propensity-score matching. There was no difference in early mortality at 100 days, with an adjusted relative risk of 0.69 (95% CI, 0.43–1.10; *P*=0.148). However, the propensity-matched survival curves diverged after 100 days (Figure 6). At 1-year follow-up, the relative risk for death comparing ICU-admitted patients to ward-admitted patients was 0.68 (95% CI, 0.49–0.94) in the propensity-matched sample (Table 4, bottom), indicating significantly improved survival up to 1 year among those initially admitted to the ICU (*P*=0.022). There was no significant time-ICU interaction (*P*=0.746).

Sensitivity Analysis

In the sensitivity analysis, we identified 638 ward-admitted and ED-discharged pairs in a 1:1 ratio with a probability of 30-day death <5%, who were well matched after propensity matching (all standardized differences <10%). We also identified 529 ICU- and ward-admitted pairs with a probability of 30-day death <5%, with standardized differences <10% after 1:1 propensity matching. The propensity-score–adjusted relative risks for ward-admitted versus ED-discharged patients

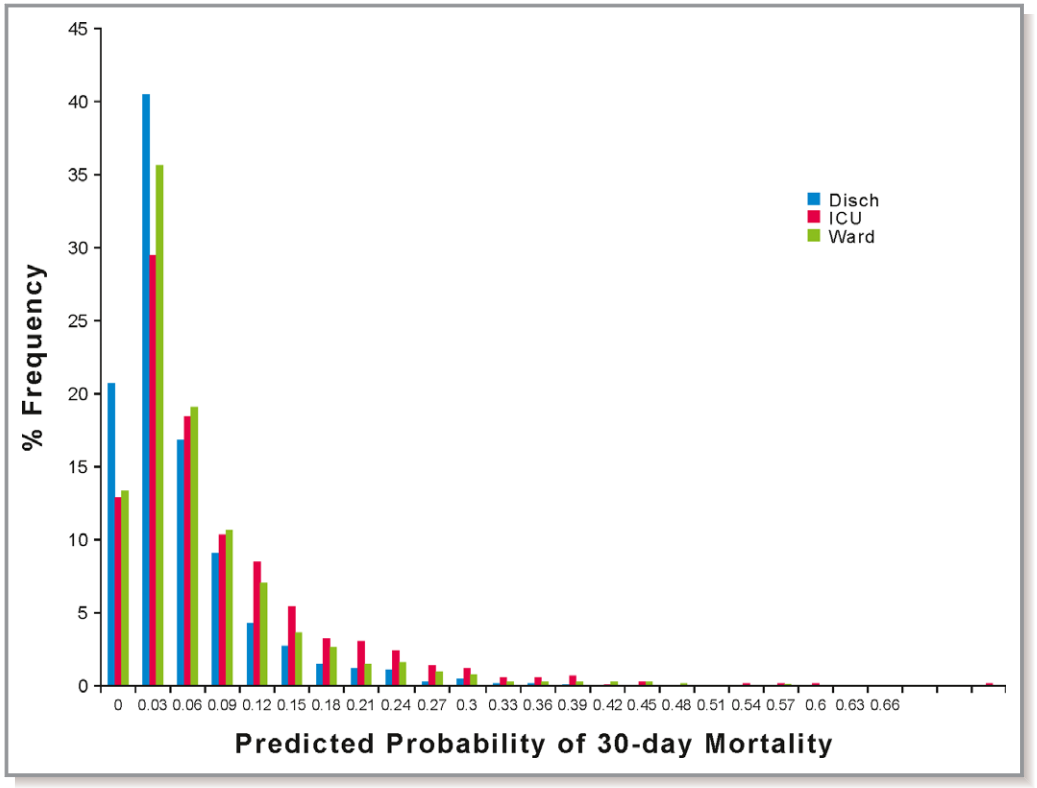

Figure 2. Predicted probabilities of 30-day mortality among patients admitted to ICU versus ward, or discharged home. Disch indicates discharge; ICU, intensive care unit.

and ICU-admitted versus ward-admitted patients were consistent with the primary analyses reported above (data not shown), indicating that the probability-based results were similar to the aforementioned EHMRG risk-based results.

Processes of Care

Comparing lower-risk patients admitted to the ICU with propensity-matched patients admitted to the ward, there were differences in care received in the hospital. ICU-admitted patients exhibited higher rates of cardiac catheterization (22.0% vs 13.6%; $P<0.001$), coronary revascularization with PCI or CABG (5.7% vs 2.6%; $P=0.014$), and assessment of left ventricular ejection fraction (LVEF) by echocardiogram or radionuclide angiography (31.6% vs 25%; $P=0.029$).

Discussion

Among patients with HF who present to the ED, determining the hospital setting where care will be provided is an important decision. Of all HF patients presenting emergently, two thirds were admitted, and, of these, 1 in 5 were admitted to the ICU directly from the ED. Patient factors associated with admission to a higher-intensity setting (ie, ICU vs ward or ward vs ED discharge) were related to respiratory status, such as use of NPPV in the ED, respiratory rate, and oxygen saturation. Other clinical factors suggesting physiological abnormalities (elevated white blood cell count, creatinine, or troponin elevation) and atherosclerotic disease or risk factors (past MI, peripheral arterial disease, hypertension, or smoking history) were also predictors of higher-intensity admission to the ICU or hospital ward. In the examination of care setting intensity and outcomes, we found no difference in early mortality among lower-risk ICU-admitted compared to ward-admitted patients. We also found that some lower-risk ward-admitted patients did not demonstrate differences in survival compared to those discharged home from the ED. Collectively, these findings promote the hypothesis that decisions regarding care setting intensity could potentially be improved.

The US National Ambulatory Care Survey reported that admissions to the ICU from the ED are increasing faster (14% biennially) than population growth and ED visits overall, and HF is one of the 3 major reasons for this increase over time.[20] Variations in ICU admissions for HF were demonstrated by Safavi et al., who reported that ICU admission rates in the United States ranged from 0% to 88%.[6] There is also substantial variation in hospitalizations for HF, although few have differentiated admissions to higher-intensity care settings and factors associated with higher rates of admission are not known.[21] Past studies have not explored patient factors predisposing to ICU or hospital admission when compared to a lower-intensity setting. We found that clinical

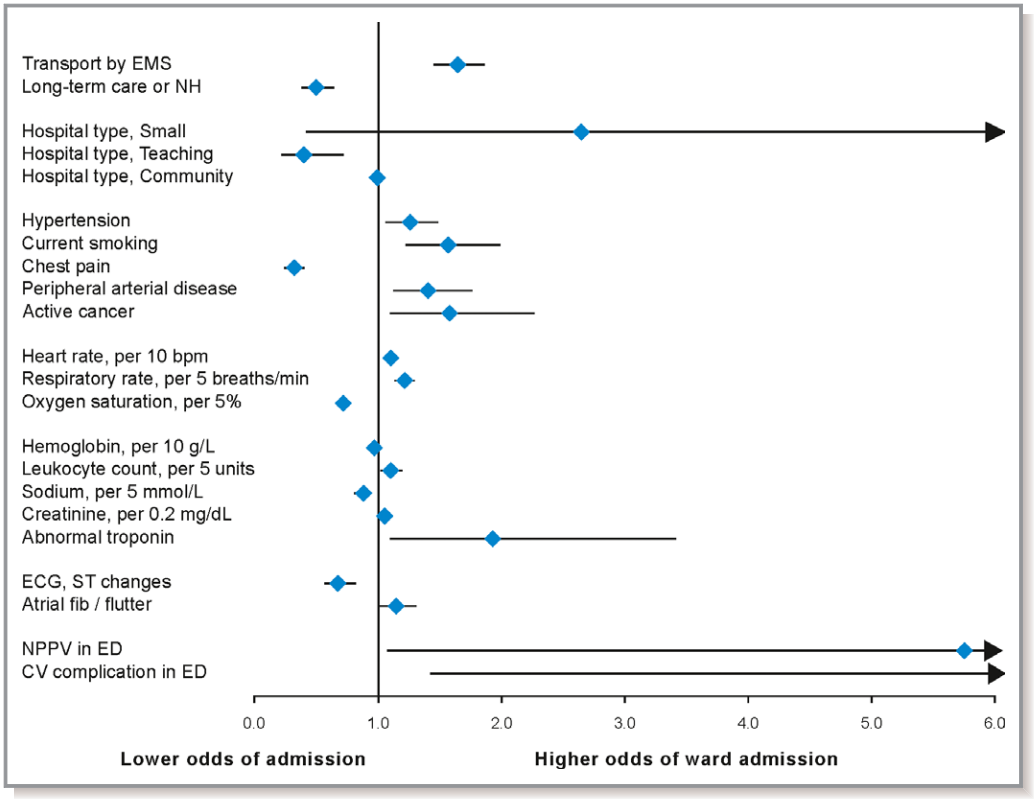

Figure 3. Multivariable predictors of hospitalization on the ward (vs ED discharge) with $P<0.05$ in multivariable model. OR >1 indicates higher odds of ward admission. bpm indicates beats per minute; CV, cardiovascular; ECG, electrocardiogram; ED, emergency department; EMS, emergency medical services; fib, fibrillation; NH, nursing home; NPPV, noninvasive positive pressure ventilation; OR, odds ratio.

factors indicative of HF acuity, concomitant disease conditions, and hospital type were associated with the type of care setting to which the HF patient was admitted with good discrimination.

Past studies have examined outcomes associated with varying degrees of hospital admission for HF. Smaller-volume hospitals discharge proportionately more patients home,[22] and the corresponding lower admission rates tended to result in higher rates of repeat ED visits and hospital readmissions among those who were discharged.[7] Ross et al. found that hospitals with lower HF volume exhibited higher 30-day mortality than higher-volume hospitals, which tended to be larger in size.[23] In the ICU setting, Safavi et al. reported somewhat contrasting results, finding that in-hospital mortality was not substantially different in hospitals with the highest ICU admission-rate quartile compared to other hospitals.[6] Whereas these studies compared outcomes at the institutional level, our study contributes to the literature by examining the relationship between intial care setting intensity and survival in a patient-level analysis with both short- and near-term time horizons. Consequently, we observed that the survival curves of ICU- and ward-admitted patients diverged at ≈100 days, with lower mortality observed at 1-year follow-up. Whereas this may suggest that higher care setting intensity may have contributed to improved outcomes, we cannot exclude the potential influence of other downstream processes of care, which may also have had an impact.

Considered broadly, the decision to admit a patient to either the hospital ward or ICU may be explained, in part, by concern about patients' acute prognosis, few objective guidelines for selection of care setting, limitations of clinical judgment when making decisions, and perceived benefits of higher-intensity compared to lower-intensity care settings. The observations of substantial overlap in both predicted and observed risks among patients who were admitted to higher- or lower-intensity units may be partly explained by the fact that clinical judgment alone was used for admission decisions, and intensity of in-hospital care was not contingent on patients' risk. Accounting for patients' acuity and concomitant conditions, teaching hospitals were less likely to admit patients to higher-intensity units than nonteaching hospitals. This suggests that teaching hospitals, which are often tertiary or quaternary care centers, may have a higher threshold to admit to higher-intensity settings.

Although our study begins to identify some of the issues related to acute HF triage to ICU, ward, or discharge home,

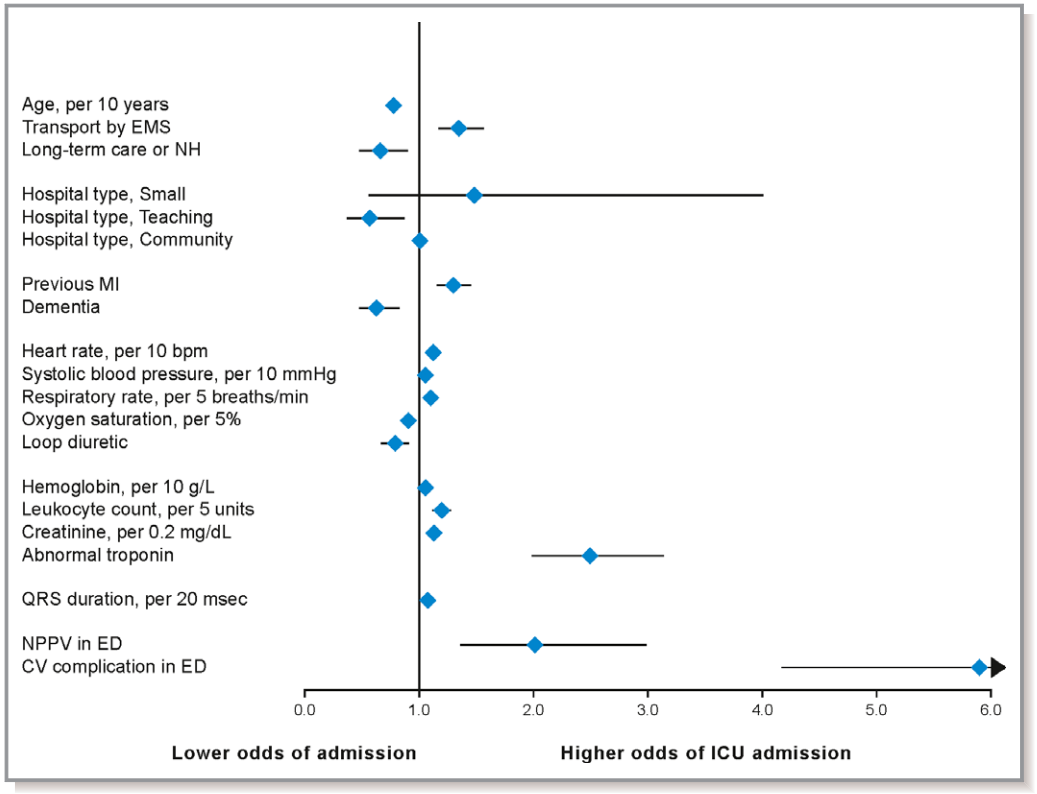

Figure 4. Multivariable predictors of hospitalization in the ICU (vs ward) with $P<0.05$ in multivariable model. OR >1 indicates higher odds of ICU admission. bpm indicates beats per minute; CV, cardiovascular; ED, emergency department; EMS, emergency medical services; ICU, intensive care unit; MI myocardial infarction; NH, nursing home; NPPV, noninvasive positive pressure ventilation; OR, odds ratio.

further research is needed to support evidence-based guideline recommendations, which currently do not exist. The American Heart Association and Heart Failure Society of America guidelines for HF suggest that physicians should select an appropriate level of care for inpatient monitoring and nursing care, but do not provide specific guidance on how such a setting should be decided.[24,25] The European Society of Cardiology guidelines for HF state that some patients are best managed in an ICU, suggesting that systolic blood pressure, heart rhythm and rate, oxygen saturation, and renal function may be frequently monitored in that setting; however, there is, again, no guidance on selection of patients for ICU admission.[26] Our findings suggest that there may be opportunity costs whereby patients with critical care needs may be denied access to critical care or high-intensity care is delayed because ICU beds are occupied by patients who could

Table 3. ORs of 30-Day Mortality Stratified by Admission Location and EHMRG30-ST Quintiles

	Discharged From ED (N=2651)		Admitted to Ward (N=5240)		Admitted to ICU (N=1163)	
	30-Day Mortality					
EHMRG30-ST Quintiles	n (%)	OR (95% CI)	n (%)	OR (95% CI)	n (%)	OR (95% CI)
Q1–2	1318 (49.7)	Reference	1934 (36.9)	Reference	370 (31.8)	Reference
Q3–4	983 (37.1)	3.38 (1.76, 6.47)*	2182 (41.6)	3.89 (2.57, 5.90)*	457 (39.3)	4.46 (2.06, 9.64)*
Q5	350 (13.2)	10.45 (5.44, 20.09)*	1124 (21.5)	12.30 (8.19, 18.47)*	336 (28.9)	8.28 (3.87, 17.72)*

ED indicates emergency department; EHMRG, Emergency Heart Failure Mortality Risk Grade; ICU, intensive or coronary care unit; OR, odds ratio.
$P<0.05$.
$P<0.01$.
*$P<0.001$.

Table 4. Propensity-Matched Analysis for Mortality in Lower- Versus Higher-Intensity Care Settings

	Lower-Intensity Setting	Higher-Intensity Setting	
	Discharged From ED (N=531)	Admitted to Ward (N=531)	*P* Value
30-day mortality			
Crude mortality rate	2.26 (1.17, 3.95)	1.51 (0.65, 2.97)	
PS-adjusted relative risk (95% CI)	Reference	0.67 (0.27, 1.63)	0.503
1-year mortality			
Crude mortality rate	16.57 (13.29, 20.42)	15.44 (12.28, 19.17)	
PS-adjusted relative risk (95% CI)	Reference	0.93 (0.71, 1.22)	0.673
	Admitted to Ward (N=509)	Admitted to ICU (N=509)	
30-day mortality			
Crude mortality rate	2.95 (1.65, 4.86)	3.54 (2.10, 5.59)	
PS-adjusted relative risk (95% CI)	Reference	1.20 (0.62, 2.33)	0.720
1-year mortality			
Crude mortality rate	15.32 (12.11, 19.13)	10.41 (7.80, 13.62)	
PS-adjusted relative risk (95% CI)	Reference	0.68 (0.49, 0.94)	0.022

Variables included in this propensity-matched analysis: age, sex, transported by EMS, nursing home or long-term care resident, Canadian Triage and Acuity Scale score (1, 2–3, or 4–5), chest pain symptoms, systolic blood pressure, heart rate, respiratory rate, oxygen saturation, previous myocardial infarction, diabetes mellitus, hypertension, smoking, cerebrovascular disease, peripheral artery disease, chronic pulmonary disease, dementia, active cancer, hemoglobin, white blood cell count, sodium level, potassium level, creatinine, abnormal troponin value, atrial fibrillation or flutter on ECG, ST segment changes on ECG, Q wave on ECG, QRS duration, implanted device (ICD or CRT), BIPAP use in ED, inotrope use in ED, intubation or respiratory arrest in ED, cardiac arrest in ED, VT in ED, cardiogenic shock in ED, hospital type (teaching, large community, or small), and prehospital medications (ACE inhibitor or ARB, beta-blocker, digoxin, furosemide, and metolazone). ACE indicates angiotensin-converting enzyme; ARB, angiotensin II receptor blocker; BiPAP, Bi-level positive airway pressure; CRT, cardiac resynchronization therapy; ECG, electrocardiogram; ED, emergency department; EMS, emergency medical services; ICD, implantable cardioverter defibrillator; PS, propensity score; VT, ventricular tachycardia.

be managed safely in a lower-intensity setting. Potentially, one could hypothesize that the use of ED-based risk assessment algorithms may assist physicians in deciding upon the initial level of care intensity that is best suited to patients' prognosis. However, further study is necessary before these strategies can be implemented broadly to assist triage decisions. Our study focused on patient characteristics that were associated with admission to higher intensity units. However, nonpatient (eg, institution and provider) characteristics may also contribute significantly to the setting where care was provided. A detailed analysis of these contributors may provide insights in future studies.

Some limitations merit consideration. Propensity-matched analyses allow for adjustment based on measured covariates.

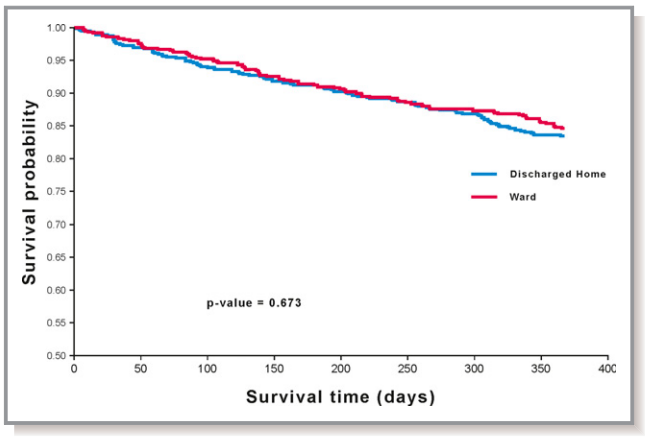

Figure 5. Comparison of 1-year survival estimate in the propensity-score–matched patients between discharged home and ward by Kaplan–Meier curve: time to death for propensity-score–matched cohort.

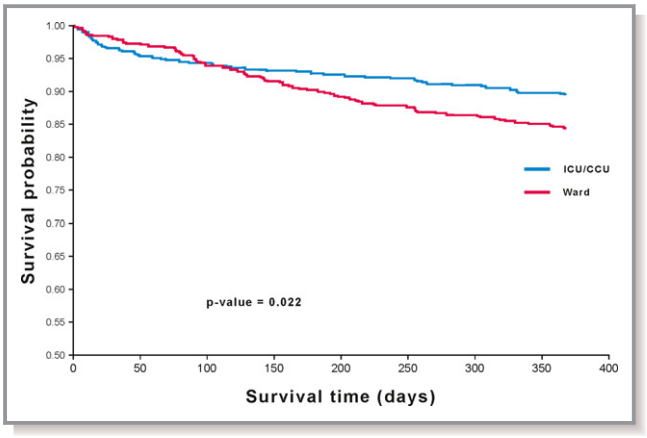

Figure 6. Comparison of 1-year survival estimate in the propensity-score–matched patients between ICU and ward by Kaplan–Meier curve: time to death for propensity score-matched cohort. ICU indicates intensive care or coronary care unit. CCU indicates coronary care unit; ICU, intensive care unit.

We examined patient-level outcomes in our propensity-matched analyses, comparing patients with similar predicted probabilities of death where the primary difference was the setting of care. However, it is conceivable that variations in the criteria for admission to ICU or ward, which is difficult to objectify (eg, patient preferences and social circumstances), could have impacted on outcomes. For example, unmeasured factors, such as poor social supports and limited bed availability (which may also influence disposition decisions), were not considered in our analysis. Patients who were transferred to the ICU after initial ward admission were not distinguished separately from ward-admitted patients. Use of cardiac telemetry on the ward was unknown, which may have attenuated differences between ward and ICU groups.[6,27] Though 98% of ICU-admitted patients were successfully matched, the proportion of ward-admitted patients who were matched to ED-discharged patients was 22%. Therefore, our comparison of ward-admitted and ED-discharged patients only applies to some patients who have similarly low risk of events. Finally, our study was population based, and therefore elderly patients were included. However, all patients were nonpalliative and did not have DNR directives, and thus our study cohort was eligible for the broad range of care intensities available in the hospital setting.

In conclusion, many indicators of heightened clinical risk and worsened cardiorespiratory status at acute HF presention were associated with increased odds of admission to higher-intensity units. However, there was substantial overlap in risk profiles of ward-admitted versus ED-discharged patients and ICU-admitted versus ward-admitted patients. There was no difference in early mortality among lower-risk patients admitted to the ICU versus ward-admitted patients. There was also no difference in early or near-term survival among some lower-risk patients admitted to ward versus those discharged home. Overall, our findings indicate potential opportunity for improvement in the quality of decision making for AHF patients presenting to hospital EDs.

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Disclosures

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SUPPLEMENTAL MATERIAL

Data S1.

Supplemental Methods

Variables examined in univariate analysis for inclusion in the multivariable model include: age, sex, transport by EMS, nursing home or long-term care facility, hospital type (teaching, community, small), prior MI, diabetes, hypertension, current smoking, cerebrovascular disease, peripheral arterial disease, COPD, dementia, active cancer, Q-waves or ST-changes on ECG, atrial fibrillation/flutter, QRS duration, implanted device (CRT or ICD), beta-adrenoreceptor antagonist, digoxin, diuretics (loop or thiazide), systolic blood pressure (mmHg), heart rate (beats/min), respiratory rate (breaths/min), oxygen saturation (%), chest pain, non-invasive positive pressure ventilation (NPPV) in the ED, cardiovascular complication in ED (ventricular tachycardia, cardiogenic shock, cardiac arrest, intubation or respiratory arrest, inotropes used in ED), hemoglobin (g/dL), leukocyte count (/μL), serum sodium (mEq/L), potassium concentration (mEq/L), creatinine concentration (mg/dL), abnormal troponin (> upper limit of normal range).

Table S1. Standardized differences before and after propensity matching for low-risk ward vs. all ED discharged patients for 30-day and 1-year survival.

Propensity-Matched Covariate	Before Matching	After Matching
	Standardized Difference	Standardized Difference
Age	0.44	0.03
Men vs. Women	0.06	0.02
Transport by EMS	0.41	0.01
Nursing home or long-term care resident	0.41	0.01
CTAS score	2.61	0.02
Hospital type (teaching, large community or small)	0.20	0.07
Previous MI	0.08	0.03
Diabetes	0.13	0.02
Hypertension	0.19	0.02
Current smoking	0.31	0.03
Cerebrovascular disease	0.02	0.04
Peripheral artery disease	0.15	0.01
COPD	0.03	0.06
Dementia	0.15	0.02
Active neoplasia	0.12	0.10
ECG, ST changes	0.26	0.02
ECG, Q waves	0.05	0.03
Atrial fibrillation or flutter on ECG	0.04	0.02
QRS duration	0.02	0.04
Implanted device (CRT or ICD)	0.03	0.06
ACE inhibitor or ARB	0.02	0.02
Beta-blocker	0.04	0.08

Digoxin	0.09	0.03
Diuretic, loop	0.23	0.08
Diuretic, thiazide	0.07	0.05
Systolic blood pressure	0.43	0.03
Heart rate	0.19	0.06
Respiratory rate	0.26	0.01
Oxygen saturation	0.28	0.07
Chest pain	0.58	0.08
BIPAP in ED	0.06	0.03
Cardiovascular complication in ED	0.13	0.06
Hemoglobin	0.14	0.01
White blood cell count	0.13	0.03
Sodium	0.02	0.02
Potassium	0.04	0.03
Creatinine	0.13	0.01
Abnormal troponin value	0.09	0.03

ED, emergency department; EMS, Emergency Medical Services; CTAS, Canadian Triage and Acuity Scale; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease; ECG, electrocardiogram; CRT, cardiac resynchronization therapy; ICD, implantable cardiac defibrillator; ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker; BIPAP, bi-level positive airway pressure.

Table S2. Demographic and clinical characteristics of the propensity-matched ED-discharge vs. ward-admitted study cohort

	Discharged from ED	**Admitted to Ward**
N	532	532
Demographics		
Age, years (IQR)	74 (63, 81)	74 (64, 80)
Sex, male, n(%)	266 (50.0%)	267 (50.2%)
Long-term care resident, n(%)	19 (3.6%)	17 (3.2%)
Transported by EMS, n(%)	89 (16.7%)	93 (17.5%)
Hospital type - teaching, n(%)	165 (31.0%)	164 (30.8%)
Hospital type – community/small, n(%)	367 (69.0%)	368 (69.2%)
Comorbidities, n(%)*		
Diabetes mellitus	219 (41.2%)	219 (41.2%)
Hypertension	392 (73.7%)	374 (70.3%)
Current smoking	65 (12.2%)	70 (13.2%)
Previous myocardial infarction	152 (28.6%)	154 (28.9%)
Previous PCI	38 (7.6%)	37 (7.5%)
Previous CABG	76 (14.3%)	89 (16.8%)
Peripheral arterial disease	63 (11.8%)	63 (11.8%)
Cerebrovascular disease	87 (16.4%)	96 (18.0%)
Chronic lung disease	109 (20.5%)	112 (21.1%)
Dementia	25 (4.7%)	24 (4.5%)
Active cancer	37 (7.0%)	47 (8.8%)
Implanted device	36 (6.8%)	33 (6.2%)
Clinical presentation, median (IQR)		
Systolic blood pressure, mmHg	157 (137, 178)	155 (141, 172)
Heart rate, beats/min	84 (71, 100)	84 (70, 101)
Respiratory rate, breaths/min	22 (18, 26)	22 (18, 26)
Oxygen saturation, %	95 (92, 97)	95 (91, 97)
Preadmission medications, n(%)		
ACE inhibitor or ARB	315 (59.2%)	312 (58.6%)
Beta blocker	272 (51.1%)	263 (49.4%)
Digoxin	86 (16.2%)	87 (16.4%)
Spironolactone	39 (7.3%)	27 (5.1%)
Loop diuretic	235 (44.2%)	240 (45.1%)
Thiazide diuretic	59 (11.1%)	61 (11.5%)
Anticoagulant	167 (31.4%)	151 (28.4%)
Laboratory, median (IQR)		
Hemoglobin, g/L	126 (114, 139)	126 (113, 141)
Leukocyte count, $x10^9$ cells/L	8.3 (6.7, 10.0)	8.4 (6.9, 10.4)
Sodium, mmol/L	139 (137, 141)	139 (137, 141)

Potassium, mmol/L	4.1 (3.8, 4.4)	4.1 (3.8, 4.4)
Creatinine, μmol/L	93 (76, 113)	92 (77, 116)
Creatinine, mg/dL	1.1 (0.9, 1.3)	1.0 (0.9, 1.3)
Abnormal troponin, n(%)	23 (4.3%)	30 (5.6%)
LVEF ≤ 40%, n(%)	234 (44.7%)	235 (44.4%)
Electrocardiographic features, n(%)		
Atrial fibrillation or flutter	163 (30.6%)	175 (32.9%)
ST depression	123 (23.1%)	134 (25.2%)
Q-waves	79 (14.8%)	85 (16.0%)
QRS duration, msec	94 (84, 112)	94 (85, 114)

ED, Emergency Department; ICU, intensive or coronary care unit; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker.
* Cirrhosis not shown due to small cells.

Table S3. Standardized differences before and after propensity matching for low-risk ICU vs. all ward patients for 30-day and 1-year survival.

Propensity-Matched Covariate	Before Matching	After Matching
	Standardized Difference	Standardized Difference
Age	0.88	0
Men vs. Women	0.27	0.03
Transport by EMS	0.38	0.05
Nursing home or long-term care resident	0.28	0.04
CTAS score	0.28	0.08
Hospital type (teaching, large community or small)	0.2	0.03
Previous MI	0.09	0
Diabetes	0.08	0.01
Hypertension	0.01	0.01
Current smoking	0.3	0.02
Cerebrovascular disease	0.18	0.02
Peripheral artery disease	0	0.05
COPD	0.12	0.02
Dementia	0.27	0.02
Active neoplasia	0.25	0.03
ECG, ST changes	0.01	0.03
ECG, Q waves	0.11	0.04
Atrial fibrillation or flutter on ECG	0.13	0.02
QRS duration	0	0
Implanted device (CRT or ICD)	0.04	0.04
ACE inhibitor or ARB	0.07	0.03
Beta-blocker	0.03	0.03
Digoxin	0.2	0.01
Diuretic, loop	0.26	0.02

Diuretic, thiazide	0.05	0.03
Systolic blood pressure	0.53	0.02
Heart rate	0.36	0.02
Respiratory rate	0.27	0.03
Oxygen saturation	0.08	0
Chest pain	0.11	0.07
BIPAP in ED	0.05	0
Cardiovascular complication in ED	0.36	0.02
Hemoglobin	0.42	0.02
White blood cell count	0.27	0.01
Sodium	0.1	0.03
Potassium	0.12	0
Creatinine	0.04	0.02
Abnormal troponin value	0.01	0.06

ICU, intensive care unit; EMS, Emergency Medical Services; CTAS, Canadian Triage and Acuity Scale; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease; ECG, electrocardiogram; CRT, cardiac resynchronization therapy; ICD, implantable cardiac defibrillator; ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker; BIPAP, bi-level positive airway pressure; ED, emergency department.

Table S4. Demographic and clinical characteristics of the propensity-matched ward-admitted vs. ICU-admitted study cohort

	Admitted to Ward	**Admitted to ICU**
N	509	509
Demographics		
Age, years (IQR)	67 (58, 76)	68 (59, 76)
Sex, male, n(%)	302 (59.8%)	309 (60.7%)
Long-term care resident, n(%)	SC	6 (1.2%)
Transported by EMS, n(%)	122 (24.0%)	134 (26.3%)
Hospital type - teaching, n(%)	103 (20.2%)	99 (19.4%)
Hospital type – community/small, n(%)	406 (79.8%)	410 (80.6%)
Comorbidities, n(%)*		
Diabetes mellitus	207 (40.7%)	204 (40.1%)
Hypertension	334 (65.6%)	336 (66.0%)
Current smoking	106 (20.8%)	110 (21.6%)
Previous myocardial infarction	195 (38.3%)	195 (38.3%)
Previous PCI	55 (10.9%)	57 (11.4%)
Previous CABG	75 (14.7%)	83 (16.3%)
Peripheral arterial disease	52 (10.2%)	60 (11.8%)
Cerebrovascular disease	51 (10.0%)	54 (10.6%)
Chronic lung disease	137 (26.9%)	122 (24.1%)
Dementia	8 (1.6%)	7 (1.4%)
Active cancer	18 (3.5%)	27 (5.3%)
Implanted device	33 (6.5%)	27 (5.3%)
Clinical presentation, median (IQR)		
Systolic blood pressure, mmHg	162 (138, 184)	160 (142, 184)
Heart rate, beats/min	100 (83, 118)	100 (82, 118)
Respiratory rate, breaths/min	24 (20, 28)	24 (20, 30)
Oxygen saturation, %	95 (90, 97)	95 (89, 97)
Preadmission medications, n(%)		
ACE inhibitor or ARB	283 (55.6%)	275 (54.0%)
Beta blocker	207 (40.7%)	215 (42.2%)
Digoxin	60 (11.8%)	58 (11.4%)
Spironolactone	27 (5.3%)	29 (5.7%)
Loop diuretic	176 (34.6%)	180 (35.4%)
Thiazide diuretic	62 (12.2%)	49 (9.6%)
Anticoagulant	119 (23.4%)	108 (21.2%)
Laboratory, median (IQR)		
Hemoglobin, g/L	133 (119, 148)	135 (121, 146)
Leukocyte count, $x10^9$ cells/L	9.2 (7.7, 11.8)	9.6 (7.7, 12.1)
Sodium, mmol/L	139 (137, 142)	140 (137, 142)

Potassium, mmol/L	4.1 (3.8, 4.5)	4.1 (3.8, 4.4)
Creatinine, μmol/L	96 (78, 119)	96 (82, 115)
Creatinine, mg/dL	1.1 (0.9, 1.3)	1.1 (0.9, 1.3)
Abnormal troponin, n(%)	52 (10.2%)	61 (12.0%)
LVEF ≤ 40%, n(%)	278 (54.8%)	274 (54.6%)
Electrocardiographic features, n(%)		
Atrial fibrillation or flutter	149 (29.3%)	144 (28.3%)
ST depression	96 (18.9%)	103 (20.2%)
Q-waves	102 (20.0%)	110 (21.6%)
QRS duration, msec	100 (86, 120)	100 (88, 115)

ED, Emergency Department; ICU, intensive or coronary care unit; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker.
* Cirrhosis not shown due to small cells.