ORIGINAL RESEARCH

Predictive Value of the Get With The Guidelines Heart Failure Risk Score in Unselected Cardiac Intensive Care Unit Patients

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Background—The cardiac intensive care unit (CICU) population is no longer composed of only patients with acute coronary syndromes, and includes those with acute heart failure and multiple comorbidities. We hypothesized that the GWTG-HF (Get With The Guidelines–Heart Failure) risk score that predicts inpatient mortality in hospitalized patients with heart failure would predict mortality in CICU patients.

Methods and Results—We retrospectively analyzed CICU patients at a tertiary care hospital from 2007 to 2015. The GWTG-HF risk score was calculated at CICU admission. As a secondary analysis, the EFFECT (Enhanced Feedback for Effective Cardiac Treatment), OPTIMIZE-HF (Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients With Heart Failure), and ADHERE (Acute Decompensated Heart Failure National Registry) risk scores were calculated. Kaplan–Meier survival analysis and the area under the receiver operating characteristic curve value were determined for inpatient and 1-year mortality. The GWTG-HF risk score was calculated in 9532 (95%) patients, with a median value of 40 (interquartile range, 35–47). Inpatient mortality occurred in 824 (8.6%) patients, and 2075 (21.8%) patients died by 1 year. Patients who died in hospital had a significantly higher mean GWTG-HF score (47.7 versus 40.2; $P<0.001$). Inpatient and 1-year mortality increased in each GWTG-HF risk score quartile ($P<0.0001$). Discrimination of the GWTG-HF, EFFECT, OPTIMIZE-HF, and ADHERE risk scores was assessed using area under the receiver operating characteristic curve values for hospital mortality, and were similar for all risk scores (0.72–0.74; $P>0.05$). The Hosmer–Lemeshow statistic suggested poor calibration for hospital mortality by the GWTG-HF risk score ($P<0.001$).

Conclusions—The GWTG-HF risk score and other heart failure prediction tools demonstrate good discrimination for inpatient and 1-year mortality in a heterogeneous cohort of CICU patients. Our study emphasizes that prognostic variables overlap in cardiac patients, regardless of the admission diagnosis. **(*J Am Heart Assoc*. 2020;9:e012439. DOI: 10.1161/JAHA.119.012439.)**

Key Words: cardiac intensive care unit • coronary care unit • heart failure • mortality • risk score

Heart failure is one of the most common causes for hospitalizations among Americans, accounting for over 1 million annual hospital discharges in the United States.[1] Following the initial diagnosis of heart failure, it has been estimated that 83% of patients will be hospitalized at least once, and often these patients require management in the cardiac intensive care unit (CICU).[2,3] The epidemiology of the modern CICU population is evolving to reflect this increase in acute heart failure syndrome (AHFS) admissions. Acute coronary syndromes, once the principal pathology populating the CICU, are being replaced by patients with AHFS complicated by coexisting acute and chronic comorbidities.[4]

There are multiple clinical risk prediction models designed to risk stratify hospitalized heart failure patients and estimate mortality risk, including the ADHERE (Acute Decompensated Heart Failure National Registry),[5] the EFFECT (Enhanced Feedback for Effective Cardiac Treatment) risk score,[6] the OPTIMIZE-HF (Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients With Heart Failure),[7] and the GWTG-HF (Get With The Guidelines - Heart Failure) registry[8] risk prediction models. There is substantial overlap in the risk factors included in the GWTG-HF, ADHERE, EFFECT

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Accompanying Table S1 and Figures S1, S2 are available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.119.012439

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Clinical Perspective

What Is New?

- Heart failure (HF) risk scores such as the GWTG-HF (Get With The Guidelines–Heart Failure) risk score use vital sign and laboratory data have been derived and validated to predict short-term mortality risk in patients hospitalized with HF, but this is the first study to examine the predictive value of these scores in a mixed cardiac intensive care unit (CICU) population including patients with and without HF.

What Are the Clinical Implications?

- The GWTG-HF risk score, along with other previously validated HF risk scores containing similar variables, had good discrimination for hospital and 1-year mortality in this unselected CICU cohort of 9532 patients using data from CICU admission; risk score performance was better in patients without a discharge diagnosis of HF compared with patients with a discharge diagnosis of HF, suggesting that common variables predict mortality in CICU patients with and without HF.
- Dividing hospital survivors based on quartiles of admission GWTG-HF risk score effectively provided postdischarge mortality risk stratification, emphasizing that postdischarge mortality can be predicted at the time of CICU admission among patients surviving hospitalization and that the variables in the GWTG-HF risk score remain relevant for predicting long-term prognosis.

and OPTIMIZE-HF risk prediction models (Table S1).[5–9] Of these scores, the GWTG-HF risk score is the most recently published and externally validated risk model, with good discrimination for inpatient mortality in hospitalized patients with acute heart failure (c-statistic of 0.75 in the original derivation and validation cohorts) and similar performance in a separate cohort of hospitalized patients with heart failure from Japan and a community-based cohort of heart failure admissions in Minnesota.[8–10]

As heart failure admissions continue to rise in the CICU,[11] risk stratification is important to identify patients at higher risk of adverse outcomes. Heart failure readmissions and management of lower-risk patients in a CICU setting can lead to increased use of resources.[12] Given that risk factors for mortality may be shared between AHFS populations and other CICU patients, we hypothesized that the GWTG-HF risk score would have prognostic value in a heterogeneous population of unselected CICU patients. The aim of this study is to apply the GWTG-HF score, in comparison with other heart failure risk prediction models, to assess overall prognostic value for short- and long-term morbidity and mortality in a large cohort of unselected CICU patients.

Methods

The data, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure. This study was approved by the Mayo Clinic Institutional Review Board under an exception from informed consent as posing minimal risk to patients. This study is a historical cohort analysis using an institutional database of patients admitted to the CICU at the Mayo Clinic Hospital, St. Mary's Campus, a tertiary-care hospital in Rochester, Minnesota. The CICU at this facility is a single, 16-bed, closed unit in which all admissions are triaged, accepted, and cared for by a board-certified cardiologist, with comanagement of respiratory failure by intensivists.[4,11] Unique adult patients ≥18 years old admitted to the CICU between January 1, 2007, and December 31, 2015, were identified by searching the archived electronic medical records. Only data from the first CICU admission were used for patients with CICU readmissions during the same hospitalization. Patients admitted to the CICU before January 1, 2007; patients still undergoing CICU care on December 31, 2015; and patients who did not provide Minnesota Research Authorization under Minnesota state law statute 144.295 were excluded. Patients with any missing data for calculating the GWTG-HF risk score were excluded as well.

We collected demographics, admission vital signs, and laboratory data, as well as data on procedures and therapies administered during the CICU and hospitalization.[13] The GWTG-HF risk score was calculated on the basis of variables at the time of CICU admission, including age, systolic blood pressure, heart rate, blood urea nitrogen, sodium, creatinine, race, and history of chronic obstructive pulmonary disease.[8] As a secondary analysis, the EFFECT, OPTIMIZE-HF, ADHERE risk score, and the Thrombolysis in Myocardial Infarction risk index[14] were similarly calculated using admission data; data on left ventricular ejection fraction and admission diagnosis were not available and were not included in the OPTIMIZE-HF risk score.[5–7] We determined comorbidities based on the electronically calculated Charlson Comorbidity Index, as previously described.[15] Hospital discharge *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes were reviewed for relevant diagnoses; the primary discharge diagnosis could not be identified. The accuracy of *ICD-9* codes for heart failure in administrative databases has been previously validated.[16,17]

The primary end point was all-cause hospital mortality; secondary outcomes included CICU mortality and postdischarge survival. Follow-up was assessed at the last available clinic follow-up or death, and all mortality follow-up was obtained by searching internal electronic medical records. Mortality data were extracted from Mayo Clinic electronic databases, the state of Minnesota electronic death

certificates, and the Rochester Epidemiology Project database, as previously described.[18] The GWTG-HF risk score quartiles were compared using chi-squared tests for categorical variables and ANOVA for continuous variables, with the Cochran-Armitage test used to determine trends. Postdischarge survival was compared between groups using Kaplan–Meier analysis. Cox proportional hazards models were used to determine predictors of long-term mortality among hospital survivors. The area under the receiver operating characteristic curve (AUROC) values were determined for hospital mortality for each risk score, and compared using the DeLong test. Calibration for original and modified GWTG-HF scores was assessed for both intensive care unit and hospital mortality. The integer score was transformed into a predicted probability

Table 1. Baseline Patient Characteristics and Outcomes as a Function of GWTG-HF Risk Score Quartile

	Overall (n=9532)	Quartile 1 (n=2364)	Quartile 2 (n=2044)	Quartile 3 (n=2694)	Quartile 4 (n=2430)	*P* Value (Between Groups)
Age, y	67.5±15.1	56.5±15.0	66.2±14.2	70.9±12.8	75.5±11.4	<0.001
Female sex	3578 (37.5%)	807 (34.1%)	767 (37.5%)	1057 (39.2%)	947 (39.0%)	<0.001
Nonblack race	9408 (98.7%)	2299 (97.2%)	2022 (98.9%)	2669 (99.1%)	2418 (99.5%)	<0.001
Prior myocardial infarction	1904 (20.0%)	304 (12.9%)	404 (19.8%)	578 (21.5%)	618 (25.4%)	<0.001
Prior heart failure	1894 (19.9%)	169 (7.2%)	269 (13.2%)	611 (22.7%)	845 (34.8%)	<0.001
Prior diabetes mellitus	2735 (28.7%)	440 (18.6%)	542 (26.5%)	841 (31.2%)	912 (37.5%)	<0.001
Prior COPD	1309 (13.7%)	102 (4.3%)	194 (9.5%)	392 (14.6%)	621 (25.6%)	<0.001
Prior stroke	1178 (12.4%)	168 (7.1%)	228 (11.2%)	376 (14.0%)	406 (16.7%)	<0.001
Prior moderate-severe CKD	1965 (20.6%)	196 (8.3%)	284 (13.9%)	610 (22.6%)	875 (36.0%)	<0.001
Prior dialysis	555 (5.8%)	57 (2.4%)	79 (3.9%)	163 (6.0%)	256 (10.5%)	<0.001
CCI	5.66±3.31	3.43±2.64	5.13±2.88	6.22±3.02	7.64±3.13	<0.001
ICD-9 Dx heart failure	3746 (39.3%)	471 (20.0%)	633 (31.0%)	1180 (43.8%)	1462 (60.2%)	<0.001
ICD-9 Dx acute coronary syndrome	4079 (42.8%)	1175 (49.8%)	924 (45.2%)	155 (42.9%)	825 (34.0%)	<0.001
ICD-9 Dx cardiac arrest	758 (8.0%)	156 (6.6%)	167 (8.2%)	212 (7.9%)	223 (9.2%)	0.012
ICD-9 Dx VT/VF	1580 (16.6%)	381 (16.1%)	347 (17.0%)	443 (16.5%)	409 (16.8%)	0.86
ICD-9 Dx shock	1011 (10.6%)	87 (3.7%)	128 (6.3%)	301 (11.2%)	495 (20.4%)	<0.001
ICD-9 Dx cardiogenic shock	793 (8.3%)	73 (3.1%)	105 (5.1%)	248 (9.2%)	367 (15.1%)	<0.001
ICD-9 Dx sepsis	638 (6.7%)	50 (2.1%)	85 (4.2%)	178 (6.6%)	325 (13.4%)	<0.001
ICD-9 Dx atrial fibrillation	3053 (32.1%)	365 (15.5%)	517 (25.3%)	965 (35.8%)	1206 (49.7%)	<0.001
ICD-9 Dx respiratory failure	1823 (19.1%)	206 (8.7%)	305 (14.9%)	562 (20.9%)	750 (30.9%)	<0.001
ICD-9 Dx organ failure	3428 (36.0%)	378 (16.0%)	521 (25.5%)	1050 (39.0%)	1479 (60.9%)	<0.001
BMI, kg/m^2	29.5±7.0	29.9±7.0	29.6±6.9	29.3±6.8	29.3±7.3	0.005
ICU LOS	2.6±4.6	2.1±2.5	2.4±6.1	2.8±5.6	2.9±3.4	<0.001
Hospital LOS	8.1±13.3	5.2±6.7	7.2±17.0	8.9±13.2	10.6±14.2	<0.001
Invasive ventilator use	1564 (16.4%)	241 (10.2%)	277 (13.6%)	485 (18.0%)	561 (23.1%)	<0.001
Sepsis in hospital	1641 (17.2%)	201 (8.5%)	264 (12.9%)	512 (19.0%)	664 (27.3%)	<0.001
Severe AKI in hospital	1522 (17.0%)	185 (8.0%)	227 (11.6%)	456 (18.0%)	654 (30.1%)	<0.001
ICU mortality	508 (5.3%)	38 (1.6%)	56 (2.7%)	130 (4.8%)	284 (11.7%)	<0.001
Hospital mortality	828 (8.7%)	58 (2.4%)	83 (4.1%)	231 (8.6%)	456 (18.8%)	<0.001
30-d mortality	1057 (11.1%)	74 (3.1%)	108 (5.3%)	282 (10.5%)	593 (24.4%)	<0.001
180-d mortality	1740 (18.2%)	116 (4.9%)	192 (9.4%)	497 (18.4%)	935 (38.5%)	<0.001
1-y mortality	2085 (21.9%)	152 (6.4%)	239 (11.7%)	609 (22.6%)	1085 (44.6%)	<0.001

Quartile 1 includes patients with GWTG-HF risk score <35; quartile 2, 35 to 39; quartile 3, 40 to 46; and quartile 4, ≥47. Data presented as mean (± SD) or number (%). AKI indicates acute kidney injury; BMI, body mass index; CCI, Charlson Comorbidity Index; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; Dx, diagnosis; GWTG-HF, Get With The Guidelines–Heart Failure; *ICD-9, International Classification of Diseases, Ninth Revision;* ICU, intensive care unit; LOS, length of stay; MI, myocardial infarction; VF, ventricular fibrillation; VT, ventricular tachycardia.

via the nomogram previously provided in the original GWTG-HF manuscript,[8] and then the calibration curves were plotted and performance assessed by visual inspection. The calibrations of both scores and both outcomes were also assessed via the Hosmer–Lemeshow goodness-of-fit test, although the utility of such a test in a large population warrants a degree of skepticism. $P<0.05$ was considered statistically significant. Statistical analyses were performed using JMP version 10.0 (SAS Institute, Cary, NC) and R version 3.2.0 (https://www.r-project.org/).

Results

A total of 12 904 adult CICU admissions were screened and 10 004 patients were eligible for inclusion.[4] Of these, 9532 (95.3%) had complete available data to calculate the GWTG-HF risk score and comprised the final study population (Figure S1), with baseline and admission characteristics listed in Table 1. A discharge diagnosis of heart failure was present in 3746 (39.3%) patients, and a discharge diagnosis of cardiomyopathy was present in 1329 (14.0%); 1894 (19.9%) had a history of heart failure based on the Charlson Comorbidity Index. Median (interquartile range) values of the GWTG-HF, EFFECT, and OPTIMIZE risk scores were 40 (35–47), 78 (58–100), and 31 (26–38), respectively. All 3 heart failure risk scores were strongly correlated with each other, with Pearson *r* values of 0.80 to 0.81 between the EFFECT risk score and either the GWTG-HF or OPTIMIZE-HF risk scores and 0.93 for the correlation between the GWTG-HF and OPTIMIZE-HF risk scores (all $P<0.001$).

Tables 1 and 2 show baseline characteristics for the study population, divided into GWTG-HF risk score quartiles. Significant differences in most measured variables were present as a function of GWTG-HF risk score quartile, including many variables not used to calculate the GWTG-HF score. Overall comorbidities and illness severity increased as a function of GWTG-HF risk score quartile, and a shift from discharge diagnoses of acute coronary syndrome to heart failure was seen. CICU therapies and complications (Table 1) also

Table 2. Baseline Hemodynamic and Laboratory Characteristics and Risk Scores as a Function of GWTG-HF Risk Score Quartile

	Overall (n=9532)	Quartile 1 (n=2364)	Quartile 2 (n=2044)	Quartile 3 (n=2694)	Quartile 4 (n=2430)	*P* Value (Between Groups)
Admission systolic blood pressure, mm Hg	123.0±26.3	143.6±25.5	129.2±21.4	118.0±20.3	103.3±19.2	<0.001
Admission diastolic blood pressure, mm Hg	69.4±17.0	76.6±16.1	71.7±15.8	67.7±16.4	62.1±15.9	<0.001
Admission heart rate, BPM	82.1±23.4	74.6±18.2	77.2±20.9	82.4±22.8	93.3±26.1	<0.001
Admission shock index, BPM/mm Hg	0.70±0.27	0.54±0.15	0.61±0.22	0.71±0.21	0.92±0.30	<0.001
Admission respiratory rate	18.4±5.7	17.0±5.2	17.9±5.6	18.7±5.7	20.0±6.0	<0.001
Admission oxygen saturation, %	95.8±5.8	96.9±4.8	96.2±4.9	95.5±5.9	94.5±7.0	<0.001
Admission serum sodium, mEq/L	137.8±4.4	139.0±3.1	138.4±3.9	137.6±4.3	136.3±5.4	<0.001
Admission BUN, mg/dL	26.6±18.8	16.1±7.4	20.2±9.5	26.1±13.8	43.0±25.3	<0.001
Admission creatinine, mg/dL	1.36±1.13	1.01±0.89	1.12±0.78	1.36±1.06	1.92±1.43	<0.001
Admission eGFR, mL/min	66.0±33.8	85.0±36.5	73.1±28.2	62.1±28.6	45.6±27.8	<0.001
Admission BUN:creatinine ratio	20.8±9.1	17.3±8.6	19.5±6.9	21.1±7.8	25.0±10.9	<0.001
Admission hemoglobin, g/dL	12.1±2.1	13.1±1.9	12.5±2.0	11.9±2.1	11.2±2.1	<0.001
TIMI risk index	33.0±18.7	16.7±6.8	25.7±8.0	34.9±10.9	52.9±20.9	<0.001
APACHE-III score	61.8±25.2	45.8±20.4	56.2±21.6	64.6±21.4	79.0±24.4	<0.001
Day 1 SOFA score	3.51±3.16	2.07±2.26	2.79±2.63	3.67±2.99	5.35±3.55	<0.001
GWTG-HF risk score	40.9±8.9	30.0±3.7	37.1±1.4	42.9±2.0	52.5±5.1	<0.001
EFFECT risk score	80.1±30.1	49.6±18.4	70.3±18.0	86.5±19.0	111.9±22.4	<0.001
OPTIMIZE-HF risk score	31.9±8.8	21.7±4.3	28.3±3.2	33.9±3.7	42.5±5.7	<0.001

Quartile 1 includes patients with GWTG-HF risk score <35; quartile 2, 35–39; quartile 3, 40–46; and quartile 4, ≥47. Data presented as mean (± SD) or number (%). APACHE indicates Acute Physiology and Chronic Health Assessment; BPM, beats per minute; BUN, blood urea nitrogen; EFFECT, Enhanced Feedback for Effective Cardiac Treatment; eGFR, estimated glomerular filtration rate; GWTG-HF, Get With The Guidelines–Heart Failure; OPTIMIZE-HF, Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients With Heart Failure; SOFA, Sequential Organ Failure Assessment; TIMI, Thrombolysis in Myocardial Infarction.

increased with rising GWTG-HF risk score quartile. A total of 416 (4.4%) patients underwent left ventricular assist device placement or transplant during hospitalization.

CICU mortality occurred in 508 (5.3%) patients and hospital mortality occurred in 824 (8.6%) patients. Patients who died in the hospital had higher mean values of the GWTG-HF, EFFECT, and OPTIMIZE-HF risk scores (Table 2, all $P<0.001$). CICU and hospital mortality increased in a stepwise manner with increasing quartile of the GWTG-HF risk score (Figure 1A; $P<0.001$ for trend); Figure 1B illustrates CICU and hospital mortality as a function of GWTG-HF risk score. Among patients in GWTG-HF risk score quartile 4, those undergoing left ventricular assist device placement or transplant had lower hospital mortality (6.3% versus 19.3%, unadjusted odds ratio, 0.28; 95% CI, 0.12–0.65; $P=0.002$); there was no difference for patients in GWTG-HF risk score

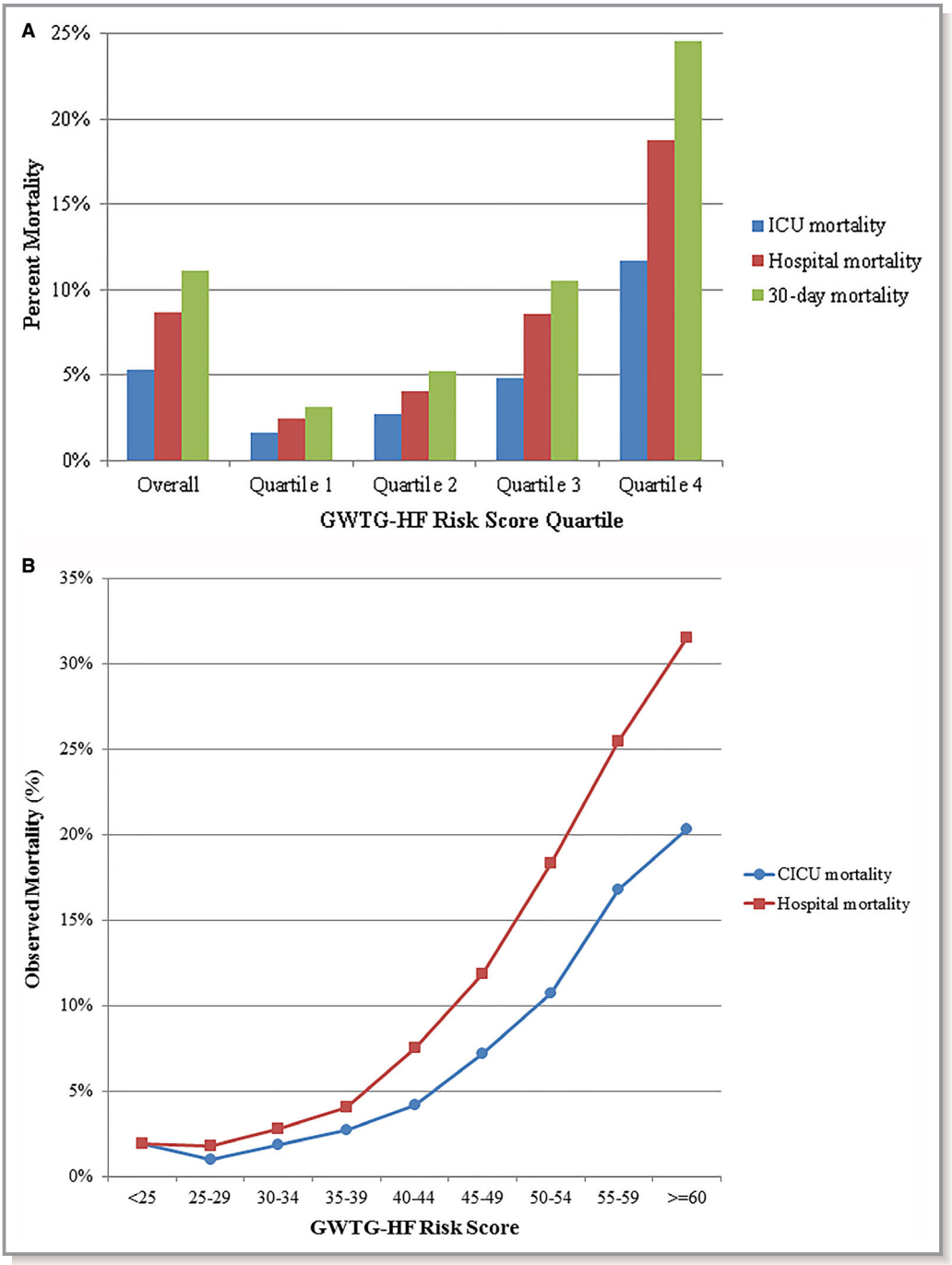

Figure 1. **A**, CICU and inpatient mortality based on GWTG-HF quartiles. **B**, CICU and hospital mortality as a function of GWTG-HF risk score. CICU indicates cardiac intenstive care unit; GWTG-HF, Get With The Guidelines–Heart Failure; ICU, intensive care unit.

quartiles 1 to 3. Stepwise increases in hospital mortality were observed when patients were divided into groups based on the ADHERE risk model[5] using systolic blood pressure, blood urea nitrogen, and creatinine (Figure 2) or based on systolic blood pressure and creatinine alone, as per the OPTIMIZE-HF study[7] (Figure 3), which highlights the relevance of these risk scores in the unselected CICU population.

Discrimination of each risk score was assessed using AUROC values for hospital mortality on univariable analysis (Table 3). AUROC values for all heart failure risk scores were similar (0.72–0.74; $P>0.05$ by DeLong test), and higher than the AUROC value for the Thrombolysis in Myocardial Infarction risk index (0.68; $P<0.01$ by DeLong test). The optimal GWTG-HF cutoff for predicting hospital mortality by AUROC analysis was 44; the 3160 (33.2%) patients with a GWTG-HF risk score >44 were at increased risk of hospital mortality (17.1% versus 4.5%; odds ratio, 4.33; 95% CI, 3.73–5.03; $P<0.001$). Removal of race and chronic obstructive pulmonary disease history from the GWTG-HF risk score did not affect the AUROC value for hospital mortality (0.73 versus 0.73; $P>0.05$ by DeLong test). Calibration was reasonable, especially for lower scores, but due to small patient numbers at higher scores, CIs were quite wide (Figure S2). The best calibrated score was the original GWTG-HF predicting intensive care unit mortality. For all pairs, the Hosmer–Lemeshow P value was <0.001, reflecting loss of calibration at higher scores.

Patients with an *ICD-9* discharge diagnosis of heart failure were at higher risk of hospital mortality (11.4% versus 7.0%; unadjusted odds ratio, 1.72; 95% CI, 1.49–1.98; $P<0.001$). As shown in Table 3, all 3 heart failure risk scores had lower AUROC values for hospital mortality in patients with a discharge diagnosis of heart failure when compared with patients without a diagnosis of heart failure. Similarly, all 3 heart failure risk scores had lower AUROC values for hospital mortality in patients with a history of heart failure based on the Charlson Comorbidity Index (Table 3). Table 4 illustrates a multivariable logistic regression including the risk factors included in the GWTG-HF risk score as predictors of hospital mortality; notably, race and history of chronic obstructive pulmonary disease were not associated with hospital mortality ($P>0.05$).

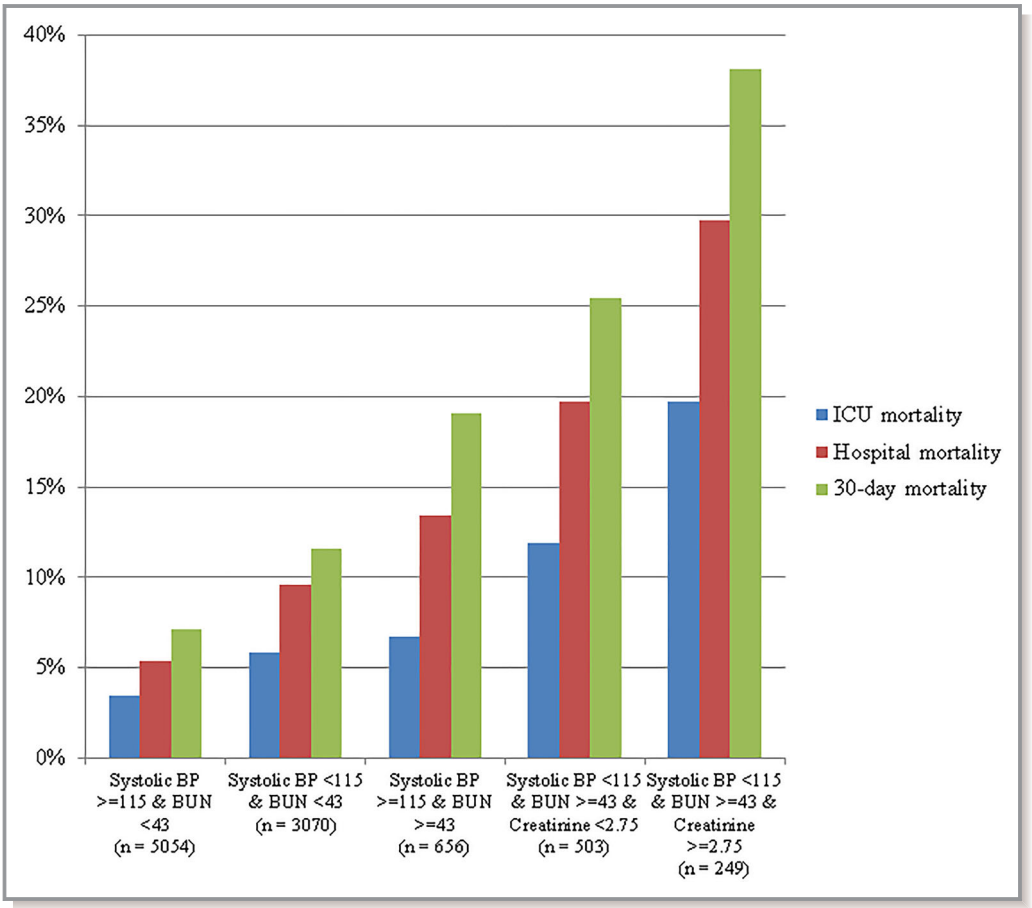

Figure 2. Inpatient mortality based on the ADHERE risk score. ADHERE indicates Acute Decompensated Heart Failure National Registry; BP indicates blood pressure; BUN, blood urea nitrogen; ICU, intensive care unit.

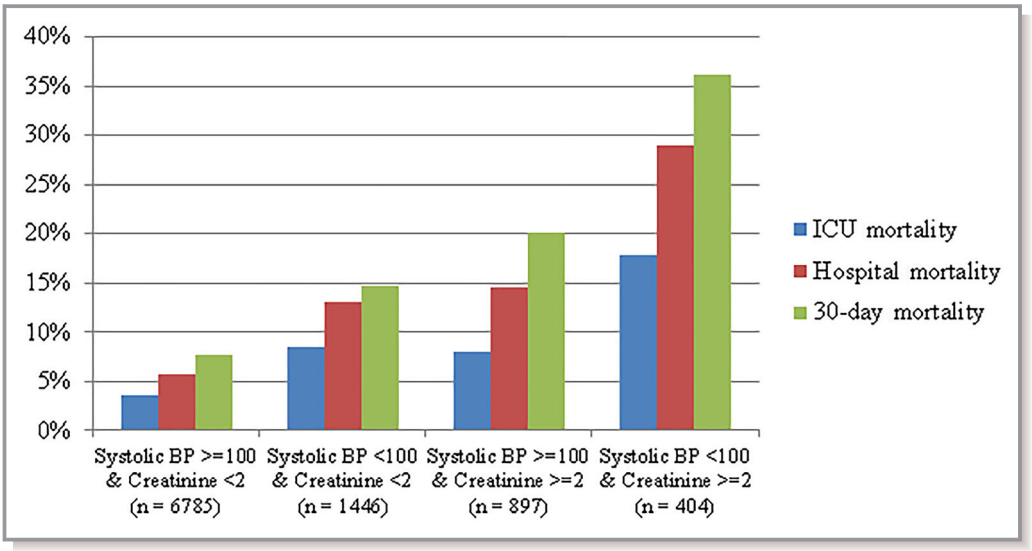

Figure 3. Inpatient mortality based on the OPTIMIZE-HF risk score. BP indicates blood pressure; ICU, intensive care unit; OPTIMIZE-HF, Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients With Heart Failure.

A total of 8704 (91.3%) patients survived to hospital discharge. Overall survival was 83.3% at 1 year by Kaplan–Meier analysis; 1207 (12.7%) patients had follow-up <1 year, including those lost to follow-up. Hospital survivors had lower postdischarge survival in each higher GWTG-HF risk score quartile by Kaplan–Meier analysis (Figure 4; $P<0.001$ by log-rank). Patients in the highest GWTG-HF risk score quartile had 1-year survival of only 52.8% by Kaplan–Meier analysis, including both hospital and postdischarge mortality. Using Cox proportional hazards models, each 1-point increase in the GWTG-HF risk score was associated with 8.1% higher long-term mortality (hazard ratio, 1.081; 95% CI, 1.077–1.084; $P<0.001$). Compared with GWTG-HF risk score quartile 1, long-term mortality was progressively higher in quartile 2 (hazard ratio, 1.894; 95% CI, 1.686–2.131; $P<0.001$), quartile 3 (hazard ratio, 3.130; 95% CI, 2.818–3.483; $P<0.001$), and quartile 4 (hazard ratio, 6.610; 95% CI, 5.961–7.329; $P<0.001$). Overall mortality for patients with a GWTG-HF risk score of ≥50 was 46.2% at 6 months and 54.0% at 12 months by Kaplan–Meier survival analysis.

Table 3. Discrimination for Hospital Mortality for Risk Scores Based on AUROC Values for Hospital Mortality on Univariable Analysis

Risk Score	All Patients N=9532 (100%)	Discharge Diagnosis of Heart Failure N=3746 (39.3%)	No Discharge Diagnosis of Heart Failure N=5786 (60.7%)
EFFECT risk score	0.72	0.67	0.73
OPTIMIZE-HF risk score	0.74	0.69	0.75
GWTG-HF risk score	0.73	0.69	0.75
Modified GWTG-HF risk score*	0.73	0.69	0.75

AUROC indicates area under the receiver operating characteristic curve; EFFECT, Enhanced Feedback for Effective Cardiac Treatment; GWTG-HF, Get With The Guidelines–Heart Failure; OPTIMIZE-HF, Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients With Heart Failure.
*Excluding race and history of COPD.

Discussion

To our knowledge, this is the first study comparing the use of heart failure risk scores to predict mortality in an unselected CICU population. This study examined the prognostic value of the GWTG-HF risk score for short- and long-term mortality in the current day CICU population, with a secondary analysis comparing the prognostic value of other heart failure risk prediction tools including EFFECT, OPTIMIZE-HF, and ADHERE. All heart failure risk scores provided similar, good discrimination for hospital mortality among unselected CICU patients that was close to the original reported c-statistics. Specifically, a higher GWTG-HF risk score was associated with higher short-term and long-term mortality, and patients in the highest GWTG-HF risk score quartile were at high risk of death during and after hospitalization.

Patients in the modern-day CICU are older with significantly more comorbidities, particularly left ventricular systolic and diastolic heart failure, emphasizing a need for improved risk stratification.[19,20] Identification of higher-risk patients sooner during their hospital course can facilitate early

Table 4. Multivariable Predictors of Hospital Mortality

Multivariable Predictors	Unit OR	95% CI	*P* Value
Age	1.022	1.017 to 1.027	<0.001
Nonblack race	2.025	0.805 to 5.093	0.134
Systolic BP	0.987	0.983 to 0.990	<0.001
Heart rate	1.014	1.011 to 1.016	<0.001
Sodium	0.972	0.958 to 0.988	<0.001
BUN	1.018	1.014 to 1.021	<0.001
Creatinine	1.087	1.020 to 1.155	0.0086
History of COPD	1.196	0.988 to 1.448	0.0664

BP indicates blood pressure; BUN, blood urea nitrogen; COPD, chronic obstructive pulmonary disease; OR, odds ratio.

initiation of second-line interventions such as pulmonary artery monitoring catheters, advanced mechanical support, and even palliative care consultation. Currently, there are no well-established risk stratification tools to predict inpatient mortality for all patients admitted to the CICU. The Sequential Organ Failure Assessment score was recently used for short-term mortality prediction for patients in the CICU, and it was determined that increasing Sequential Organ Failure Assessment scores over the first 3 CICU days were strongly predictive of increased short-term mortality risk. In this study, the observed discrimination of the Sequential Organ Failure Assessment score on CICU day 1 was significantly higher than that of the GWTG-HF risk score.[4] Overall, our prior studies in this CICU population examining the Acute Physiology and Chronic Health Assessment and Sequential Organ Failure Assessment scores demonstrated superior discrimination when compared with the GWTG-HF risk score, emphasizing the utility of these general intensive care unit risk scores in CICU patients.[4,21]

The common variables found in all of the heart failure risk scores examined in this study are also included in the Global Registry of Acute Coronary Events risk score for acute

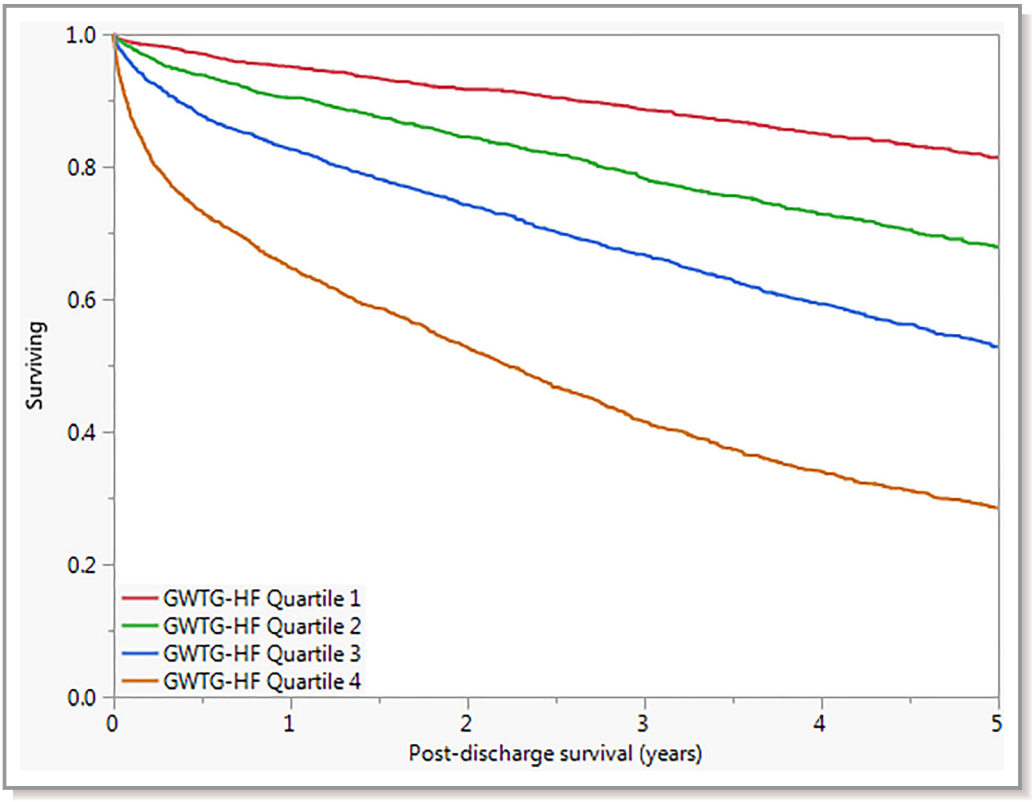

Figure 4. Postdischarge survival based on GWTG-HF risk score quartile. GWTG-HF indicates Get With The Guidelines–Heart Failure.

coronary syndromes and general ICU risk scores such as Acute Physiology and Chronic Health Assessment.[22,23] It is therefore not surprising that all these scores would be able to predict adverse outcomes in CICU patients, even among patient populations not targeted by the original score. Given the numerous disease-specific risk scores for acutely ill cardiac patients, it would be ideal to combine shared risk factors to develop a universal risk score for unselected CICU patients. Our study highlights the similarities in risk factors between patients with and without heart failure, which emphasizes the importance of a general risk prediction model in CICU patients rather than focusing on separate diagnostic subgroups. The CICU cohort is unique when compared with typical heart failure populations on the basis of the need for interventions such as mechanical ventilation, inotropes, and continuous renal replacement therapy; the addition of these ICU specific variables may improve discrimination when added to the GWTG-HF risk score. Also, calculating the GWTG-HF risk score at bedside can be cumbersome, so leveraging the electronic medical record and incorporating an online calculator may help with quick assessment.

Risk assessment scores have proven advantageous for predicting outcomes and identifying the need for escalation of care. However, previous studies have illustrated that risk scores work well on a population level, but are often not effective for use on an individual patient level.[24] It remains unclear how to leverage the GWTG-HF and other risk scores among hospitalized patients with heart failure, particularly in the CICU. Given the lack of definitive evidence-based medical or interventional therapies for the majority of patients with AHFS, it is unclear whether such a risk-based treatment approach can be used. For patients with the highest risk, consideration should be given to the need for advanced heart failure therapies and palliative care, depending on patient characteristics. Although the area under the curve values we observed using the GWTG-HF risk score in our unselected CICU cohort were similar to those previously reported in AHFS populations, the area under the curve value was unexpectedly lower in patients with HF. This may represent the challenges in risk stratification among critically ill CICU patients with HF, whose baseline mortality is higher and can be potentially influenced by candidacy for advanced HF therapies.

There are several limitations with this study, particularly those associated with retrospective, observational data from a single historical center. Mayo Clinic Rochester is a tertiary referral center with a large volume of patients, so this could have affected the characteristics of the patient population, making it distinct from other centers. This cohort of CICU patients was heterogeneous, with a smaller proportion of patients with a history of heart failure than expected. There is little ethnic diversity within this study population, which could limit the ability to apply the results and estimate the utility of the risk stratification tool for a broader population. A further limitation is the lack of left ventricular ejection fraction data in OPTIMZE, which does affect the accuracy of the OPTIMIZE scoring system. Also, the Hosmer–Lemeshow statistic has been shown to be sensitive to sample size and can suggest poor calibration in large populations such as this one with only minor deviations from ideal mortality prediction.[17]

Only discharge diagnoses were used, and not CICU admission diagnoses; these *ICD-9* codes for heart failure may not consistently differentiate acute versus chronic heart failure. Mortality was determined by chart review, and the use of electronic health record review instead of the National Social Security Death Index to determine patient death may underestimate postdischarge mortality by potentially failing to capture patients dying in other health systems; as such, the postdischarge mortality analysis should be considered exploratory. Another relevant limitation of this database study is the use of administrative data, which may be less accurate when compared with manual chart review.

Conclusions

The GWTG-HF risk score and other heart failure risk prediction tools demonstrate good discrimination for inpatient and 1-year mortality in a heterogeneous cohort of CICU patients, despite the majority being admitted for a diagnosis other than heart failure. These results emphasize that important prognostic clinical variables overlap among different groups of acutely ill cardiac patients, with certain parameters serving as markers for increased mortality in all patients in a manner that may allow development of a risk score that applies broadly to all CICU patients instead of patients with a specific admission diagnosis. Leveraging the electronic medical record to allow for an easily accessible tool that calculates risk, using common variables from heart failure risk scores such as the GWTG-HF risk score, and adding critical care therapies such as mechanical ventilation or inotropes may help with general risk prediction in CICU patients for better risk stratification. Better and more standardized risk assessment in the CICU population will allow for facilitation of second-line interventions and earlier involvement of palliative care if necessary and should be an area of future research.

Disclosures

None.

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Supplemental Material

Table S1. Most Predictive Clinical Parameters Utilized for Risk Prediction Models.

Risk Factor	ADHERE[1]	EFFECT[2]	OPTIMIZE[3]	GWTG[4]	GRACE[5]	TIMI[6]
SBP (mmHg)	X	X	X	X	X	
Heart rate, (bpm)			X	X	X	
Respiratory rate		X				
Age (years)		X	X	X	X	X
Black race				X		
BUN	X	X		X		
Creatinine (mg/dL)	X		X			
Sodium		X	X	X		
LV dysfunction (LVEF < 40%)			X			
Heart Failure (Killip Class)			X		X	
COPD				X		
3 risk factors for CAD (HTN, DM, HLD, Smoking)						X
Prior coronary artery stenosis						X
ST segment deviation					X	X
2 anginal episodes in 24 hours						X
Elevated serum cardiac biomarkers					X	X
Use of aspirin in past 7 days						X
Cardiac arrest					X	

SBP, systolic blood pressure; BPM, beats per minute; BUN, blood urea nitrogen;LV, left ventricular; COPD, chronic obstructive pulmonary disorder;CAD, coronary artery disease;HTN, hypertension;DM, diabetes mellitus; HLD, hyperlipidemia [1]ADHERE, The Acute Decompensated Heart Failure National Registry;[2]EFFECT, Enhanced Feedback for Effective Cardiac Treatment;[3]OPTIMIZE, Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure;[4]GWTG, Get With The Guidelines;[5]GRACE, The Global Registry of Acute Coronary Events;[6]The Thrombolysis in Myocardial Infarction

Figure S1. Flow diagram describing inclusion/exclusion criteria that defined the final study population.

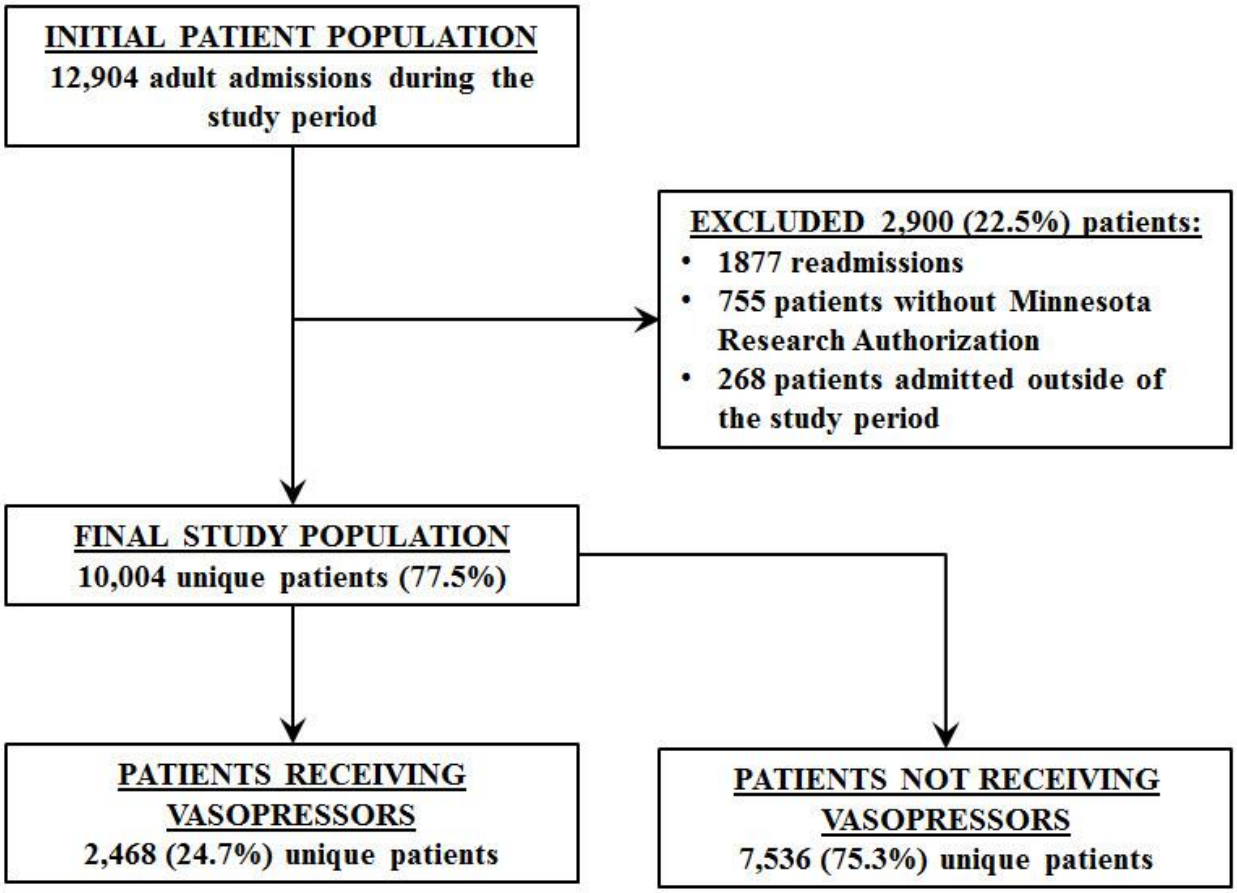

Figure S2. Calibration plot for GWTG-HF Scores for hospital mortality. Note that the event rate is zero for higher probabilities because per the definition of the GWTG score the maximum probability of death is 50%.