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# Risk Stratification for Acute Heart Failure in the Emergency Department

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## Abstract

### Background

Heart Failure (HF) is a primary diagnosis for hospital admission in adults from the Emergency Department (ED), but not all patients require hospitalization. Emergency Heart Failure Mortality Risk Grade (EHMRG) is designed to estimate mortality in patients with acute HF in ED settings.

### Objectives

To risk-stratify patients with acute HF using EHMRG scores and assess patient safety.

### Methods

Retrospective cohort analysis of 304 patients with acute HF presenting to an ED at a large tertiary healthcare center. EHMRG scores were calculated per previous thresholds. Mortality and Major Adverse Cardiac Event (MACE) rates were analyzed.

### Results

EHMRG risk group respective seven-day mortality rates 0.0% in very low and low-risk groups. Mortality and MACE rates are significantly less in lower-risk groups at 30 days.

### Conclusions

ED risk stratification with EHMRG has the potential to revolutionize care for patients with acute HF. Lower-risk patients may be safely discharged or treated in ED observation units (EDOUs).


**Keywords:** Heart Failure, Emergency Department, Emergency Heart Failure Mortality Risk Grade (EHMRG), Mortality, Risk stratification, Emergency Department Observation Unit (EDOU)

## Introduction

Heart Failure (HF) affects an estimated 6.2 million adults in the United States (US) and prevalence is increasing.[1] It is projected by 2050, that one in five people over the age of 65 will be diagnosed with HF.[2] Patients with acute HF often present to the Emergency Department (ED) to access care and more than 80% of these patients are admitted to the hospital.[3] HF is a leading cause of costly hospital admissions in adults greater than 65 years of age; however, up to 50% of hospital admissions for HF may not be required.[4 5] For patients diagnosed with HF, the age-adjusted all-cause mortality rate is tripled in comparison to patients without HF, yet this mortality risk is difficult for ED providers to quantify.[8 9] However, select patients with acute HF may be considered for direct discharge or management in an ED observation unit (EDOU) as an alternative option for care.[6]

EDOUs were created to care for patients that need further observation and/or treatment, but do not necessarily require admission to the hospital.[6] Common cardiac diagnoses managed in EDOUs include, chest pain, atrial fibrillation (AF), syncope, and lower risk patients with acute HF, as described in the literature.[6 9] Risk stratification in the form of an objective tool is a approach to assess patients in the ED with acute HF, to identify lower-risk patients that may be appropriate for further care in EDOUs.[6]

Emergency Heart Failure Mortality Risk Grade (EHMRG), a prospectively and externally validated risk stratification tool (RST), was developed specifically for patients with acute HF that present to ED settings.[7] Patients with acute HF are stratified with EHMRG into five risk groups according to projected seven-day mortality.[7] EHMRG was first assessed in 2012 with a derivation cohort of nearly 7500 patients and a validation cohort of approximately 5000 patients from 86 hospitals in Ontario, Canada.[7] Associated seven-day mortality in the risk groups was

reported as 0.3% (lowest risk), 0.3% (low risk), 0.7% (intermediate), 1.9% (high), 3.5% (very high A), and 8.2% (very high B) risk groups.[7] In 2019, the ACUTE study was completed as prospective validation of EHMRG scores in nine hospitals in Ontario, Canada.[9] With prospective validation, seven-day mortality rates were reported as 0.0%, 0.0%, 0.6%, 1.9%, and 3.9% for the five risk groups respectively.[9] It was determined that patients in lower-risk categories may be more appropriate for direct discharge from the ED or EDOU management.[6 9] Although the mortality risk associated with acute HF intensifies patient management, EHMRG is designed to enhance disposition planning in the ED to promote informed decisions.[9] Establishing mortality risk, in conjunction with early, aggressive treatment, may lead to improved management for patients with acute HF who present to the ED setting. [6 9] Combined with early post-discharge care, EHMRG can identify lower-risk patients that may be appropriate for discharge or management in an EDOU, as an alternative to hospital admission. The purpose of this study is to risk-stratify patients with acute HF using EHMRG scores in an ED in the United States (US), while assessing patient outcomes.

## Methods

A retrospective cohort analysis was conducted at a large Midwestern tertiary healthcare center to assess the use of EHMRG scores. The study sought to determine, in patients who present to the ED with acute HF, do EHMRG scores, compared to not using EHMRG scores, appropriately risk stratify patients to be treated in the EDOU without compromising patient safety, during a one-year retrospective study period? Institutional review board (IRB) review was sought at the healthcare institution and collaborating university. The project was deemed IRB exempt, minimal risk to human subjects, from by both institutions.

Patients presenting to the ED, from January 1, 2020 to December 31, 2020, with a diagnosis of acute HF were reviewed. Each patient ED visit for acute HF was included in the cohort study; therefore, some patients had multiple ED visits in the study period. More than 340 patient visits, as identified by the International Classification of Diseases, Tenth Revision (ICD-10) codes for heart failure, were reviewed. ICD-10 codes used for data extraction included, 150.2, 150.21, 150.22, 150.23, 150.31, 150.33, 150.41, 150.43, 150.811, 150.813, and 150.9. Patients with a missing variable were excluded as the EHMRG score could not be calculated. Patients without a primary diagnosis of acute HF, and those actively receiving dialysis or those enrolled in palliative care management were excluded, as previously described as exclusion criteria.[7] A patient research authorization was required to use patient data.

Patient characteristics and variables were extracted from the study cohort. A total of 10 variables deemed predictors of HF mortality in the ED are required to calculate EHMRG scores including, age, transported by EMS, triage systolic blood pressure, triage heart rate, triage oxygen saturation, creatinine, potassium, troponin greater than the upper limit of normal (ULN), active cancer, and metolazone use (a marker of diuretic resistance).[7] A clinician and trained study coordinator entered variables into a Research Electronic Data Capture (REDCap) database provided by the healthcare institution. REDCap is a secure, web-based software platform created to store and manage data collected for research.[10 11] A clinician manually reviewed electronic health records (EHR) regarding each patient visit to determine if patients met inclusion criteria for the cohort study. Additionally, any elevation of troponin was reviewed by a clinician to determine clinical significance in the setting of acute HF, in accordance with clinical use of high sensitivity troponins at the healthcare center.

Patients were categorized into five groups according to estimated mortality risk, from very low to very high risk, according to EHMRG thresholds defined in the original derivation/validation study.[7] EHMRG risk groups are defined as very low (scores less than or equal to - 49.1), low (scores - 49.0 to - 15.9), intermediate (scores - 15.8 to 17.9), high (scores 18.0 to 56.5), and very high-risk (scores 56.6 or greater). The very high risk group was further divided into A (scores 56.6 to 89.3) and B (scores greater than or equal to 89.4) subgroups to appreciate the B subgroup's extreme mortality risk.[7]

*Patient Outcomes as Measures of Safety*

Assessment of EHMRG scores in relation to patient outcomes measures were analyzed to determine safety. Mortality rates and Major Adverse Cardiac Event (MACE) rates at seven and 30 days post-discharge were obtained for each patient in the study cohort. In this cohort study, MACE rates were defined as acute myocardial infarction (MI); cardiac arrest; coronary revascularization via coronary artery bypass grafting (CABG), stent, or percutaneous coronary intervention (PCI); stroke; hospitalization for acute HF; and return to the ED for acute HF. MACE event rates were extracted by ICD-10 codes.

*Statistical Analyses*

Continuous features are summarized with medians and interquartile ranges (IQRs); categorical features are summarized with percentages. The frequency of patient mortality and MACE events at seven and 30 days were compared between EHMRG risk groups using odds ratios (ORs) and Wald's tests. For groups with zero outcomes, ORs were computed using the Haldane-Anscombe correction to avoid issues when dividing by zero.

The observed seven and 30-day mortality rate for each EHMRG risk group in this study was compared to mortality rates using pairwise Chi-squared and Fisher's exact tests. All tests were two-sided, and p-values less than 0.05 were considered significant.

## Results

The final study cohort was comprised of 304 patients. All participants were evaluated in the ED with a primary diagnosis of acute HF, at the tertiary health care center, during the one-year timeframe.

*Cohort Characteristics*

The study cohort had a median age of 77.5 years. Males comprised 53.6% of the study cohort, whereas females were 46.4%. Within the study cohort, race was described as 94.7% White and 5.3% Asian, Black/African American, or Other/Did Not Disclose. Details of ethnicity included 99% not Hispanic or Latino, and 1% Other. The median left ventricular ejection fraction was 50% (Table 1).

*EHMRG Risk Groups*

The median EHMRG score for the study cohort was 15.0. Within the study cohort, 12.8% of patients were very low-risk (median score of -71.0);18.8% low-risk (median score of -33.0); 20.1% intermediate risk (median score of 1.0); 19.1% high-risk (median score of 37.0); and 29.2% very high-risk. The very high group was further subdivided into very high A at 15.1% (median score 74.0) and very high B at 14.1% (median score of 119.0) in Table 1. Table 2 details variables of EHMRG scores by EHMRG risk groups.

*Cohort Hospitalization and Discharge Rates*

In the study cohort, more than 87% of patients with acute HF were admitted to the hospital. Whereas 8.6% of patients with acute HF were discharged from the ED. Patients with acute HF managed in the EDOU comprised 2.6% of the study cohort (Table 1).

*Mortality and MACE Rates*

Seven-day mortality rates in the very low and low-risk EHMRG risk groups were 0.0%. More than 90% of patient deaths within seven days post-discharge from the ED were in the very high A or very high B EHMRG risk groups. Mortality rates at 30 days were lowest in the very low and low risk groups. 77% of patient deaths within 30 days post-discharge from the ED were in the high and very high EHMRG risk groups. A linear increase in MACE event rates is reflected at seven days for all EHMRG risk groups, with the least number of events in the lowest EHMRG risk groups. Whereas MACE rates at 30 days for any event were lowest in the very low risk group. The results reflect a predominantly upward trend in MACE events as risk increases between the lower and higher risk groups, supporting that EHMRG scores can risk stratify for mortality and MACE events. Overall, lower risk EHMRG groups have lower mortality rates and less MACE events.

A comparison of EHMRG risk groups was completed. The highest EHMRG risk groups (very high A and B) have 27.1 times greater odds of seven-day mortality when compared to the other groups (95% CI 3.4 – 215.1, p = .002), and 3.76 times greater odds of 30-day mortality when compared to all other groups (95% CI 1.65 – 8.55, p = .002). Whereas the very low and low risk EHMRG groups have 74% decreased odds of experiencing 30-day mortality (OR 0.26, 95% CI 0.08 – 0.89, p = .031). The very low-risk EHMRG group also has a 60% decrease in odds of 30-day MACE events compared to all other risk groups (OR 0.40, 95% CI 0.16 – 0.99, p = .047).

## Discussion

The retrospective cohort study explores the utility of EHMRG scores within an ED in a large Midwestern tertiary healthcare center within the US. The project's importance is to obtain baseline clinical data to translate the use of EHMRG scores to clinical practice. Moreover, the association of mortality and MACE rates with EHMRG groups provides perspective toward future clinical use of EHMRG scores when determining the appropriate disposition for patients who present to the ED with acute HF.

*Opportunity for EDOU Management*

Consistent with the literature, 87.2% of patients in this cohort with acute HF in the ED at this healthcare center were admitted to the hospital. [3] However, 8.6% of patients with acute HF were discharged from the ED at this health care center which is lower than the average percentage of 16.3% reported at other US institutions.[12] The number of patients with acute HF admitted to the EDOU is minimal at 2.6%. All patients admitted to the EDOU were representative of the very low or low-risk groups, except one patient was from the intermediate risk group. Patients in the very low and low-risk groups comprise 31.6% of the study cohort; therefore, the potential for increased utilization of the EDOU to treat appropriate patients is an option. Associated seven-day mortality was 0.0% for both lower-risk groups. MACE rates were lowest in the very low and low groups at seven days post-discharge, supporting patient safety in lower-risk groups. Although some patient's scores may fit in the lower-risk EHMRG groups, clinical judgment from the emergency medicine or cardiology providers exceeds risk scores when determining if individual patients require hospital admission over management in an EDOU. It has been described that approximately 20% of patients managed in EDOUs may require hospital admission due to inadequate response to treatment or worsening clinical features necessitating hospital admission.[13] Patients with acute HF that exhibit high-risk features; cardiac ischemia or

arrhythmias; unstable hemodynamics; worsening comorbidities like renal dysfunction, hyponatremia, or exacerbations of other disease processes; require hospital admission.[13] Ultimately, the purpose of the EDOU is to identify changes in patient clinical status that warrant further investigation that may include hospitalization.

*Limitations*

There are several limitations to this retrospective analysis. First, the study cohort may not represent the entire population of patients presenting to the ED with acute HF at the healthcare center. Although the data were extracted according to ICD-10 codes, some patients may have been coded incorrectly. It is also possible that some patients with acute HF were not captured with the selected ICD-10 codes.

Another limitation was the patient cohort was reviewed by a clinician who manually entered data to calculate EHMRG scores. While this process provides consistency in using EHMRG scores, the interpretation was also limited by the clinician's judgment. Furthermore, an error in data entry could have occurred.

The retrospective review was restricted to one-year with approximately 300 patients. Although this provides baseline data to validate EHMRG scores in this study cohort in the US, a larger analysis is more desirable to obtain results that reflect a larger population of HF patients over an extended time. Lastly, the study cohort was quite homogeneous, as evidenced by race/ethnicity statistics from this Midwestern healthcare center. Overall, a larger, more diverse population is needed to further validate EHMRG scores in ED settings in the US.

*Clinical Implications*

EHMRG scores may be easily calculated as most of the variables are obtained through VS during triage, during patient history, or obtaining typical laboratory tests in the ED. However,

several common themes emerged during this analysis (Table 3). When patients are transported via EMS, an upload of initial VS in the EHR may be delayed. Access to the initial VS from EMS would improve the accuracy of this data. A process to obtain triage VS is essential for the clinical use of EHMRG, as it is recommended that initial triage VS should be used when available for the most accurate scores. [7]

The second theme identified that troponin values were not routinely drawn in every patient in acute HF as part of the laboratory assessment. Several patients were excluded in the retrospective review due to a missing troponin value. Further education of providers to obtain a baseline troponin values may improve the ability to calculate additional EHMRG scores.

A third theme is evolution of high sensitivity cardiac troponins (hs-cTnTs). At this healthcare center, the specific hs-cTnT assay was chosen for its accuracy in the evaluation of myocardial injury/infarction. [14] Although hs-cTnT is extremely sensitive for myocardial injury, it has been established that troponin elevation may be present due to various cardiac and non-cardiac reasons including HF, which is not determined by this test. [15] At this healthcare center an established protocol, which is known to the ED practice, using serial hs-cTnTs exists for evaluation of patients with elevated initial value. Serial hs-cTnT values are drawn at baseline, two hours, and six hours, while a delta change is calculated between samples. Elevation of serial troponins without a significant delta change were commonly seen in this study cohort of patients with acute HF. It was observed that nearly all patients in this study cohort had an elevation in hs-cTnT above the 99% percentile; however, this was reflective of chronic myocardial injury rather than an acute cardiac event. Therefore, according to the healthcare centers standard of practice, the majority of patients in the study cohort required a baseline and two-hour troponin, with an associated delta, to determine clinical significance in the setting of acute HF. An

algorithm to decipher low, intermediate, and high-risk hs-cTnT thresholds is already established. Delta change between serial troponin values, plus assessment of 12 lead electrogram (ECG), is defined to determine if the myocardial injury is acute. [14] Although no distinct thresholds for hs-cTnT have been established to reflect acute HF mortality, a well-defined algorithm has been designed for clinical use, which was followed to establish the clinical significance of troponin values for calculating EHMRG scores.

Patients with advanced stage three, four, or five chronic kidney disease (CKD), not receiving dialysis, often have elevations in hs-cTnTs that are well above the 99% percentile, without associated ischemic changes on 12 lead ECG or significant delta change in serial troponins. It has been established that patients with stable chronically elevated troponin levels without significant rise and fall between serial samples, exhibiting chronic hs-cTnT elevations greater than the 99$^{th}$ percentile, are most commonly associated with diagnoses of structural heart disease and/or chronic kidney disease. [16] Elevated hs-cTnT is associated with increased mortality; however, reasonable thresholds for hs-cTnT values in patients with advanced CKD are not clearly defined. More research is needed to quantify appropriate hs-cTnT cut-offs associated with mortality risk in patients with acute HF and CKD.

The final theme noted was that many patients are admitted with multifactorial dyspnea, including acute HF. Some patients may have associated pneumonia, COPD exacerbation, or atrial fibrillation, in addition to acute HF. Because they are all treated as potential causes of dyspnea, it may be unclear which diagnosis was of greater importance clinically.

In summary, these themes were identified during the retrospective analysis. Further clarification of the use of hs-cTnT with EHMRG will be help improve standardization when using EHMRG scores clinically.

*Thresholds for Adverse Events*

Thresholds for adverse event rates in patients treated in EDOUs for acute HF are recommended. Specifically, it is described EDOUs should aim to achieve a 30-day mortality rate of less than 2%, a seven-day ED revisit rate of less than 10%, and a 30-day ED/hospital revisit rate of less than 20% per expert opinion.[12] Patients in the lower EHMRG risk groups had associated seven-day mortality rates of 0.0%, which was also shown in the ACUTE study in 2019.[9] Mortality in the very high B group was much higher, which perhaps reflects the severe acuity of the highest risk group at this healthcare center. There were several patients in the highest risk groups that discharged from the hospital with hospice care that had anticipated mortality events within the next seven to 30 days. This may also reflect cultural differences in end of life care in different countries. Overall, a larger sample size for validation of these results is needed.

Publicly reported 30-day mortality rates for heart failure are benchmarked 11.3%.[17] The study cohort had a 30-day mortality rate of 8.6%, similar to the respective publicly reported rate at 9.1% at this health care center.[17] MACE rates were an addition to this study in an attempt to further clarify patient safety measures. Return ED visits rates at seven days was below the recommended threshold of 10%.[12] Thirty-day return to the ED visit rates were below the recommended 20%, whereas 30-day rehospitalization for HF rates were slightly higher than the recommended threshold of 20%. [12]

## Conclusion

Risk stratification with EHMRG was easily applied to a retrospective clinical population in an ED at a large Midwestern tertiary healthcare center in the US. The application of EHMRG at this healthcare center shows that mortality rates for lower EHMRG risk groups are similar to other studies. MACE rates in the study cohort were added as an additional measure of patient safety

which were consistent with the literature reflecting expert opinion and publicly available measures. Although the study cohort is a smaller sample and lacks generalizability to all patients with acute HF, results reflect that appropriate lower-risk patients, as stratified by EHMRG, have the potential to be safely managed in EDOUs. Furthermore, establishing specific inclusion/ exclusion criteria for EDOU, criteria for admission to the hospital or discharge home, and early follow-up care, is essential for this model of care to reduce unnecessary hospital admissions. Validation of mortality and MACE event rates in a larger sample of more diverse patients is recommended. Overall, clinical use of EHMRG should be considered as an automated process as a way to reduce hospital admissions and shift care to supportive outpatient environments for lower-risk patients.

Further research is also needed to determine safety with using hs-cTnT values to accurately reflect patient's seven-day mortality risk in acute HF and CKD. Although hs-cTnT is very sensitive and found to be elevated in multiple cardiac and non-cardiac conditions, it is also highly predictive of patient mortality.[15] Distinguishing thresholds for EHMRG risk groups will provide more accurate and replicable use of EHMRG in future studies.

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## Appendices

**Table 1. Cohort Characteristics**

| | |
|---|---|
| **Sex** | |
| Male | 53.6% |
| Female | 46.4% |
| **Age** – Median [IQR] | 77.5 [70.0, 84.2] |
| **Race** | |
| Asian | 5.3% |
| Black/African American | |
| Other/Did Not Disclose | |
| White | 94.7% |
| **Ethnicity** | |
| Not Hispanic or Latino | 99.0% |
| Other | 1.0% |
| **LVEF Percent** – Median [IQR] | 50.0 [32.0, 61.0] |
| **EHMRG Score** – Median [IQR] | 15.0 [-28.0, 69.2] |
| **EHMRG Risk Group** | |
| Very Low Risk | 12.8% |
| Low Risk | 18.8% |
| Intermediate Risk | 20.1% |
| High Risk | 19.1% |
| Very High Risk A | 15.1% |
| Very High Risk B | 14.1% |
| **ED Disposition** | |
| Admitted | 87.2% |
| Discharged | 8.6% |
| ED Observation Unit | 2.6% |
| Left Before Treatment/AMA | 1.6% |

IQR = Interquartile Range; LEVF = Left Ventricular Ejection Fraction; EHMRG = Emergency Heart Failure Risk Grade.
ED = Emergency Department; AMA = Against Medical Advice

**Table 2. EHMRG Variables by Risk Category**

| | EHMRG Risk Category | | | | | |
|---|---|---|---|---|---|---|
| | **Very Low** | **Low** | **Intermediate** | **High** | **Very High A** | **Very High B** |
| **Age** | 66 [58, 75] | 74 [67, 80] | 80 [70, 85] | 77 [71, 84] | 80 [75, 87] | 83 [78, 91] |
| **Arrival by EMS** | 3% | 12% | 25% | 47% | 65% | 79% |
| **SBP** | 157 [142, 175] | 141 [126, 153] | 139 [123, 153] | 130 [117, 153] | 135 [117, 153] | 122 [110, 143] |
| **Heart Rate** | 70 [65, 86] | 80 [65, 92] | 77 [70, 91] | 82 [66, 98] | 83 [70, 87] | 81 [68, 98] |
| **Oxygen Saturation** | 96 [93, 97] | 96 [94, 97] | 96 [93, 98] | 96 [94, 98] | 95 [90, 97] | 96 [93, 97] |
| **Creatinine** | 1.04 [0.91-1.24] | 1.06 [0.88, 1.24] | 1.13 [1.02, 1.53] | 1.42 [1.08, 2.09] | 1.56 [1.24, 2.13] | 1.91 [1.32, 2.56] |
| **Potassium** | | | | | | |
| < 4 mmol/L | 31% | 28% | 33% | 22% | 17% | 19% |
| 4-4.5 mmol/L | 59% | 51% | 38% | 40% | 44% | 21% |
| > 4.5 mmol/L | 10% | 21% | 30% | 38% | 39% | 61% |
| **Troponin** > ULN | 0% | 2% | 15% | 30% | 39% | 58% |
| **Active Cancer** | 0% | 4% | 7% | 7% | 15% | 30% |
| **Metolazone at Home** | 0% | 2% | 8% | 9% | 15% | 26% |
| **EHMRG Score** | -71 [-83, -64] | -33 [-42, -23] | 1 [-7, 10] | 37 [27, 48] | 74 [66, 84] | 119 [104, 150] |

EHMRG = Emergency Heart Failure Mortality Risk Grade; EMS = Emergency Medical Services; SBP = Systolic Blood Pressure; ULN = Upper Limit Normal

**Table 3. Common Themes with EHMRG Scores**

| Common Themes |
| --- |
| 1. Timely and accurate triage vital signs |
| 2. Missing troponin variable |
| 3. Use of high-sensitivity troponins in acute HF and advanced CKD |
| 4. Multifactorial dyspnea in the setting of acute HF |

HF = Heart Failure; CKD = Chronic Kidney Disease