# Safe Triage of STEMI Patients to General Telemetry Units After Successful Primary Percutaneous Coronary Intervention

John Z. Nan, MD; Jacob C. Jentzer, MD; Robert C. Ward, MD; Rachel J. Le, MD; Megha Prasad, MD; Gregory W. Barsness, MD; Rajiv Gulati, MD, PhD; Gurpreet S. Sandhu, MD, PhD; and Malcolm R. Bell, MD

## Abstract

**Objective:** To analyze outcomes of patients with ST-segment elevation myocardial infarction (STEMI) after successful primary percutaneous coronary intervention (PCI) triaged to the cardiac intensive care unit (CICU) vs a general telemetry unit by a Zwolle risk score−based algorithm.

**Methods:** We introduced a quality improvement protocol in 2014 encouraging admission of STEMI patients with Zwolle score of 3 or less to general telemetry units unless they were hemodynamically unstable. We subsequently conducted a retrospective single-center cohort study of consecutive STEMI patients who had undergone primary PCI from January 1, 2014, to December 31, 2018. Outcomes studied include immediate complications, need for urgent unplanned intervention, need for CICU care, length of hospitalization, and survival.

**Results:** We identified 547 patients, 406 with a Zwolle score of 3 or less. Of these, 192 (47.3%) were admitted to general telemetry and 214 (52.7%) to the CICU. Reasons for CICU admission included persistent chest pain, late presentation, and procedural complications. The average hospital length of stay was 2.1±1.4 days for non-CICU patients and 3.3±2.8 days for low-risk CICU patients ($P<.001$). Two patients initially admitted to general telemetry required transfer to the CICU. There were 26 patients who required unplanned cardiovascular intervention within 30 days, 5 from the general telemetry unit; 540 patients survived to discharge. One in-hospital death occurred among those initially triaged to the general telemetry unit, and this was due to a noncardiac cause.

**Conclusion:** A Zwolle score−based algorithm can be used to safely triage post-PCI STEMI patients to a general telemetry unit.

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From Department of Cardiovascular Medicine, Mayo Clinic, Rochester, MN (J.Z.N., J.C.J., R.C.W., G.W.B., R.G., G.S.S., M.R.B.); Providence Spokane Cardiology, Spokane, WA (R.J.L.); and Division of Cardiology, Columbia University, New York, NY (M.P.).

ST-segment elevation myocardial infarction (STEMI) accounts for approximately one-third of all acute coronary syndrome presentations, with overall incidence rate between 50 and 150 cases per 100,000 people per year.[1] Historically, STEMI was associated with a high rate of morbidity and mortality,[1] and as a result, most STEMI patients have traditionally been admitted to and managed in a coronary care unit or a cardiac intensive care unit (CICU) after such units were introduced for this purpose more than 50 years ago.[2] In recent years, primary percutaneous coronary intervention (PCI) has become the dominant and preferred mode of acute reperfusion in STEMI and is associated with excellent outcomes and few serious complications,[3-6] and close monitoring with telemetry has become feasible in non-CICU units. Despite these improvements in outcomes, most patients are still routinely admitted to the CICU and account for more than 15% to 25% of all CICU admissions in North America.[7,8] However, recent studies have suggested that most STEMI patients do not require intensive care interventions after primary PCI,[9] although other studies have suggested that the overall mortality for STEMI patients appears lower when they are admitted to the CICU.[10] The 2004 American College of


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Cardiology/American Heart Association guidelines recommend routine CICU admission after primary PCI for STEMI, although it is considered reasonable to admit low-risk patients directly to a step-down unit.[11] This was not mentioned in the 2013 updates. The 2017 STEMI guidelines from the European Society of Cardiology give a strong recommendation for admission to the CICU after reperfusion.[12] As such, opinions about the best disposition for patients after intervention for STEMI continue to differ.

Risk stratification algorithms for STEMI date back to the early days of the CICU with the introduction of the Killip classification.[13] The Zwolle risk score (Figure 1) is more recent and specifically applies to patients who have undergone successful primary PCI, integrating clinical risk factors with the Killip classification into a simple risk score that can readily identify low-risk patients.[14] Ebinger et al[15] implemented a triage protocol in 2013 using the Zwolle score, whereby admission of low-risk patients to a non-CICU telemetry unit was encouraged, and published an analysis in 2018 of 462 STEMI patients, 286 of whom were categorized as low risk and 177 of whom were admitted to general telemetry. This showed low rates of major adverse cardiovascular events in the low-risk cohort, with shorter length of stay and health care cost with admission to a lower acuity unit.

During the past 5 years, our institution has also triaged patients on the basis of a clinical algorithm incorporating the Zwolle risk score (Figure 2), allowing many low-risk patients (Zwolle score $\leq$3) to be admitted directly to the general telemetry unit rather than to the CICU. This study aimed to describe the clinical outcomes of STEMI patients who were admitted to the CICU or general telemetry unit based on the Zwolle score and to assess the safety and efficiency of this strategy.

## METHODS

### Population of Patients

This was a retrospective cohort study and was approved by the Mayo Foundation Institutional Review Board (19-004617). Consecutive adult patients who were admitted to Mayo Clinic Hospital, Saint Marys Campus (Rochester, Minnesota) after primary PCI for STEMI from January 2014 to December 2018 were included. Patients were identified through our catheterization laboratory database by query for diagnosis of STEMI and PCI.

Patients were excluded from this analysis if they did not provide consent for research or met any of the following definite indications for CICU admission: administration of fibrinolysis before PCI as part of a pharmacoinvasive approach (n=42), cardiac arrest before or during PCI (n=99), temporary pacemaker implantation (n=37), or any hemodynamic instability requiring inotropic or mechanical support (n=99).

General telemetry units were continuously staffed by cardiac nurses at a ratio of 3 to 5 patients per nurse and an attending cardiologist. All patients were monitored with continuous cardiac rhythm monitoring for the duration of their hospitalization. Oral and intravenous medications as well as heparin and nitroglycerin infusions where needed were able to be administered as indicated. The CICU was continuously staffed by ICU-trained nurses at a ratio of 1 to 2 patients per nurse and an intensive care cardiologist. All patients were continuously monitored with rhythm monitoring for the duration of their hospitalization. In addition, positive pressure ventilation, mechanical ventilation, temporary cardiac pacing, invasive hemodynamic monitoring, infusion of inotropic medications, and mechanical hemodynamic support were provided as indicated.

### Data Collection

Baseline demographics, medical conditions, and procedural variables were collected from review of medical records. Calculated Zwolle risk scores were also collected, with low risk defined as a Zwolle score of 3 or less. Patients were divided into 3 groups: low-risk patients admitted to the general telemetry unit; low-risk patients admitted to the CICU; and high-risk patients, defined as patients with a Zwolle score of more than 3 (all of whom were admitted to the CICU).

Recorded post-PCI outcomes included complication rates of recurrent myocardial infarction, heart failure, major arrhythmias (defined as sustained ventricular tachycardia, ventricular fibrillation, and high-grade heart block), need for unplanned repeated percutaneous or surgical intervention within 30 days, Zwolle score

| Variable | Points |
|---|---|
| Killip class | |
| I | 0 |
| II | 4 |
| III-IV | 9 |
| TIMI flow post PCI | |
| 3 | 0 |
| 2 | 1 |
| 0-1 | 2 |
| Age | |
| ≤60 yrs | 0 |
| >60 yrs | 2 |
| 3-vessel disease | |
| No | 0 |
| Yes | 1 |
| Anterior MI | |
| No | 0 |
| Yes | 1 |
| Ischemic time - onset of chest pain prior to PCI (excluded lytic-treated patients) | |
| ≤4 hours | 0 |
| >4 hours | 1 |

Killip class

| Variable | Clinical characteristics |
|---|---|
| Killip class | |
| I | No clinical signs of heart failure |
| II | Heart failure: S3, basal rales, venous hypertension |
| III | Severe heart failure: acute pulmonary edema |
| IV | Cardiogenic shock |

**FIGURE 1.** Zwolle score, Killip class variables, and calculation. MI, myocardial infarction; PCI, percutaneous coronary intervention; TIMI, Thrombolysis in Myocardial Infarction.

and need for transfer to the CICU as well as length of stay and survival to discharge and at 1 month and 12 months after initial presentation based on electronic chart review. In-hospital death was determined by chart review, and post-discharge survival data were extracted from the Mayo Clinic electronic databases, the State of Minnesota electronic death certificates, and the Rochester Epidemiology Project database.[16]

### Statistical Analyses

Continuous variables are presented as mean ± standard deviation unless otherwise specified and compared by Student *t*-tests. Categorical variables are presented as percentages and compared by $\chi^2$ tests or Fisher exact tests when applicable. Multivariate Cox regression analysis was adjusted for baseline demographics and comorbidities, and Kaplan-Meier analysis was used to assess event-free survival, accounting for all mortality as well as need for urgent unexpected procedures. C statistics were performed to confirm correlation of the Zwolle score with outcomes as well as to analyze optimal cutoff values for the score. *P* values below .05 were considered statistically significant. Statistical analysis was performed using R statistical software (version 3.4.2; R Foundation for Statistical Computing).

## RESULTS

### Study Population

Of the 547 eligible STEMI patients identified, 406 (74.2%) patients had a Zwolle score of 3 or less, and 192 (47.3%) of these low-risk patients were admitted directly from the cardiac catheterization laboratory to the general telemetry unit. Reasons for admission of low-risk patients to the CICU are shown in Figure 3 and included persistent chest pain or ST-segment elevation, late presentation, and procedural complications. Nearly one-third (30.8%) of low-risk patients admitted to the CICU did not have a clearly documented reason for admission to the CICU, although most of these admissions (77.3%) occurred

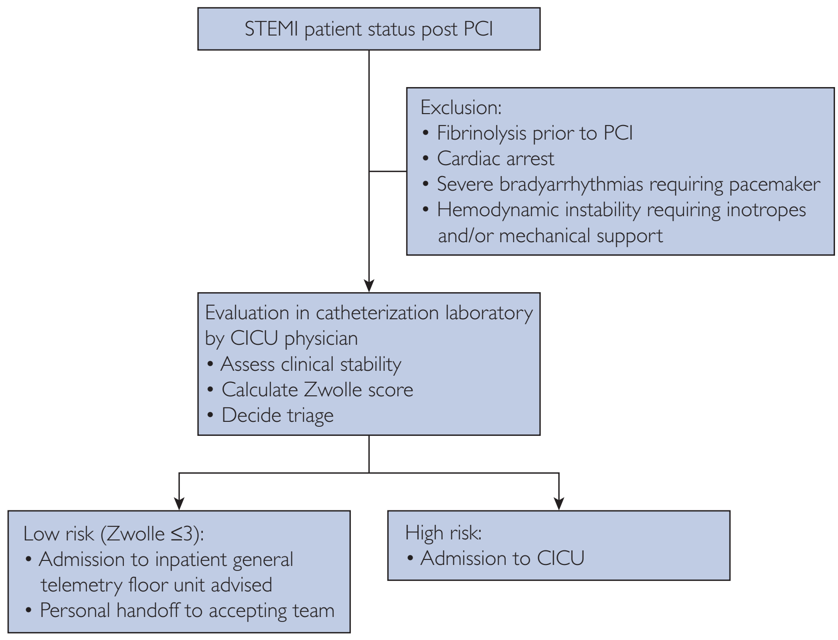


**FIGURE 2.** Mayo Clinic triage protocol (first introduced in 2014) for patient disposition after primary percutaneous coronary intervention (PCI) for ST-segment elevation myocardial infarction (STEMI) to determine admission to the cardiac intensive care unit (CICU) vs general telemetry unit.

within the first year of implementation of our triage protocol, suggesting lack of adherence to the new protocol as the most likely contributor. All patients were treated at the discretion of the inpatient cardiologist with guideline-directed medical therapy, including dual antiplatelet therapy as well as beta blockers, angiotensin system blockers, and diuretics where indicated.

### Clinical Characteristics

Baseline characteristics of these groups were compared; similar age, ethnic background, disease distribution, and comorbidities were found between the low-risk general telemetry unit group and the low-risk CICU group. In the high-risk group, there was similar ethnic background, more female patients, and older age and more left anterior descending artery disease. Comorbidities of the groups were also compared; similar rates of smoking and dyslipidemia and higher rates of hypertension, diabetes, prior cardiovascular disease, and late presentation (>4 hours after onset of symptoms) were found in the high-risk group (Table 1).

### Hospital Course

Among patients with low Zwolle scores who were initially admitted to the CICU, the average length of stay was 3.3±2.8 days, including 1.7±1.6 days of CICU stay before transfer to the general telemetry unit (n=141) or direct discharge from the hospital (n=73). The average length of stay was significantly shorter for patients admitted to the general telemetry unit (2.1±1.4 days; $P<.001$; Table 2). Two patients (1.3%) admitted initially to the telemetry unit were subsequently transferred to the CICU during their hospitalization, 1 patient because of severe alcohol withdrawal and the other because of transient recurrent ST-segment elevation on electrocardiography without new coronary lesions on repeated angiography. Patients admitted to the CICU with high Zwolle scores (n=141) had a longer length of stay of 4.4±3.8 days ($P=.003$ compared with patients with low Zwolle scores admitted to the CICU), including 1.8±2.0 days in the CICU before transfer to the general unit; there was no difference in length of CICU stay before

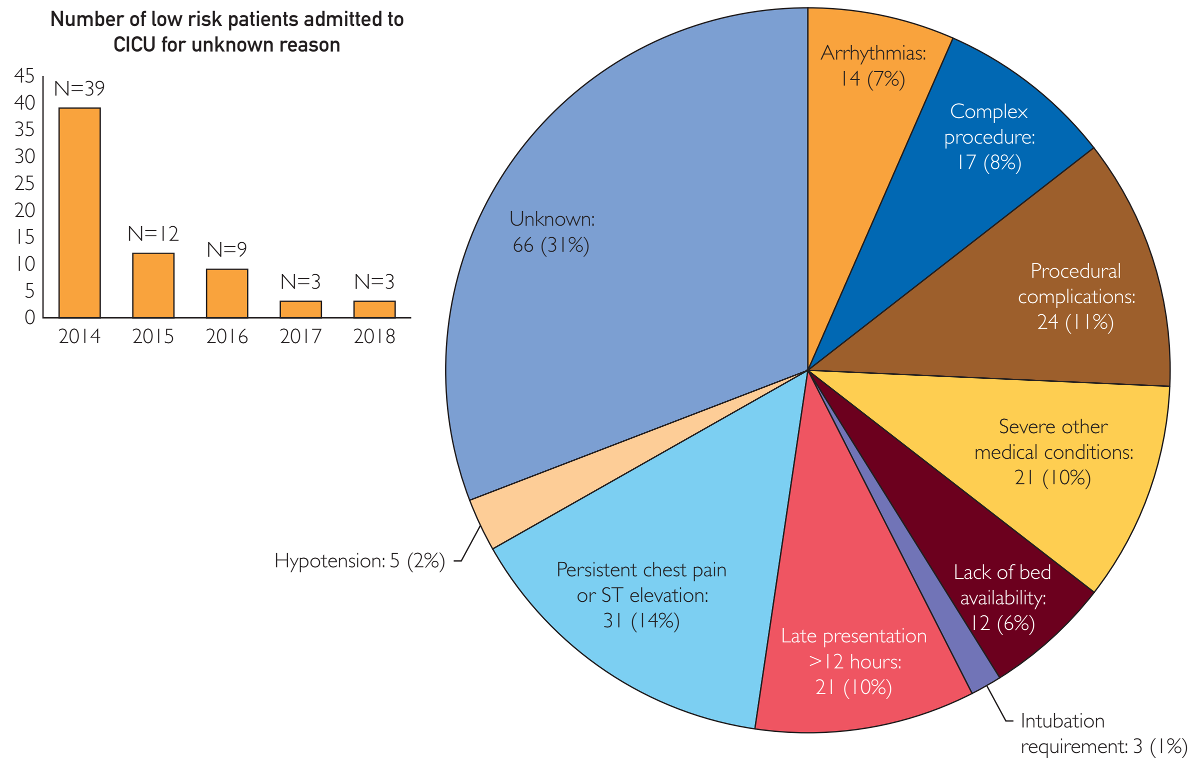


**FIGURE 3.** Patients admitted to the cardiac intensive care unit (CICU) with low-risk scores for unknown reasons by year of presentation (left). Reasons for CICU admission among patients with low Zwolle scores (right).

transfer between low-risk and high-risk patients admitted to the CICU.

### Unplanned Procedures

There were 26 (4.8%) patients who had unplanned urgent cardiovascular procedures within 30 days (Table 3), 13 (50%) of which were during the index hospitalization. These included 5 (2.6%) patients in the low-risk group admitted to the general telemetry unit, 13 (6.1%) low-risk patients admitted to the CICU, and 8 (5.8%) patients in the high-risk group. There were no clinically notable delays to procedures in patients admitted to the general telemetry units. Of the patients admitted to the CICU with low Zwolle scores, 2 patients (1%) required urgent critical care interventions, with both surviving hospitalization. One patient had high-degree atrioventricular block requiring placement of a temporary pacemaker, and the other had a pulseless electrical activity cardiac arrest that required temporary support with extracorporeal membrane oxygenation (repeated angiography revealed no new lesions).

### Survival

Survival to discharge was seen in 98.5% of the entire population. In-hospital deaths (1.5% of all patients) included 1 (0.5%) patient with a low Zwolle score admitted to the general telemetry unit and 6 (4.3%) patients with a high Zwolle score; no patient with a low Zwolle score who was admitted initially to the CICU died (Table 3). The sole in-hospital death in the group with a low Zwolle score resulted from respiratory complications of advanced squamous cell carcinoma of the lung.

In-hospital death and other complications increased as a function of the Zwolle score (C statistic = 0.762 for mortality), with most adverse events occurring in high-risk patients with Zwolle scores higher than 3 and a very


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**TABLE 1. Baseline Characteristics of the Study Population[a,b]**

| | Low Zwolle score (≤3) | | |
|---|---|---|---|
| | General telemetry | CICU | High Zwolle score (>3) |
| Total patients | 192 | 214 | 141 |
| Male | 140 (72.9) | 158 (73.8) | 89 (63.1) |
| White | 183 (95.9) | 205 (95.8) | 134 (95.0) |
| Age (y) | 62.2±12.5 | 62.8±13.4 | 71.9±12.9 |
| Smoking | | | |
| Current | 61 (31.8) | 74 (34.6) | 40 (28.4) |
| Former | 61 (31.8) | 60 (28.0) | 43 (30.5) |
| Hypertension | 126 (65.6) | 143 (66.8) | 108 (76.6) |
| Dyslipidemia | 137 (71.4) | 143 (66.8) | 101 (71.6) |
| Diabetes | 49 (25.5) | 54 (25.2) | 46 (32.6) |
| Prior CV disease | 55 (28.6) | 62 (29.0) | 58 (41.1) |
| Late presentation | 15 (7.8) | 25 (11.7) | 24 (17.0) |
| Ejection fraction (%) | 55±9 | 53±10 | 45±11 |
| Culprit vessel | | | |
| LM | 0 | 1 (0.5) | 0 |
| LAD | 61 (31.8) | 66 (30.8) | 89 (63.1) |
| LCx | 26 (13.5) | 29 (13.6) | 16 (11.3) |
| RCA | 101 (52.6) | 107 (50.0) | 25 (17.7) |
| Graft | 2 (1.0) | 6 (2.8) | 7 (5.0) |
| Ambiguous | 2 (1.0) | 5 (2.3) | 4 (2.8) |

[a]CICU, cardiac intensive care unit; CV, cardiovascular; LAD, left anterior descending coronary artery; LCx, left circumflex coronary artery; LM, left main coronary artery; RCA, right coronary artery.
[b]Categorical variables are presented as number (percentage). Continuous variables are presented as mean ± standard deviation.

high risk of in-hospital mortality (36.4%) among the minority of patients with a Zwolle score of 10 or lower. C statistics were also performed for different Zwolle score cutoff values, with the optimal point confirmed to be a Zwolle score of 3 or less in our cohort (C index, 0.725). In-hospital deaths and other complications also increased as a function of the Killip class (C statistic = 0.612 for mortality), with a very low rate of adverse events among patients assigned to Killip class I or class II (Figure 4).

Kaplan-Meier analysis found lower event-free survival (accounting for all mortality as well as need for urgent unexpected procedures) in patients with high Zwolle scores in the hospital, at 30 days, at 1 year, and on long-term follow-up for the duration of the

**TABLE 2. Patient Outcomes Including Overall Length of Stay, Length of CICU Stay, and Need to Transfer to CICU if Initially Triaged to a General Telemetry Unit[a,b]**

| | Low Zwolle score (≤3) | | | |
|---|---|---|---|---|
| | General telemetry | CICU | High Zwolle score (>3) | *P* value[c] |
| Length of stay (days) | 2.1±1.4 | 3.3±2.8 | 4.4±3.8 | <.001 |
| Length of CICU stay (days) | N/A | 1.7±1.6 | 1.8±2.0 | |
| Transfer to CICU | 2 (1.0) | N/A | N/A | |

[a]CICU, cardiac intensive care unit; N/A, not applicable.
[b]Categorical variables are presented as number (percentage). Continuous variables are presented as mean ± standard deviation.
[c]Low Zwolle score in general telemetry unit vs low Zwolle score in CICU.

**TABLE 3. Patient Outcomes Including Requirement for Unplanned Urgent Procedures and Mortality as well as Event-Free Survival Probability Accounting for Both Procedure Requirement and Mortality[a]**

| | Low Zwolle score | | |
|---|---|---|---|
| | General telemetry (n=192) | CICU (n=214) | High Zwolle score (n=141) |
| Unplanned urgent procedure | 5 (2.6%) | 13 (6.1%) | 8 (5.7%) |
| PCI for in-stent thrombosis | 3 | 6 | 1 |
| Revascularization of nonculprit lesion | 1 | 1 | 5 |
| Repeated angiography, no new disease | 1 | 3 | 1 |
| Pacemaker implantation | 0 | 1[b] | 0 |
| Mechanical circulatory support | 0 | 1[c] | 0 |
| Cardiac surgery | 0 | 0 | 1[d] |
| Other vascular procedures | 0 | 1[e] | 0 |
| In-hospital mortality | 1 (0.5%) | 0 | 6 (4.3%) |
| 30-day mortality | 1 (0.5%) | 0 | 9 (6.5%) |
| Event-free survival probability at 30 days (95% CI) | 0.96 (0.94-0.99) | 0.93 (0.90-0.97) | 0.87 (0.82-0.93) |
| 1-year mortality | 3 (1.7%) | 3 (1.6%) | 26 (19.7%) |
| Event-free survival probability at 1 year (95% CI) | 0.95 (0.92-0.98) | 0.92 (0.88-0.96) | 0.75 (0.68-0.83) |

[a]CICU, cardiac intensive care unit; PCI, percutaneous coronary intervention.
[b]High-degree atrioventricular block.
[c]Extracorporeal membrane oxygenation for cardiac arrest.
[d]Ventricular free wall rupture repair.
[e]Thrombectomy for stroke.

study (Figure 5; $P<.001$ by log-rank). In addition, patients with low Zwolle scores initially admitted to the CICU overall had similar event-free survival outcomes compared with patients with low Zwolle scores initially admitted to the general telemetry unit ($P=.14$ by log-rank).

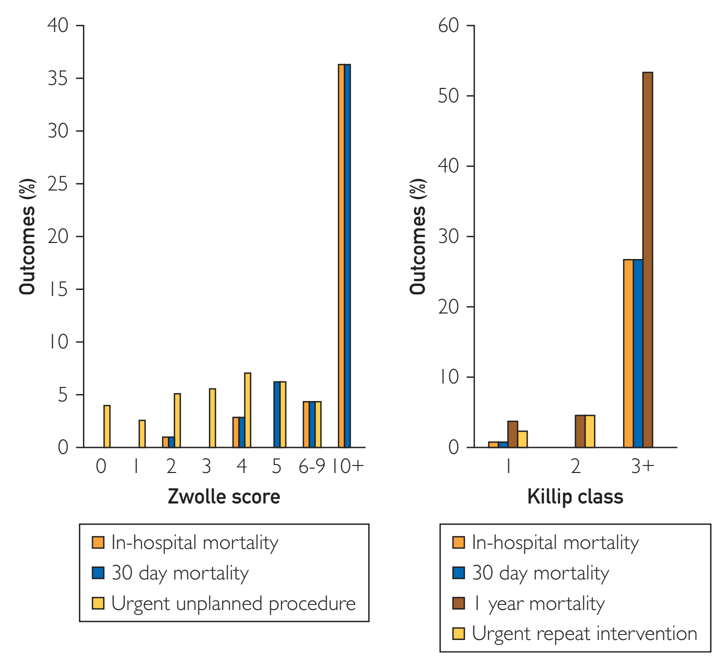


**FIGURE 4.** Mortality and need for urgent procedures on follow-up based on Zwolle score and Killip class at time of initial intervention.

Multivariate Cox regression was performed between the groups for baseline demographics including sex, race, hypertension, dyslipidemia, diabetes, tobacco use, and history of prior cardiovascular disease, confirming these results after adjustment for these covariates.

## DISCUSSION

There are several key findings in this study. First, we confirmed that a low Zwolle score is associated with a low overall mortality rate after successful primary PCI for STEMI. Second, we found that low-risk patients who were admitted to a general telemetry unit had low event rates during their hospitalization and on subsequent follow-up. Third, we found that admission to the CICU was associated with longer length of hospitalization even in low-risk patients.

In this study of STEMI patients who underwent primary PCI, we found that a low Zwolle score of 3 or less is associated with low risk of mortality in the hospital, at 30 days, and at 1 year regardless of initial

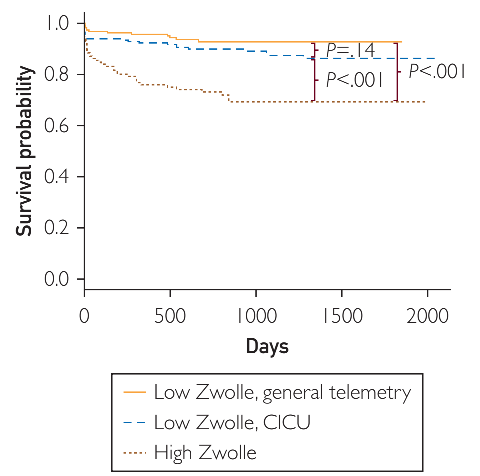


**FIGURE 5.** Kaplan-Meier analysis for event-free survival, accounting for all mortality as well as need for urgent repeated procedures. CICU, cardiac intensive care unit.

admission to CICU vs general telemetry unit. A high Zwolle score of 3 or more is associated with a higher risk of mortality at all time points. Adverse outcomes appeared to be most associated with a very high Zwolle score (≥10). In our cohort of 406 patients, we did not observe any cardiovascular deaths among patients with a Zwolle score of 3 or less or Killip class I. The use of the Zwolle score appears to be a feasible option in predicting which hemodynamically stable STEMI patients can be safely triaged to the general telemetry unit after successful primary PCI. In addition, admission to the CICU was associated with longer length of hospital stay among low-risk patients, including an average of 2 days in the CICU before transfer to the general telemetry unit. Appropriate triage of these patients to the telemetry unit initially may have significantly decreased length of stay and utilization of resources without compromising care.

Mortality and morbidity in patients presenting with STEMI have dramatically improved during the past decades, with 6-month mortality decreasing from more than 15% in 1995 to approximately 5% in 2015.[6] Increases in general awareness as well as improvements in rapid diagnosis, transportation of patients to PCI-capable centers, and overall door-to-balloon time have significantly improved outcomes and decreased the incidence of mechanical complications that cause substantial morbidity and mortality, such as free wall rupture, ventricular septal defects, and papillary muscle rupture.[3,6]

Recent publications have reported that few patients admitted to the CICU after primary PCI for STEMI required critical care[9] and that hospitalization on a lower acuity unit was associated with shorter length of stay and lower cost.[15] Although monitoring for ventricular arrhythmias was an initial justification for CICU admission after STEMI, Vallabhajosyula et al[17] found that only 0.5% of all STEMI patients suffered in-hospital cardiac arrest after primary PCI, with most of these events (>80%) occurring on the first day of hospitalization, and Al-Hijji et al[18] found that only 7% of all STEMI patients had any telemetry alarm that was deemed actionable during their hospitalization. However, Valley et al,[10] using the Medicare database, argued that among hospitals where more than 85% of STEMI patients were admitted to the CICU after primary PCI, those patients had lower mortality compared with the minority of patients admitted to the floor according to an instrumental variable analysis. As these studies did not elaborate on the rationale for triaging patients to the CICU vs general telemetry unit, there is still uncertainty about the optimal triage of patients after PCI for STEMI.

In our study, 65% of included STEMI patients were admitted to the CICU, with more than half of those patients determined to be low risk on the basis of Zwolle scores. Our study found that regardless of admission to CICU vs general telemetry unit, the Zwolle score reliably identified patients with low risk of mortality. This study finds that low-risk patients with a Zwolle score of 3 or less or Killip class I can be safely managed on a general telemetry unit after successful PCI, which avoids use of intensive care resources and potentially shortens overall length of stay in the hospital without significantly increasing the risk for adverse outcomes.

More than half of patients with low Zwolle scores who met the inclusion and exclusion criteria in our study were still admitted to the CICU rather than to the general unit. Common reasons for this were persistent chest pain or persistent ST-segment elevation after PCI; very late presentation; and procedure-related complications, including coronary perforation, distal embolization, and access site injury. The increased number of patients with residual symptoms or procedural complications in this group may explain the observed increased rate of unplanned urgent procedures, which consisted largely of need for repeated angiography. Exceedingly few (1%) of these patients required critical care interventions, although it is difficult to project the outcomes of this group of patients to whether they had been initially admitted to the general telemetry unit instead of to the CICU.

There are several limitations to this study. This was a retrospective single-center analysis at a large tertiary care academic medical center with a mature STEMI program, and it may not be able to be generalized to all PCI centers. A main limitation was the significant number of patients with low Zwolle scores who were admitted to the CICU without clearly documented reasons. This raises the potential for unmeasured confounders in interpreting the outcomes and complications rates. In addition, the rate of adverse outcomes and complications were low across the groups in this single-center study, and a larger sample size would be needed to help determine potential adjustments to our triage algorithm or Zwolle score cutoff to better predict patients who would benefit from higher level of care; it might also be beneficial to compare the performance of the Zwolle score with other risk scores, such as the second Primary Angioplasty in Myocardial Infarction (PAMI II) score,[19] in this triage algorithm. Furthermore, this study must be interpreted with the understanding that we systematically excluded unstable patients from this analysis and that these patients should be cared for in the CICU regardless of Zwolle score.

## CONCLUSION

Our study finds that a Zwolle risk score–based algorithm can be used to triage stable low-risk patients to a general telemetry unit rather than to the CICU after successful primary PCI for STEMI, with low frequency of mortality and major complications. The shorter hospital length of stay observed in this group emphasizes the potential safety and conservation of resources associated with this approach. Further analysis is needed to prospectively confirm our findings and to identify other clinically relevant risk factors in addition to the Zwolle score to improve the reliability of the algorithm.

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Abbreviations and Acronyms: **CICU**, cardiac intensive care unit; **PCI**, percutaneous coronary intervention; **STEMI**, ST-segment elevation myocardial infarction

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Correspondence: Address to John Z. Nan, MD, Mayo Clinic, 200 First St SW, Rochester, MN 55905 (Nan.John@mayo.edu; Twitter: @JohnNanMD).

ORCID

John Z. Nan: https://orcid.org/0000-0002-0450-0964; Jacob C. Jentzer: https://orcid.org/0000-0002-6366-2859; Robert C. Ward: https://orcid.org/0000-0001-8115-413X; Gregory W. Barsness: https://orcid.org/0000-0002-6353-6780

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