ORIGINAL RESEARCH

Using the Zwolle Risk Score at Time of Coronary Angiography to Triage Patients With ST-Elevation Myocardial Infarction Following Primary Percutaneous Coronary Intervention or Thrombolysis

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BACKGROUND: The Zwolle Risk Score was designed to identify the risk of complications in patients with ST-segment–elevation myocardial infarction (STEMI) following percutaneous coronary intervention (PCI). Its utility following PCI in STEMI treated with thrombolysis is unknown. The objective was to evaluate the safety of using the Zwolle Risk Score to triage patients with STEMI following PCI, including patients receiving thrombolysis.

METHODS AND RESULTS: Patients aged ≥18 years with STEMI and primary PCI or PCI after thrombolysis were included. A triage protocol was developed, with high-risk patients those with Zwolle Risk Score ≥4 triaged to the cardiac intensive care unit. A prospective evaluation of the triaging protocol was performed on 452 patients, mean age 65±12 years, 73% men. Median Zwolle Risk Score was 3 (interquartile range, 2–5), with 257 low-risk (57%), and 195 high-risk (43%) patients. Adherence to the protocol was 91%. In-hospital mortality was 0.4% in low-risk and 13% in high-risk patients (P<0.001). Seventy-two patients (16%) received thrombolysis. Median time post-thrombolysis to PCI was 281 minutes (interquartile range, 219–376). In-hospital mortality was 0% versus 9% (P=0.083) for low- and high-risk patients, respectively. High-risk patients had higher rates of cardiogenic shock (34% versus 1%, P<0.001), pulmonary edema (60% versus 9%, P<0.001), arrhythmia (25% versus 2%, P<0.001), blood transfusion (10% versus 2%, P<0.001), and stroke (4% versus 0.4%, P=0.011). Median hospital costs decreased by $1419 per low-risk patient after protocol implementation.

CONCLUSIONS: For patients with STEMI following primary PCI or PCI following thrombolysis, a Zwolle-based triaging system is safe and may decrease cardiac intensive care unit usage costs.

Key Words: cardiac intensive care • PCI • percutaneous coronary intervention • quality • ST-elevation myocardial infarction • STEMI • thrombolitics • Zwolle risk score
use of ICU for patients with STEMI internationally and within Canada, with two thirds of Canadian patients with STEMI receiving ICU-level care.

Since the 1990s, concurrent to improvements in timing of revascularization, in-hospital clinical outcomes in patients with STEMI have improved despite a relative increase in age, comorbidities, and body mass index. More recently, this temporal trend for in-hospital mortality has plateaued, even as door-to-balloon times have improved. Studies show that patients with STEMI who require intubation or who suffer cardiac arrest have markedly worse outcomes than those who do not. When adjusted for these high-risk characteristics, the in-hospital mortality of patients with STEMI undergoing PCI has continued to improve. Meanwhile, critical care bed capacity and resource scarcity are especially contemporaneous considering the current pandemic. Strategies to reduce ICU utilization in a crisis surge capacity involves a hospital-wide effort. This may involve re-assignment of cardiac ICU (CICU) beds and redeployment of ICU staff. The development of safe triaging protocols is key to identifying ways to preserve ever-shrinking CICU capacity for patients who truly benefit.

The Zwolle Risk Score (ZRS) was designed to identify patients with STEMI at time of coronary angiography who are at risk of in hospital complications (Table 1). The parameters of the ZRS suggest that a more profound or extensive myocardial injury results in a poorer short-term prognosis. It has been validated for identifying patients with low-risk STEMI for early discharge, and several studies have evaluated its use in triaging stable patients with STEMI after primary PCI to the telemetry ward instead of the intensive care unit.

The utility of the ZRS is for patients with STEMI who undergo early PCI following thrombolysis is currently unknown. Moreover, a contemporary assessment of the effects of a STEMI triaging protocol on CICU-specific utilization and costing during an era of relentless ICU scarcity has yet to be performed. We adopted a ZRS-based triaging protocol to include patients with STEMI receiving both primary PCI or early PCI following thrombolysis to determine safety, feasibility, and cost of this system-level intervention.

Table 1. Zwolle Risk Score Variables

| Points | Points |
|---|---|
| Killip class | | |
| 1 | 0 |
| 2 | 4 |
| 3–4 | 9 |
| TIMI flow post | | |
| 3 | 0 |
| 2 | 1 |
| 0–1 | 2 |
| Age, y | | |
| <60 | 0 |
| ≥60 | 2 |
| 3-vessel disease | | |
| No | 0 |
| Yes | 1 |
| Anterior infarction | | |
| No | 0 |
| Yes | 1 |
| Ischemia time >4 hours | | |
| No | 0 |
| Yes | 1 |

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TIMI indicates thrombolysis in myocardial infarction.
METHODS

The present study comprised a sequential retrospective run-in feasibility study and a prospective evaluation of a single-center standardized triaging protocol based on the ZRS. Both phases included all adult patients aged ≥18 years who presented to a single tertiary care center (St. Boniface Hospital, Winnipeg, Canada) with a diagnosis of acute STEMI. Patients were excluded if no PCI was performed, if the patient had a diagnosis other than STEMI, if the patient died before having been triaged, if the patient was admitted to ICU before cardiac catheterization, or if the patient was already in an ICU setting at the time of STEMI diagnosis. The study design and protocol were approved by the University of Manitoba Bannatyne Campus Health Research Ethics Board (Ethics # HS23533 H2020:002) and the St. Boniface Hospital Research Review Committee. The requirement for informed consent was waived. The data, analytic methods, and study materials that support the findings of this study are available from the corresponding author upon reasonable request.

In the run-in phase from September 1, 2019 to October 31, 2019, the ZRS was computed for all patients meeting study criteria. This score was computed immediately following PCI by the interventional cardiologist based on history, physical examination, and angiographic images at time of coronary intervention.9 During this run-in phase, all patients with STEMI were sent to the CICU subsequent to coronary intervention, as per the existing hospital policy. Demographic and clinical information were collected retrospectively. Left ventricular ejection fraction and end diastolic pressure were obtained from the left heart catheterization report. Data for in-hospital clinical course, including in-hospital complications and survival, were also gathered from hospital records. Thrombolysis in Myocardial Infarction (TIMI) Risk Score for STEMI was computed retrospectively, as previously described.12

Procedural success was <50% residual stenosis with antegrade TIMI flow grade 3 at the end of the procedure. An in-hospital complication requiring ICU level of care was defined as death, cardiac arrest, post-admission shock, stroke, significant arrhythmia, or post-admission respiratory failure.2 Significant arrhythmia was defined as ≥3 seconds of electrical pause or asystole, high-grade Mobitz type II atrioventricular block or complete heart block, ventricular fibrillation, sustained ventricular tachycardia.13 Respiratory failure was defined as acute respiratory distress syndrome, acute respiratory failure, respiratory arrest, or mechanical ventilation.14 Cardiogenic shock was defined as a systolic blood pressure of <90 mm Hg for >30 minutes or needing infusion of catecholamines to maintain a systolic pressure >90 mm Hg, having clinical signs of pulmonary congestion, and having impaired end-organ perfusion.15 A patient was considered to have pulmonary edema if there was a clinical diagnosis of acute cardiogenic pulmonary edema or pulmonary edema shown by a chest radiograph.16 At our center, all patients received chest radiographs on the day of cardiac catheterization. Renal replacement therapy was any dialysis or hemofiltration including continuous hemofiltration and hemodialysis, intermittent hemodialysis, and peritoneal dialysis.

An existing protocol for triaging patients with STEMI following PCI was evaluated.11 This triaging protocol cut point was designed to minimize in-hospital mortality in patients considered low-risk. Review of outcomes in the retrospective analysis revealed that a ZRS <4 portended no in-hospital deaths; accordingly, this was chosen as the cut-off for our protocol. Patients were considered high-risk if ZRS ≥4 or if the patient had cardiac arrest at time of presentation or in the cardiac catheterization laboratory, although the interventional cardiologist could decide to admit to CICU at their discretion. The rationale for admitting low-risk patients to CICU was tracked separately. Patients considered high-risk were triaged to the CICU. Those considered low-risk were transferred to a cardiology telemetry unit.

The hospital-wide triaging protocol was implemented on November 12, 2019. Before the protocol, all patients with STEMI were admitted to CICU, and none to the telemetry ward. There was a hospital-wide change in bed management policy after institution of the protocol, with the designation of at least 1 and up to 3 existing telemetry beds as reserved for the patients with STEMI. If these telemetry beds were full at the end of a working day, then the ward charge nurse would save new open telemetry beds for patients with STEMI when other patients were routinely discharged or transferred. A prospective evaluation was performed from November 12, 2019 to July 31, 2020. Adherence to the triaging protocol was tracked and routine feedback to cardiac care providers was provided to promote the usage of the triaging protocol. Clinical outcomes were defined, and data collected as in the run-in phase. The primary outcome for the prospective phase was in-hospital mortality. Individual secondary outcomes were red blood cell transfusion, cardiogenic shock, renal replacement therapy, significant arrhythmia, and stroke. ICU-level complications, as defined previously, was a secondary composite outcome.

The costs represented in this study represent how much the hospital paid, on average, to provide care for a patient. Accordingly, the direct costs for each individual patient were an average cost per “bed day”, calculated based on the funding allocation for a given hospital ward. The overall funding allocation accounted for non-physician staffing, supplies, equipment, and other miscellaneous costs. Physician remuneration was not included in this cost estimate. This average
Increased rates of cardiogenic shock (40% versus 0%, \( P<0.001 \)), and arrhythmia (11% versus 0% \( P=0.016 \)). Of the 6 patients with in-hospital mortality, causes of death were cardiac arrest (2 patients, 33%), cardiogenic shock (1 patient, 17%), gastrointestinal bleeding (1 patient, 17%), hypoxic respiratory failure (1 patient, 17%), and ischemic encephalopathy (1 patient, 17%). Total length of stay was higher in the high-risk group (4 days; IQR, 3–5) compared with the low-risk group (3 days; IQR, 2–3; \( P=0.003 \)). There was no difference in ICU length of stay between high-risk (24 hours; IQR, 22–49) and low-risk (23 hours; IQR, 21–27) groups (\( P=0.179 \)).

**Prospective Phase**

The ZRS-based triaging protocol was implemented on November 12, 2019. Of the 533 patients assessed, a total of 452 patients were included (Figure 1). Mean age was 65±12 years and 73% were men (Table 2). Of the 81 patients excluded, 50 patients (62%) did not have an STEMI, 24 patients (30%) did not undergo PCI, and 7 patients (9%) were triaged before the performance of a diagnostic coronary angiogram. Median Zwolle was 3 points (IQR, 2–5), with 257 low-risk (57%) and 195 high-risk (43%) patients (Figure 2) (Figure S1).

In the protocol phase, 27 patients (6%) died in hospital, at a median of 3 (IQR, 1–10) days. In-hospital mortality was 0.4% (1 patient) in low-risk and 13% (26 patients) in high-risk patients (\( P<0.001 \)). There was 1 additional death at 30 days, in the high-risk group. Causes of in-hospital death include cardiogenic shock (11 patients, 41%), ischemic encephalopathy (8 patients, 30%), cardiac arrest (3 patients, 11%), respiratory failure (2 patients, 7%), hemorrhage (2 patients, 7%), and sepsis (1 patient, 4%). The 1 low-risk patient (0.4%) who died in hospital was a 62-year-old man admitted for anterolateral STEMI, with a ZRS of 3. On admission day 2, he was found in pulseless electrical activity for which cardiopulmonary resuscitation was not successful. The etiology of cardiac arrest was not elucidated, as necropsy was not performed.

High-risk patients had higher rates of cardiogenic shock (34% versus 1%), pulmonary edema (60% versus 9%), arrhythmia (25% versus 2%, \( P<0.001 \)), blood transfusion (10% versus 2%, \( P<0.001 \)), and stroke (4% versus 0.4%, \( P=0.011 \)) (Figure 3). In high-risk patients, there was a trend toward increased renal replacement therapy (2% versus 0.4%, \( P=0.090 \)) and repeat myocardial infarction (2% versus 0.8%, \( P=0.243 \)) (Table S1). There was a total of 18 patients (4%) receiving any mechanical cardiac support (not mutually exclusively consisting of 18 intra-aortic balloon pump, 1 ventricular assist device, 1 venoarterial extracorporeal membrane oxygenation), all in the high-risk group. Among patients receiving mechanical cardiac support,
15 patients (83%) had mechanical support inserted at time of initial angiogram and 3 patients (17%) had mechanical support later in hospitalization. Only 1 low-risk patient (0.4%) was transferred to CICU after an initial telemetry ward admission. This patient was a 63-year-old man who presented with inferior STEMI. He was admitted to a low-risk unit based on a ZRS of 2 but was subsequently transferred to CICU on admission day 1 for undifferentiated hypotension, transiently requiring vasopressor support. Repeat urgent coronary angiogram showed no new obstructive lesions or angiographic complications. The patient was discharged home without any ICU-level complications after 48 hours of admission.

Protocol deviations in which a patient was admitted to a unit other than the one assigned by the ZRS-based protocol occurred in 41 patients (9%). Forty protocol deviations occurred for low-risk patients assigned to the CICU, and 1 protocol deviation occurred for a high-risk patient sent to the telemetry ward. Reasons for protocol deviations included bradycardia (9 patients, 22%), glycoprotein IIb/IIIa inhibitor infusion (7 patients, 17%), ventricular tachycardia (5 patients, 12%), PCI-related complications (5 patients, 12%), bleeding (3 patients, 7%), ongoing chest pain (2 patients, 5%), hypotension (2 patients, 5%), hypertensive emergency (1 patient, 2%), left ventricular aneurysm (1 patient, 2%), aspirin desensitization (1 patient, 2%), and not specified (5 patients, 12%). When comparing low-risk patients assigned to telemetry to those low-risk patients assigned to CICU (Figure 4), those assigned to CICU had a higher rate of ICU-level care complications (13% versus 2%, P<0.001). There was no statistical difference in other individual adverse outcomes between the 2 low-risk groups based on location, although there was a trend toward higher cardiogenic shock (3% versus 0%, P=0.16) and renal replacement therapy (3% versus 0%, P=0.16) in low-risk patients assigned to CICU.

Seventy-two patients (16%) received thrombolysis. Median age was 64±12 years, with 72% men. All patients receiving thrombolysis had subsequent PCI, with 59% patients having rescue PCI versus 41% having early facilitated PCI after successful lysis. The median time from thrombolysis to PCI was 281 minutes (IQR, 219–376, n=56). Median ZRS was 3 points (IQR, 2–4). There were 40 low-risk (56%) and 32 high-risk (44%) patients. Among patients having rescue PCI, 23 patients (53%) were low-risk and among patients with facilitated PCI, 17 patients (58%) were low-risk (p for difference=0.67). There were 5 protocol violations (7%) among patients with thrombolysis. In-hospital mortality was 0% in low-risk and 9% in high-risk patients (P=0.083). Among patients with thrombolysis, high-risk patients had higher rates of cardiogenic shock (22% versus 0%, P<0.001), pulmonary edema (66% versus 5%, P<0.001), and composite ICU-level care complications (44% versus 5%, P<0.001) (Table S2). There was a non-significant trend in high-risk patients for arrhythmia (22% versus 5%, P=0.068) and stroke (6% versus 0%, P=0.194).

The AUC for ZRS as a predictor of in-hospital mortality (Figure 5) was 0.91 (95% CI, 0.88–0.94). In comparison, the AUC for the TIMI Risk Score as a predictor of in-hospital mortality was 0.85 (95% CI, 0.82–0.88), with no statistical difference (P=0.358). The AUC as a predictor of ICU-level care complications was 0.81 (95% CI, 0.77–0.84) for ZRS and 0.77 (95% CI, 0.74–0.80) for the TIMI Risk Score (P=0.092).
Table 2. Characteristics of Low-Risk and High-Risk Patients With STEMI by Modified Zwolle Risk Score

| Protocol                        | Low-risk (n=257) | High-risk (n=195) | P value |
|--------------------------------|------------------|------------------|---------|
| Age, y (SD)                    | 63 (±12)         | 68 (±12)         | <0.001  |
| Men (%)                        | 183/257 (71%)    | 146/195 (75%)    | 0.386   |
| BMI, kg/m² (SD)                | 29.3 (±6.2)      | 28.6 (±5.3)      | 0.691   |
| Hypertension (%)               | 143/257 (56%)    | 120/195 (62%)    | 0.208   |
| Diabetes (%)                   | 65/257 (25%)     | 63/195 (32%)     | 0.101   |
| Dyslipidemia (%)               | 107/257 (42%)    | 97/195 (50%)     | 0.086   |
| Current smoker (%)             | 93/257 (36%)     | 49/195 (25%)     | 0.012   |
| Family history of coronary disease (%) | 56/257 (22%) | 35/195 (18%) | 0.313   |
| Peripheral vascular disease (%) | 5/257 (2%)      | 6/195 (3%)       | 0.439   |
| Chronic kidney disease (%)     | 19/257 (7%)      | 25/195 (13%)     | 0.054   |
| Previous percutaneous coronary intervention (%) | 31/257 (12%) | 30/195 (15%) | 0.306   |
| Previous coronary bypass (%)   | 4/257 (2%)       | 8/195 (4%)       | 0.095   |
| FMC-PCI time, mins (IQR)       | 97 (71–141)      | 108 (79–160)     | 0.069   |
| Killip class (%)               |                  |                  | <0.001  |
| I                              | 257/257 (100%)   | 106/195 (54%)    |         |
| II                             | 0/257            | 43/195 (22%)     |         |
| III–IV                         | 0/257            | 46/195 (24%)     |         |
| TIMI-STEMI score, points (IQR) | 3 (1–4)          | 5 (4–7)          | <0.001  |
| Triple-vessel disease (%)      | 22/257 (9%)      | 52/195 (27%)     | <0.001  |
| Anterior infarct (%)           | 55/257 (21%)     | 114/195 (58%)    | <0.001  |
| Ischemic time ≥4 h (%)         | 100/257 (39%)    | 142/195 (73%)    | <0.001  |
| Presenting cardiac arrest (%)  | 0/257            | 51/195 (26%)     | <0.001  |
| Zwolle risk score, points (IQR)| 2 (1–3)          | 5 (4–8)          | <0.001  |
| Thrombolysis (%)               | 40/257 (16%)     | 32/195 (16%)     | 0.808   |
| Procedural success* (%)        | 252/257 (98%)    | 143/195 (73%)    | <0.001  |
| Maximum troponin T, ng/L (IQR) | 1684 (495–4768)  | 4345 (1933–7811) | <0.001  |
| Maximum creatine kinase, U/L (IQR) | 736 (231–1522) | 1395 (736–3289) | <0.001  |
| LVEDP, mm Hg (IQR)             | 19 (14–25)       | 22 (18–30)       | <0.001  |
| LVEF <40% (%)                  | 7/179 (4%)       | 23/100 (23%)     | <0.001  |

BMI indicates body mass index; FMC-PCI, first medical contact to percutaneous coronary intervention; IQR, interquartile range; LVEDP, left ventricular end-diastolic pressure; LVEF, left ventricular ejection fraction; and TIMI-STEMI, thrombolysis in myocardial infarction ST-Elevation Myocardial Infarction.

*Procedural success: less than a <50% residual stenosis with antegrade TIMI flow grade 3 at the end of the procedure.

Total length of stay was higher in the high-risk (3 days; IQR, 3–6) compared with the low-risk (3 days; IQR, 2–3) group (P<0.001). Based on local data compiled during the study period, the daily cost for 1 day of admission in the CICU was $1969 and the cost for 1 day of admission on the telemetry ward was $550. The median cost of hospitalization was $3069 for low-risk patients before the triaging protocol implementation, and $1650 for low-risk patients after protocol implementation. Differences in median hospital costs for low-risk patients between low-risk patients before and after implementation of the protocol reveal real cost savings of $1419 per low-risk patient.

DISCUSSION

The results of this study show that the application of the ZRS is a safe, discriminative tool for identifying patients with STEMI suitable for admission to a telemetry unit. This includes patients with STEMI with PCI after thrombolysis. The triaging protocol we presented stratifies patients by risk of in-hospital mortality and in-hospital complications, with a low rate of protocol deviation.

There has been only 1 previously published prospective evaluation of the ZRS to triage stable patients with STEMI undergoing primary PCI.11 Similarly using a ZRS cutoff of ≥4 as high-risk, the authors showed that in a cohort of 549 patients, patients with high ZRS had a significantly higher rate of complications and in-hospital mortality; this study was limited by a low adherence of 62% to the triaging protocol among low-risk patients. Further, the motivations for protocol deviations were not recorded, leaving speculation as to which reasons guided clinical decision making. This is in contrast to our study, which had a low protocol deviation rate. A retrospective Australian study of 183 patients with STEMI receiving primary PCI evaluated the feasibility of using the ZRS to identify patients with low-risk STEMI10; this proved lower composite adverse outcomes, length of stay, and mortality among low-risk patients at 30 days. This study showed an excellent area under the ROC of the ZRS for 30-day mortality of 0.98, which approximates the area under the ROC for in-hospital mortality of 0.91 in our population. Other non-Zwolle based approaches to triaging patients with STEMI exist. The PAMI-II (Primary Angioplasty in Myocardial Infarction) trial identified low-risk patients as those with age <70 years, left ventricular ejection fraction >45%, 1- or 2-vessel disease, successful PCI, and no persistent arrhythmias; subsequently those patients were randomized to a non-ICU setting and were discharged at 3 days. There were no differences in in-hospital mortality or complications between those assigned to a non-ICU or ICU setting. This study was limited in that less than half of patients...
identified were categorized as low-risk and contraindications to discharge at 3 days were present in 25% of those patients. Despite these efforts at identifying non-ICU dispositions for patients with STEMI, international guidelines on hospital disposition for patients with STEMI continue to recommend routine ICU care for all patients with STEMI.

To our knowledge, our study is the only ZRS-based triaging protocol to include patients undergoing early PCI after thrombolysis. We showed that a ZRS-based triaging protocol identified patients with thrombolysis at risk of cardiogenic shock, pulmonary edema, and ICU-level complications. This paralleled the risk stratification offered by the ZRS-based protocol for patients with primary PCI only. While the trend toward higher in-hospital mortality among patients with high-risk thrombolysis was not statistically significant, no patients died in the low-risk group receiving thrombolysis. Hence the generalizability of findings for in-hospital mortality may be limited in this population of patients with thrombolysis. Nonetheless, we included only patients with thrombolysis who had coronary angiography before being triaged. While the ZRS was developed for and validated only in patients undergoing primary PCI, it has been established that other risk scores have showed good discrimination in patient outcomes regardless of whether the patient had thrombolysis or not. For instance, the TIMI Risk Score has been validated in patients with STEMI who received thrombolysis and in patients with primary PCI. In our study, the c-statistic for both hospital mortality and ICU-level complications was higher with the ZRS than with the TIMI Risk Score. This suggests that in our patient population combining both primary PCI and thrombolysis, the ZRS was as good as the TIMI Risk Score in discriminating in-hospital risk.

Our study protocol allowed for interventional cardiologist discretion in triaging patients, regardless of ZRS. Protocol deviations to the triage assigned by the ZRS occurred in only 9% of all patients and 16% of low-risk patients, demonstrating excellent adherence to the triaging protocol at time of angiography. Overwhelmingly, the protocol deviations were low ZRS patients who were sent to the CICU on account of being considered high-risk by the interventional cardiologist. Just over one third of the patients sent to CICU despite a low ZRS had

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**Figure 2.** Risk and ward triage assignment of low-risk (Zwolle Risk Score <4) and high-risk STEMI (Zwolle Risk Score ≥4) patients by modified Zwolle Risk Score protocol.

*ICU-level care complication—death, cardiac arrest, post-admission shock, stroke, significant arrhythmia, or post-admission respiratory failure. ASA indicates aspirin; CICU, cardiac intensive care unit; GpIIb/IIIa, glycoprotein IIb/IIIa Inhibitor; LV, left ventricle; and PCI, percutaneous coronary intervention.
arrhythmia (bradycardia or ventricular tachycardia) immediately before or during coronary angiography. Given that low-risk patients sent to CICU had higher combined ICU-level complications and a trend to higher rates of other complications compared with low-risk patients sent to the telemetry ward, there are aspects of risk not captured by the ZRS that have important prognostic value. Identifying and incorporating risk factors not identified by the ZRS could further refine the protocol and reduce the need for interventional cardiologist-led protocol deviations, potentially further improving participation in standardized clinical pathways.

Several limitations reduce the generalizability of our study. First, all low-risk patients in our single-center study were subsequently admitted to a telemetry ward in the same hospital that PCI was performed. Although this was the regional model used in our center, the reality may be different elsewhere, where large complex regional models with repatriation to the referral hospital may predominate. The present study did not evaluate which patients with STEMI may be suitable for transfer to other centers with telemetry. Differences in expertise and equipment from the PCI-capable center may result in differences in patient outcomes, although limited data suggest that there are no differences in in-hospital mortality for repatriated patients. Further refinement of the triaging protocol can be evaluated to accommodate a distributed healthcare model, including regional models with multiple other telemetry-capable centers. Second, patients receiving thrombolysis but no immediate PCI, were not included in this study. Excluding patients by timing of early angiography post-thrombolysis could portend bias in patient selection. Those who

Figure 3. Outcomes of low-risk (Zwolle Risk Score <4) and high-risk STEMI (Zwolle Risk Score ≥4) patients by modified Zwolle Risk Score protocol.
*ICU-level care complication—death, cardiac arrest, post-admission shock, stroke, significant arrhythmia, or post-admission respiratory failure.

Figure 4. Outcomes of low-risk STEMI patients by location.
*ICU-level care complication—death, cardiac arrest, post-admission shock, stroke, significant arrhythmia, or post-admission respiratory failure.
The study was self-funded.

Disclosures
None.

Supplemental Material
Tables S1–S2
Figure S1

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CONCLUSIONS
Prospective evaluation of a cohort of patients with STEMI reveals that the use of a ZRS-based triaging system at time of coronary angiography is safe, feasible, and cost-effective for patients receiving primary PCI or PCI after thrombolysis.

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SUPPLEMENTAL MATERIAL
Table S1. Outcomes of Low-Risk and High-Risk STEMI Patients by Modified Zwolle Risk Score Protocol.

| Outcome                              | Low-Risk (n = 257) | High-Risk (n=195) | P-Value |
|--------------------------------------|--------------------|-------------------|---------|
| RBC Transfusion (%)                  | 5/257 (2%)         | 19/195 (10%)      | < 0.001 |
| Cardiogenic Shock (%)                | 1/257 (0.4%)       | 66/195 (34%)      | < 0.001 |
| Pulmonary Edema (%)                  | 22/257 (9%)        | 117/195 (60%)     | < 0.001 |
| Renal Replacement Therapy (%)        | 1/257 (0.4%)       | 4/195 (2%)        | 0.128   |
| Arrhythmia (%)                       | 6/257 (2%)         | 48/195 (25%)      | < 0.001 |
| Stroke (%)                           | 0/257 (0%)         | 6/195 (1%)        | -       |
| ICU-Level Care Complication (%)*     | 10/257 (4%)        | 98/195 (50%)      | < 0.001 |
| In-Hospital Death (%)                | 1/257 (0.4%)       | 26/195 (13%)      | < 0.001 |

*ICU-level care complication - death, cardiac arrest, post-admission shock, stroke, significant arrhythmia, or post-admission respiratory failure

**Adjusted for sex

RBC – Red Blood Cell, ICU – Intensive Care Unit

Odds ratios represent the increased odds of experiencing a clinical outcome in the high-risk versus low-risk cohort.
Table S2. Outcomes of Low-Risk and High-Risk STEMI Patients Receiving Thrombolysis by Modified Zwolle Risk Score Protocol.

| Outcome                                | Low-Risk (n = 40) | High-Risk (n = 32) | P-Value |
|-----------------------------------------|-------------------|--------------------|---------|
| RBC Transfusion (%)                     | 2/40 (5%)         | 2/32 (6%)          | 0.818   |
| Cardiogenic Shock (%)                   | 0/40 (0%)         | 7/32 (22%)         | < 0.001 |
| Pulmonary Edema (%)                     | 2/40 (5%)         | 21/32 (66%)        | < 0.001 |
| Renal Replacement Therapy (%)           | 0/40 (0%)         | 0/32 (0%)          |         |
| Arrhythmia (%)                          | 2/40 (5%)         | 7/32 (22%)         | 0.068   |
| Stroke (%)                              | 0/40 (0%)         | 2/32 (6%)          | 0.194   |
| ICU-Level Care Complication (%)*        | 2/40 (5%)         | 14/32 (44%)        | < 0.001 |
| In-Hospital Death (%)                   | 0/40 (0%)         | 3/32 (9%)          | 0.083   |

*ICU-level care complication - death, cardiac arrest, post-admission shock, stroke, significant arrhythmia, or post-admission respiratory failure

RBC – Red Blood Cell, ICU – Intensive Care Unit
ICU-level care complication - death, cardiac arrest, post-admission shock, stroke, significant arrhythmia, or post-admission respiratory failure

* ICU-level care complication - death, cardiac arrest, post-admission shock, stroke, significant arrhythmia, or post-admission respiratory failure