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Improved Survival Associated With Pre-Hospital Triage Strategy in a Large Regional ST-Segment Elevation Myocardial Infarction Program

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Objectives This study sought to compare the 1-year survival of patients diagnosed with ST-segment elevation myocardial infarction (STEMI) and transferred via pre-hospital triage strategy for primary percutaneous coronary intervention (PCI) with those transferred via inter-hospital transfer within a large suburban region in Canada.

Background Primary angioplasty is the preferred therapy for STEMI if it is done within 90 min of door-to-balloon time by an experienced team in a high-volume center.

Methods Patients identified to have STEMI on the ambulances equipped with electrocardiography bypassed the local hospitals and were sent directly to the PCI center, whereas other patients that were picked up by ambulances without electrocardiographic equipment were transported to the local hospitals where the diagnosis of STEMI was made and were re-routed to the PCI center. Patient demographic data, clinical presentation, procedural data, in-hospital course, and vital statistics were prospectively recorded in a provincial cardiac registry.

Results A total of 167 patients were brought into the PCI center via pre-hospital triage strategy, and 427 patients were brought in via inter-hospital transfer during a 2-year study period. Baseline demographic data, infarct location, cardiovascular history, and hemodynamic status were similar between the 2 groups. When compared with the inter-hospital transfer group, a significantly higher proportion of pre-hospital triaged patients achieved the 90-min door-to-balloon time benchmark (80.4% vs. 8.7%, $p < 0.001$) and post-procedural Thrombolysis In Myocardial Infarction flow grade 3 after the emergency procedure (97.6% vs. 91.4%, $p = 0.02$). In addition, the pre-hospital triage strategy was associated with a significantly lower 30-day (5.4% vs. 13.3%, $p = 0.006$) and 1-year (6.6% vs. 17.5%, $p = 0.019$) mortality. Pre-hospital triage was an independent predictor for survival at 1 year (hazard ratio: 0.37, 95% confidence interval: 0.18 to 0.75, $p = 0.006$).

Conclusions Pre-hospital triage strategy was associated with improved survival rate in patients undergoing primary PCI in a regional STEMI program. (J Am Coll Cardiol Intv 2012;5:1239–46) © 2012 by the American College of Cardiology Foundation

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Percutaneous coronary intervention (PCI) is the preferred reperfusion therapy for ST-segment elevation myocardial infarction (STEMI), provided that an experienced team is available in a timely manner (1–3). Practice guidelines have focused on ways to reduce the door-to-balloon time, which has been used as a surrogate marker for assessing the performance of individual hospitals in STEMI management (3). More recently, the total duration of ischemic time has been recognized as a more important factor in determining the 1-year survival after STEMI (4). Besides increasing the awareness of the public about the symptoms of myocardial infarction, efforts to shorten the pre-hospital phase in reaching the diagnosis and transfer to a center with capability to perform primary coronary angioplasty are seen to be important steps toward minimization of the symptom-to-balloon time.

The Fraser Health Region encompasses an area of 150 × 90 km, with a population of 1.6 million. Royal Columbian Hospital in the City of New Westminster is the regional cardiac center that provides round-the-clock PCI service for all the 12 community hospitals within the region. The distances between the PCI center and the referring hospitals ranged from 9 to 133 km (median 36 km), and the travel times varied from 15 to 60 min. Primary PCI has been adopted as the primary reperfusion therapy for STEMI treatment in the region, and occasionally fibrinolytic therapy was offered to young patients who presented early with an anterior STEMI (5,6). Beginning April 2009, ambulances with personnel trained in advanced life support (ALS) and equipment for 12-lead electrocardiogram (ECG) transmission have become available in several municipalities within the health region. When a potential STEMI patient was identified by an ECG at the scene, the ECG would be transmitted to the cardiac catheterization laboratories of the PCI center during the day or to the emergency department physicians during the nighttime for review. Once the diagnosis was confirmed by a physician, the cardiac catheterization team would be activated immediately while the patient would be transferred immediately to the PCI center.

Abbreviations and Acronyms

CI = confidence interval

FMC = first medical contact

PCI = percutaneous coronary intervention

STEMI = ST-segment elevation myocardial infarction

TIMI = Thrombolysis In Myocardial Infarction

The objective of this study was to compare the survival rate of the patients who were transferred directly to the PCI center via the pre-hospital triage strategy with those who were brought to the PCI center via inter-hospital emergency transfer.

Methods

Patient population. This study was intended to compare the survival rate of the patients who were transferred directly to the PCI center by ambulances with ALS capability due to STEMI with those who were brought to the PCI center via inter-hospital emergency transfer (Fig. 1). The ALS cars were installed with 12-lead ECG equipment (Lifepak, Physio-Control, Inc., Redmond, Washington) that had a computerized algorithm for interpretation, and the paramedics were trained in ECG interpretation. When the symptoms of a patient were consistent with acute myocardial infarction and the ECG was interpreted as STEMI (ST-segment elevation by >0.1 mV in at least 2 contiguous precordial or adjacent limb leads, left bundle branch block, or extensive ST-segment depression in the precordial leads representing posterior myocardial infarct with confirmatory posterior circulation infarction), the ECG would be transmitted electronically (Lifenet, Physio-Control, Inc.) to the PCI center cardiac catheterization laboratory during the day or its emergency department during the off-hours for physician confirmation. Once a pre-hospital diagnosis of STEMI was made, the patient would be transferred directly to the PCI center for consideration of emergency cardiac catheterization and primary PCI as deemed appropriate. By contrast, patients who were picked up by basic life support (BLS) cars that did not have ECG equipment were transferred to the local emergency rooms where the diagnosis of STEMI was made. The patients would then be transferred to the PCI center immediately for the emergency procedure.

Patients who presented themselves to a local hospital and those who lived within New Westminster, in which Royal Columbian Hospital was the local hospital, were excluded from this study.

STEMI management. Within this regional primary PCI program for STEMI, all patients considered candidates for emergency reperfusion were transferred to the PCI center once the diagnosis was made. These patients received aspirin 325 mg and clopidogrel 600 mg orally in the ambulances or in the local emergency departments. A bolus dose of intravenous unfractionated heparin and a double-bolus and infusion of Epifibatide (Millennium Pharmaceuticals, Cambridge, Massachusetts) would be given on arrival to the hospital. Emergency cardiac catheterization and PCI procedures would be performed in the standard fashion.

Due to the limited capacity of the hospital beds in the PCI center, all patients who underwent successful primary PCI would be considered for immediate repatriation to the local hospitals that have intensive care capacity. Patients who did not have a successful revascularization or those who were having electrical instability, cardiogenic shock that required intra-aortic counterpulsation, emergency cardiac surgery, or failed to achieve hemostasis with vascular closure device in the arterial access site, would be admitted to the PCI center.

Definitions. Time segments were recorded prospectively by the medical personnel in the catheterization laboratories. Symptom onset was defined as the time recalled by the

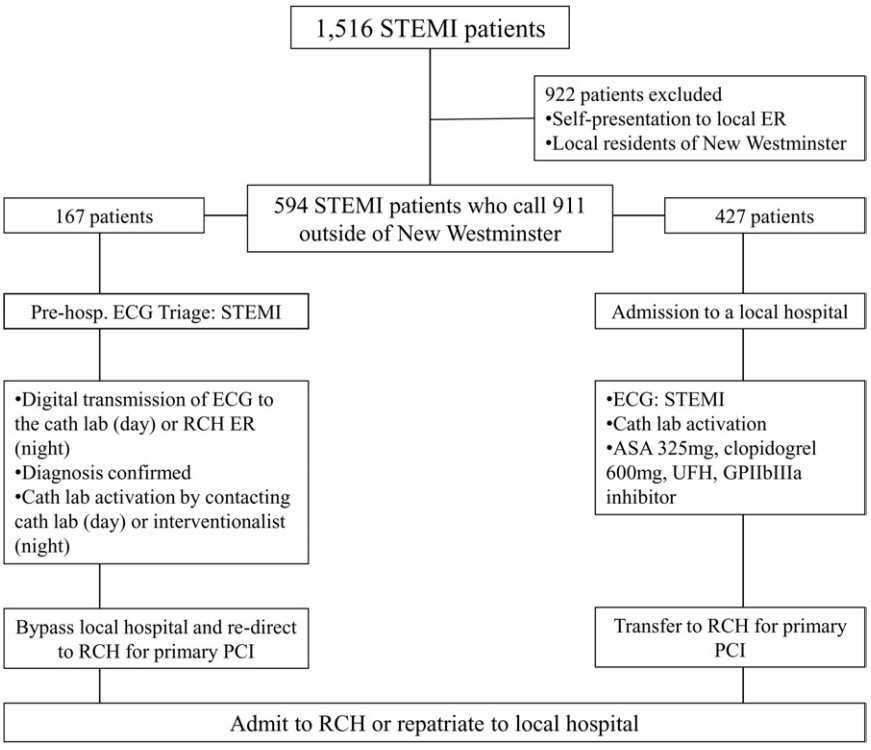

Figure 1. Study Population

ALS = advanced life support; ASA = acetylsalicylic acid; BLS = basic life support; cath = catheterization; ECG = electrocardiogram; ER = emergency department; PCI = percutaneous coronary intervention; RCH = Royal Columbian Hospital located in New Westminster; STEMI = ST-segment elevation myocardial infarction.

patient or bystanders of the onset of the presenting symptoms (e.g., chest pain, dyspnea, cardiac arrest). First medical contact (FMC) was defined as the arrival time of the paramedics at the patient's side. Door time was defined as the arrival time at the first medical institution. Balloon time was the time of the first reperfusion catheter crossing the culprit lesion.

Data collection. The demographic data, transfer modality, time segments, clinical status, and in-hospital outcomes of all patients who were referred for primary PCI were prospectively recorded in the Fraser Health STEMI database. Details related to the interventional procedures, angiographic findings, and 30-day and 1-year survival were tracked prospectively in the British Columbia Cardiac Registry. These 2 registries were merged by using health numbers of patients, which are unique identifiers for all residents in the province of British Columbia. The study was approved by the institutional ethics committee of the Fraser Health Authority.

Statistical analysis. The primary objective of the study was to compare the 30-day and 1-year mortality of STEMI patients referred via pre-hospital triage strategy with those via inter-hospital transfer for primary PCI. Categorical data were expressed as frequencies and percentages and were analyzed with chi-square tests. Continuous variables were presented as mean ± SD or median and interquartile range, and they were analyzed by Student t test or Wilcoxon rank-sum test, respectively. To examine the association of pre-hospital triage strategy and mortality, multivariate logistic regression was used to assess its relation with 30-day mortality, and Cox proportional hazards modeling was used to assess its relation with 1-year mortality (SAS version 9.2, Cary, North Carolina). Covariates that are significantly associated with mortality in the univariate analysis were considered in the multivariable logistic regression analysis and the Cox proportional hazards model. All p values were 2-tailed, and a p value < 0.05 was considered significant in all analyses.

Results

Between April 2009 and May 2011, 1,516 patients were diagnosed with STEMI in our region (Fig. 1). A total of 922 patients were excluded from the current analysis, because they either presented themselves to a local emergency department or were residents of the City of New

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Westminster where Royal Columbian Hospital served as the local hospital. Among 594 patients who called emergency medical services, STEMI was diagnosed in 167 patients in the ALS cars, and patients were transferred directly to the PCI center; the other 427 patients were brought to the local hospitals where the diagnosis of STEMI was made and were subsequently transferred to the PCI center for emergency revascularization.

The baseline characteristics of the 2 groups were listed in Table 1. Although the patients in the inter-hospital transfer group tended to be older, were more likely female, and had a past history of transient ischemic attack or stroke, the differences did not achieve statistical significance. The 2 groups were similar in terms of the cardiovascular risk factors, including diabetic status, past cardiovascular history, territory of STEMI, and number of diseased vessels; and there were similar proportions of cases complicated by cardiac arrest requiring ventilation, congestive heart failure, and cardiogenic shock.

Time intervals. When compared with the inter-hospital transfer group, the patients in the pre-hospital triage strategy had similar median symptom-to-FMC times (43 vs. 59 min, $p = 0.09$); however, the median symptom-to-balloon (150 vs. 228 min, $p < 0.001$), FMC-to-balloon (103 vs. 157 min, $p < 0.001$), and door-to-balloon (63 vs. 132 min, $p < 0.001$) times were significantly shorter (Fig. 2). With the FMC-to-balloon time as the surrogate for performance assessment, 76% of the patients in the pre-hospital triage group achieved an FMC-to-balloon time <120 min, in contrast to only 13.4% in the inter-hospital transfer group ($p < 0.001$) (Fig. 3).

Emergency treatment and angiographic findings. Of the 167 pre-hospital triage patients, the number of patients undergoing PCI, emergency surgery, and conservative treatment, were 143 (85.6%), 4 (2.4%), and 17 (10.2%), respectively. Of the 427 inter-hospital transfer patients, the number of patients undergoing PCI, emergency surgery, and conservative treatment were 370 (86.7%), 12 (2.8%), and 36 (8.4%), respectively. These were not significantly different between the 2 groups.

Although there was no significant difference in the proportion of patients with pre-procedural Thrombolysis In Myocardial Infarction (TIMI) flow grade 3 on the coronary angiogram (32.9% for pre-hospital triage vs. 31.9% for

Table 1. Characteristics of STEMI Patients That Were Brought in Via Pre-Hospital Triage Strategy and Inter-Hospital Transfer

Characteristics	Pre-Hospital Triage Strategy (n = 167)	Inter-Hospital Transfer (n = 427)	p Value
Age, yrs	63.2 ± 12.0	65.6 ± 14.4	0.06
Male	126 (75.4%)	295 (69.1%)	0.13
Heart rate, beats/min (IQR)	76 (65–90)	75 (61–90)	0.55
Systolic blood pressure, mm Hg (IQR)	132 (111–150)	132 (111–151)	0.24
Serum creatinine, mmol/l (IQR)	90 (76–109)	98 (76–112)	0.16
Current smoker	47 (28.8%)	127 (29.9%)	0.80
Hypertension	95 (57.9%)	213 (50%)	0.08
Diabetes mellitus	37 (22.7%)	95 (22.3%)	0.92
Hypercholesterolemia	70 (42.7%)	159 (37.3%)	0.23
Prior MI	28 (17.1%)	61 (14.3%)	0.40
Prior PCI	23 (14.0%)	52 (12.2%)	0.55
Prior CABG	8 (4.9%)	14 (3.3%)	0.35
History of TIA/stroke	8 (4.9%)	43 (10.1%)	0.05
Peripheral arterial disease	5 (3.1%)	10 (2.3%)	0.62
Pre-hospital arrest requiring ventilation	18 (10.8%)	34 (8.0%)	0.28
Congestive heart failure	6 (3.6%)	22 (5.2%)	0.43
Cardiogenic shock at presentation	12 (7.2%)	36 (8.4%)	0.63
LVEF <40%	34 (24.8%)	102 (32.7%)	0.10
Anterior MI	77 (47.0%)	186 (44.5%)	0.59
Number of diseased vessels			0.55
1-vessel disease	55 (33.7%)	163 (39.2%)	
2-vessel disease	49 (30.1%)	106 (25.5%)	
3-vessel disease	37 (22.7%)	99 (23.8%)	
Left main disease	10 (6.1%)	27 (6.5%)	
No disease	12 (7.4%)	21 (5.0%)	

CABG = coronary artery bypass surgery; IQR = interquartile range; LVEF = left ventricular ejection fraction; MI = myocardial infarction; PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction; TIA = transient ischemia attack.

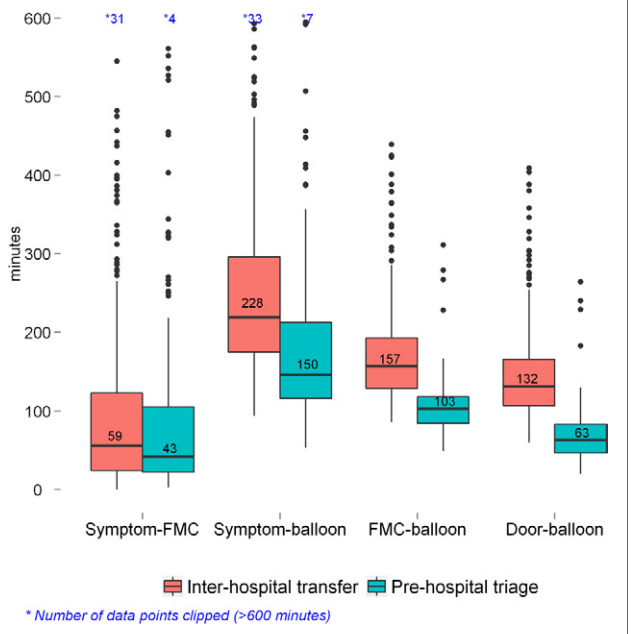

Figure 2. Time Intervals to Revascularization

The various time segments of the patients brought to the percutaneous coronary intervention center via pre-hospital triage strategy were compared with those via inter-hospital transfer. FMC = first medical contact.

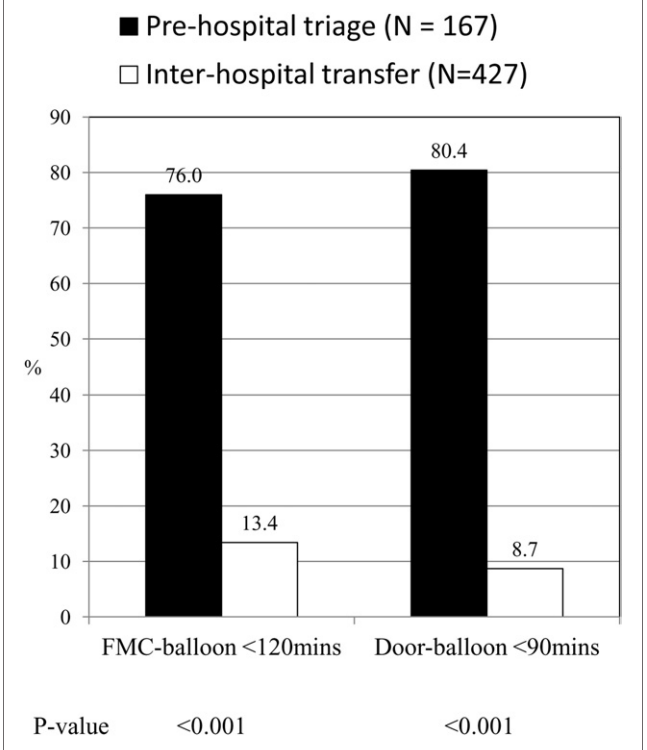

Figure 3. Time-to-Reperfusion Benchmarks

The proportions of patients that achieved the time-to-reperfusion benchmarks were compared between the 2 strategies. FMC = first medical contact.

inter-hospital transfer, p = 0.83), of the patients who underwent primary PCI, patients in the pre-hospital triage strategy were more likely to achieve TIMI flow grade 3 at the end of the procedure than those in the inter-hospital transfer group (97.6% vs. 91.4%, p = 0.02).

Survival during follow-up. All-cause mortality was significantly lower among patients in the pre-hospital triage group at 30 days (5.4% vs. 13.3%, p = 0.006) and at 1 year (6.6% vs. 17.5%, p = 0.019) (Fig. 4). The difference in mortality of the 2 groups continued to diverge from 30 days to 1 year (Fig. 5).

Univariate predictors for 30-day and 1-year mortality. Figures 6 and 7 depicted some of the factors associated with mortality at 30 days and at 1 year in the univariate analysis. Of note, cardiogenic shock and cardiac arrest requiring ventilation were the 2 strongest predictors for mortality in this population. Importantly, pre-hospital triage strategy remained a significant factor associated with survival at 30 days (odds ratio: 0.37, 95% confidence interval [CI]: 0.18 to 0.77, p = 0.006) and at 1 year (hazard ratio: 0.35, 95% CI: 0.18 to 0.68, p = 0.002). In addition, the door-to-balloon time <90 min and post-procedural TIMI flow grade 3 were consistently associated with survival at 30 days and 1 year.

Independent predictors for 30-day and 1-year mortality. After adjusting for age, cardiogenic shock, cardiac arrest requiring ventilation, left ventricular ejection fraction <40%, and prior history of myocardial infarction, the use of pre-hospital triage strategy remained an independent predictor for lower mortality at 30 days (odds ratio: 0.26, 95% CI: 0.1 to 0.7, p = 0.007) and at 1 year (hazard ratio: 0.37, 95% CI: 0.18 to 0.75, p = 0.006).

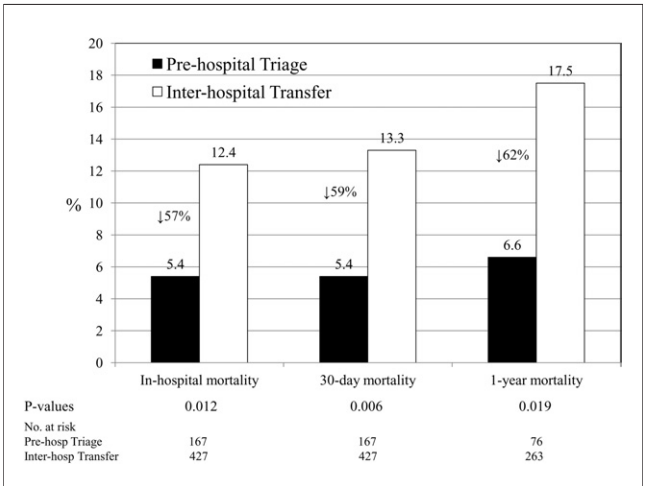

Figure 4. Mortality in Hospital, at 30 Days, and 1 Year

The mortality rates of the patients according to the transfer strategies during the hospital stay were compared.

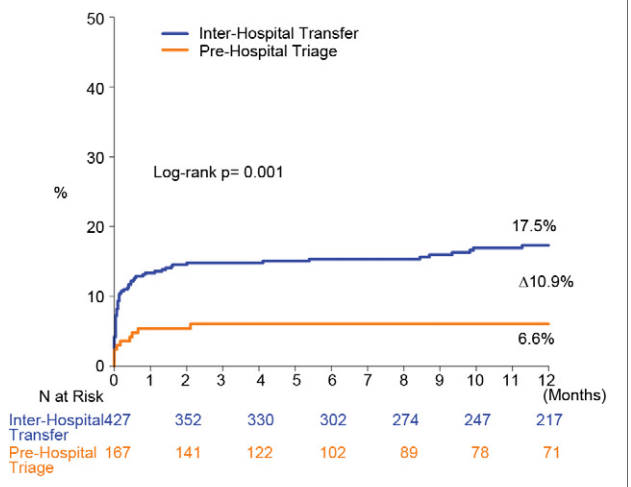

Figure 5. 1-Year Mortality

The mortality rates up to 1 year according to the transfer strategies were compared.

Discussion

In this regional STEMI program using contemporary primary PCI strategy, patients who were transferred directly to the PCI center via pre-hospital triage strategy had a significantly lower mortality at 30 days and at 1 year when compared with inter-hospital transfer patients. Importantly, the mortality difference continues to diverge after patient discharge from the hospital. To our knowledge, this is the first time that the direct transfer strategy is demonstrated to be an independent predictor for 1-year survival after STEMI, after adjusting for other important risk factors that include patient age, left ventricular ejection fraction, pre-hospital cardiac arrest, and cardiogenic shock.

The survival benefit of the pre-hospital triage strategy seemed to be mediated by a reduction in the time to reperfusion, as reflected by a nearly 10-fold improvement in the number of patients who achieved the 90-min door-to-balloon benchmark (2). The time-saving was orchestrated by the persistent effort of the paramedics in identifying and redirecting STEMI patients to the PCI center, coupled with an early activation of the catheterization laboratory team in preparation for the emergency procedure before patient arrival. The higher proportion of post-procedural TIMI flow grade 3, which was an important predictive factor for better survival in STEMI, was perhaps related to the shorter symptom-to-balloon time in the pre-hospital triage group and hence less organized thrombus burden, which translated to less likelihood of no reflow phenomenon during the procedure (7,8). Furthermore, the proportion of patients with left ventricular ejection fraction <40%, which

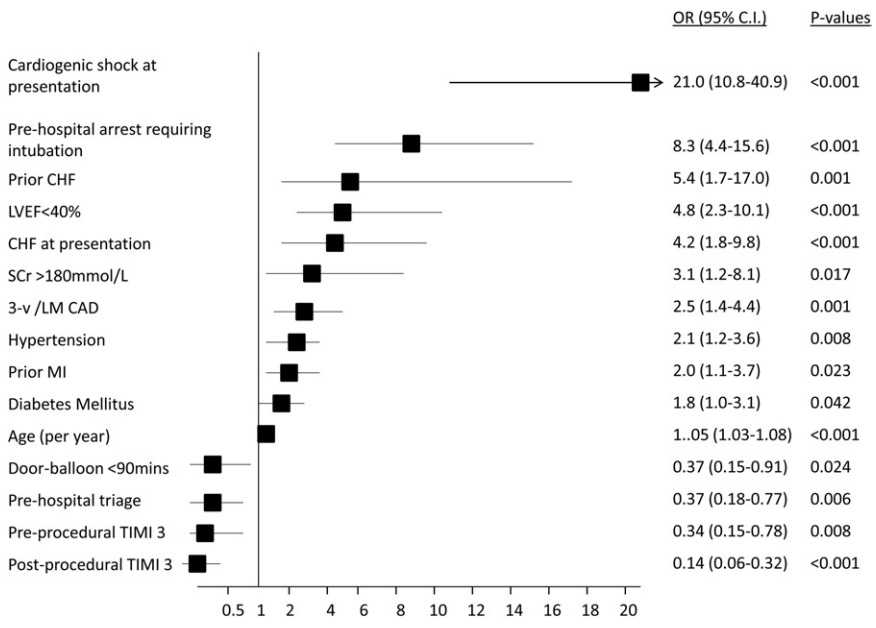

Figure 6. Univariate Predictors for 30-Day Mortality After ST-Segment Elevation MI

Cardiogenic shock and cardiac arrest were strongest predictors for mortality at 30 days after ST-segment elevation myocardial infarction (MI), whereas door-balloon time <90 min, pre-hospital triage strategy, and pre- and post-procedural Thrombolysis In Myocardial Infarction (TIMI) flow grade 3 were favorable predictors for improved survival for this period. CHF = congestive heart failure; CI = confidence interval; LM CAD = left main coronary artery disease; LVEF = left ventricular ejection fraction; OR = odds ratio; SCr = serum creatinine.

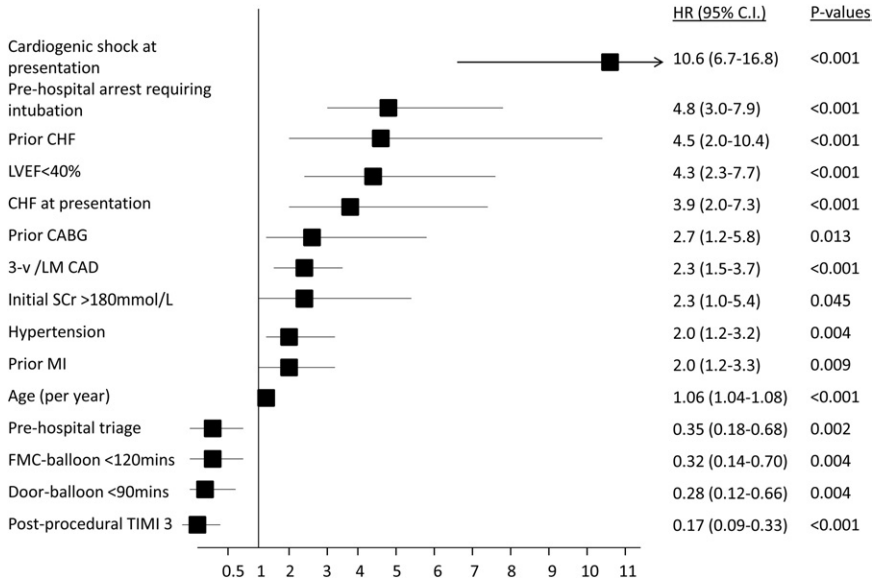

Figure 7. Univariate Predictors for 1-Year Mortality After ST-Segment Elevation MI

Cardiogenic shock was the strongest predictor for mortality at 1 year after ST-segment elevation MI, whereas pre-hospital triage strategy, FMC–balloon <120 min, door-balloon <120 min, and post-procedural TIMI flow grade 3 were favorable predictors for improved survival for this period. CABG = Coronary artery bypass surgery; HR = hazard ratio; other abbreviations as in Figures 2 and 6.

was a predictor for lower survival rate at 1 year, was lower in the pre-hospital triage group, even though the percentage of anterior infarct and the number of diseased coronary vessels were similar between the 2 groups. This might also be explained by the shorter symptom-to-balloon time achieved in the pre-hospital triage strategy.

The original idea to carry out this research study stemmed from the initial concern that the hemodynamic conditions of patients might deteriorate while re-routing these patients to the PCI center without stopping at the nearest local hospital for medical stabilization. The similarity of the baseline characteristics of both groups, including the proportions of patients suffering from cardiac arrest, congestive heart failure, and cardiogenic shock, suggested that the longer travel distance required to reach the PCI center in the pre-hospital triage strategy did not result in increased risk of hemodynamic instability. On the contrary, by including STEMI patients for whom emergency aggressive reperfusion therapy with primary PCI was the initial intention, our study shows that more patients in the traditional inter-hospital transfer arm died during the first year after the event, perhaps related to the long symptom-to-balloon time. The findings of our study corroborates with those reported by other centers and in large registries (9–12). These studies and ours confirmed that the direct transfer strategy was associated with substantial shortening of the door-to-balloon time, but our study further concluded the pre-hospital triage strategy as an independent predictor for survival at 1 year by involving a large catchment area that had a travel time up to 1 h.

Our study confirms some of the most important predictors for mortality after STEMI, namely prolonged cardiac arrest requiring airway support and cardiogenic shock. The high mortality rate at 1 year in our study perhaps was related to the inclusion of all comers, such as those in these most unstable patient categories. Importantly, by shortening the symptom-to-balloon time, the pre-hospital triage strategy was associated with a 62% lower mortality rate at 1 year when compared with the inter-hospital transfer group, even though both groups had a similar proportion of patients with these high-risk characteristics. This reaffirms the importance of the statement "time is muscle" as stated in the clinical practice guidelines, when dealing with STEMI, which is the medical condition associated with one of the highest mortality rates in western society (13). With the recognition of the superior outcome with the pre-hospital triage strategy, our direct transfer strategy has further extended to the use of air-ambulance to transfer STEMI patients directly from more remote areas (>100 km) in the region.

Study limitations. The assignment of the ALS and BLS cars was not a random process, and a systemic bias might take place such that a greater proportion of patients with atypical symptoms for STEMI were transported by the BLS cars to the local facilities. Patients in the inter-hospital transfer group tended to be older, were more often female, and had a higher rate of previous transient ischemic attack or stroke,

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although they did not reach a statistical difference when compared with the pre-hospital transfer group. Moreover, there might be differences between the 2 populations that were not identified in our prospective registries. However, the 2 populations were largely similar in terms of their past cardiovascular history, number of diseased vessels, renal function, hemodynamic status at the presentation, and proportions of patients suffering from cardiac arrest or congestive heart failure, which were the determining factors for 1-year mortality. The association of the transfer strategy and mortality was further confirmed by the multivariate models.

Conclusions

In summary, pre-hospital triage of STEMI patients within a large health region substantially shortens the time to reperfusion and was associated with improved short-term and 1-year survival after STEMI when compared with the traditional inter-hospital transfer. It is important to continue to invest our healthcare resources in building the infrastructure within a health region to facilitate pre-hospital identification of STEMI, early activation of cardiac catheterization laboratory, and direct transfer to a regional PCI center.

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