CLINICAL RESEARCH   **Myocardial Infarction**

Utilization and Impact of Pre-Hospital Electrocardiograms for Patients With Acute ST-Segment Elevation Myocardial Infarction

Data From the NCDR (National Cardiovascular Data Registry) ACTION (Acute Coronary Treatment and Intervention Outcomes Network) Registry

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Objectives	This study sought to determine the association of pre-hospital electrocardiograms (ECGs) and the timing of reperfusion therapy for patients with ST-segment elevation myocardial infarction (STEMI).
Background	Pre-hospital ECGs have been recommended in the management of patients with chest pain transported by emergency medical services (EMS).
Methods	We evaluated patients with STEMI from the NCDR (National Cardiovascular Data Registry) ACTION (Acute Coronary Treatment and Intervention Outcomes Network) registry who were transported by EMS from January 1, 2007, through December 31, 2007. Patients were stratified by the use of pre-hospital ECGs, and timing of reperfusion therapy was compared between the 2 groups.
Results	A total of 7,098 of 12,097 patients (58.7%) utilized EMS, and 1,941 of these 7,098 EMS transport patients (27.4%) received a pre-hospital ECG. Among the EMS transport population, primary percutaneous coronary intervention was performed in 92.1% of patients with a pre-hospital ECG versus 86.3% with an in-hospital ECG, whereas fibrinolytic therapy was used in 4.6% versus 4.2% of patients. Median door-to-needle times for patients receiving fibrinolytic therapy (19 min vs. 29 min, p = 0.003) and median door-to-balloon times for patients undergoing primary percutaneous coronary intervention (61 min vs. 75 min, p < 0.0001) were significantly shorter for patients with a pre-hospital ECG. A suggestive trend for a lower risk of in-hospital mortality was observed with pre-hospital ECG use (adjusted odds ratio: 0.80, 95% confidence interval: 0.63 to 1.01).
Conclusions	Only one-quarter of these patients transported by EMS receive a pre-hospital ECG. The use of a pre-hospital ECG was associated with a greater use of reperfusion therapy, faster reperfusion times, and a suggested trend for a lower risk of mortality. (J Am Coll Cardiol 2009;53:161–6) © 2009 by the American College of Cardiology Foundation

The American College of Cardiology/American Heart Association ST-segment elevation myocardial infarction (STEMI) guidelines recommend prompt reperfusion with fibrinolytic agents within 30 min of hospital arrival (door-to-needle time [DTN]) or primary percutaneous coronary intervention (PCI) within 90 min of arrival (door-to-balloon time [DTB]) (1). However, contemporary analyses show that the majority of hospitals in the U.S. do not meet these benchmarks for the

**Abbreviations
and Acronyms**

CHF = congestive heart
failure

DTB = door-to-balloon time

DTN = door-to-needle time

ECG = electrocardiogram

EMS = emergency medical
services

IQR = interquartile range

PCI = percutaneous
coronary intervention

STEMI = ST-segment
elevation myocardial
infarction

timing reperfusion therapy (2). A recent consensus statement endorsed the use of pre-hospital electrocardiograms (ECGs) to rapidly diagnose and triage patients transported by emergency medical services (EMS) with a suspected STEMI before hospital arrival (3). Regional or municipal studies performed within the last few years have shown that the use of pre-hospital ECGs was associated with shorter reperfusion times, and nationwide efforts have recently been developed to increase the availability of pre-hospital ECGs across the U.S. (4–7). We therefore analyzed data from the NCDR (National Cardiovascular Data Registry) ACTION (Acute Coronary Treatment and Intervention Outcomes Network) registry to evaluate the nationwide utilization and impact of pre-hospital ECGs in a large cohort of patients with STEMI.

Methods

The NCDR ACTION registry and quality improvement program began January 1, 2007. As applicable at each site, data collected for this registry were either approved by an institutional review board or considered quality assurance data, and not subject to institutional review board approval.
Patient inclusion criteria. Between January 1, 2007, and December 31, 2007, 271 ACTION hospitals enrolled 19,481 patients with STEMI (defined as persistent ST-segment elevation or new left bundle branch block and presenting within 24 h of ischemic symptom onset). We excluded the following patients: those not evaluated first in the emergency department or the cardiac catheterization laboratory (n = 2,575); patients transferred to an ACTION-participating hospital because the structure of the data collection form prevented delineation of location of the first ECG obtained (pre-hospital vs. in the outside hospital emergency department) (n = 4,568); those with missing information on EMS transport (n = 79); those with missing data on pre-hospital ECG (n = 69); and those not listed as being transported by EMS, but who had a pre-hospital ECG recorded (n = 93). The total initial analysis sample thus consisted of 12,097 patients with STEMI who directly presented to ACTION-participating hospitals either by self-transport or EMS transport.
Data collection and accuracy. Data were abstracted by a trained data collector at each hospital. Variables collected included pre-hospital data, medical history, treatments administered, as well as associated major contraindications to evidence-based therapies, and in-hospital outcomes.
Statistical analyses. Patients were initially categorized by whether or not they were transported by EMS. An

in-depth comparison was made among those patients with and without a pre-hospital ECG, after restricting the analysis cohort to only those transported by EMS.

Demographic and clinical characteristics, reperfusion strategies, treatment patterns, and in-hospital outcomes were compared between patients with and without a pre-hospital ECG. Median values with interquartile ranges (IQRs) (25th, 75th percentile) were used to describe continuous variables, and numbers (percentages) were used for categorical variables. Patients were additionally classified regarding presenting during "on hours" (7 AM to 7 PM, Monday through Friday) or "off hours" (all other time periods), and by the time to the in-hospital ECG ≤10 or >10 min. To test for independence, pre-hospital ECG and baseline characteristics, in-hospital care patterns and outcomes, and the continuous and ordinal categorical variables were compared using stratum-adjusted Wilcoxon rank-sum tests, whereas nominal categorical variables were compared using stratum adjusted chi-square tests, for which stratification is by hospital.

We evaluated 2 process-of-care measures: time from door to reperfusion treatment with either fibrinolytic agents or primary PCI. In examining the association between pre-hospital ECG and time to reperfusion, we used the generalized estimating equations method to account for within-hospital clustering. Variables entered into the model are based on known clinical predictors of outcome. Furthermore, the relationship between in-hospital outcomes and pre-hospital ECG was explored using the logistic generalized estimating equations method adjusting for patient baseline characteristics only. Because DTB and DTN times were skewed, a log-transformation of these times was applied to normalize the distribution. When a dependent variable of a regression analysis has been transformed, the estimated coefficients must also be transformed to be interpreted appropriately (8). All analyses were performed using SAS software (version 9.1, SAS Institute, Cary, North Carolina).

Results

Clinical characteristics and treatment. A total of 7,098 of 12,097 patients (58.7%) included were transported to the ACTION-participating hospital by EMS. Patients transported by EMS were older; were less commonly male; more commonly had prior myocardial infarction (MI), prior congestive heart failure (CHF), and signs of CHF on presentation; and had shorter times from symptom onset to hospital presentation compared with patients who were self-transported to the ACTION-participating hospital (Table 1). Among the 7,098 patients transported by EMS, 1,941 (24.7%) received a pre-hospital ECG. Patients with a pre-hospital ECG were more commonly male, and less commonly had diabetes and left bundle branch block or signs of CHF on

Table 1	Clinical Characteristics: EMS Transport Versus No EMS Transport			
Variable	**Overall (N = 12,097)**	**EMS Transport (n = 7,098)**	**No EMS Transport (n = 4,999)**	**p Value**
Demographics				
Age (yrs)*	61 (52, 72)	62 (52, 75)	59 (51, 69)	<0.0001
Male	68.4	65.9	72.0	<0.0001
Caucasian	83.4	84.1	82.4	<0.0001
Insurance status				0.0001
HMO/private	57.7	55.5	61.0	
Medicare	23.8	26.4	20.2	
Military/VAMC	1.1	1.2	1.1	
Medicaid	3.6	3.8	3.5	
Self/none	13.0	12.8	13.2	
Missing	0.7	0.4	1.1	
Medical history				
Hypertension	60.5	61.8	58.6	0.0001
Diabetes mellitus	22.6	23.0	22.0	0.05
Peripheral arterial disease	5.9	6.7	4.6	<0.0001
Current/recent smoker	40.4	40.6	40.1	0.85
Dyslipidemia	46.4	47.2	45.3	0.30
Prior MI	19.2	20.8	16.9	<0.0001
Prior PCI	19.0	20.2	17.3	<0.0001
Prior CABG	7.5	7.7	7.1	0.17
Prior CHF	5.9	7.2	4.0	<0.0001
Prior stroke	5.8	7.0	4.0	<0.0001
Dialysis use	0.9	1.0	0.8	0.68
Presentation features				
Symptom onset to hospital arrival (h)*	1.7 (1.0, 3.6)	1.5 (1.0, 2.9)	2.0 (1.0, 4.9)	<0.0001
Systolic blood pressure (mm Hg)*	138 (117, 158)	131 (112, 150)	148 (127, 167)	<0.0001
Heart rate (beats/min)*	78 (65, 93)	77 (64, 93)	80 (67, 94)	<0.0001
Signs of CHF	13.6	16.5	9.5	<0.0001
ECG findings				0.60
Persistent ST-segment elevation	95.1	95.2	95.1	
New LBBB	4.9	4.8	4.9	

Data are expressed as percentages except where indicated. *Expressed as medians (25th, 75th percentiles).
CABG = coronary artery bypass graft; CHF = congestive heart failure; ECG = electrocardiogram; EMS = emergency medical services; HMO = health maintenance organization; LBBB = left bundle branch block; MI = myocardial infarction; PCI = percutaneous coronary intervention; VAMC = Veteran Affairs Medical Center.

presentation compared with patients with an in-hospital ECG. The time from symptom onset to hospital presentation was similar between the groups (Table 2).

Use of reperfusion therapy and acute medications by pre-hospital ECG use. Patients with a pre-hospital ECG were more likely to undergo primary PCI and less likely to receive no reperfusion therapy compared with patients with an in-hospital ECG (Table 3). Patients with a pre-hospital ECG were more likely to receive aspirin, clopidogrel, and glycoprotein IIb/IIIa inhibitors within the first 24 h (Table 4).

Timing of reperfusion therapy. Among patients receiving reperfusion therapy, DTN and DTB times were faster in those with a pre-hospital ECG (Table 5). This difference persisted when stratified analysis were performed by "off-hours" versus "on-hours" presentation and by time to the in-hospital ECG (≤10 min or not). These differences in DTN and DTB times persisted after adjusting for confounders. Patients who had a pre-

hospital ECG had faster DTN times (adjusted decrease of 24.9%, 95% confidence interval: −38.1% to −9.0%) and faster DTB times (adjusted decrease of 19.3%, 95% confidence interval: −23.3% to −15.2%) compared with patients with an in-hospital ECG.

In-hospital clinical outcomes. Among the overall EMS transport population, pre-hospital ECG use was associated with a trend toward a reduced risk of adjusted in-hospital mortality, CHF, and shock (Table 6). Among patients who received any reperfusion therapy, there was no difference in the adjusted risk of mortality by pre-hospital ECG use.

Discussion

On a national level, there has been increased interest in the U.S. in the development of STEMI systems of care to develop integrated reperfusion approaches based on local and regional EMS and hospital capabilities. The utiliza-

Table 2	Clinical Characteristics Pre- Versus In-Hospital ECG Use in the EMS Transport Population			
Variable	**Overall Population (N = 7,098)**	**Pre-Hospital ECG (n = 1,941)**	**In-Hospital ECG (n = 5,157)**	**p Value**
Demographics				
Age (yrs)*	62 (52, 75)	61 (52, 73)	62 (52, 76)	0.003
Male	65.9	67.7	65.3	0.03
Caucasian	84.1	84.3	84.0	0.54
Insurance status				0.11
HMO/private	55.5	57.3	54.8	
Medicare	26.4	24.1	27.3	
Military/VAMC	1.2	1.0	1.3	
Medicaid	3.8	3.4	3.9	
Self/none	12.8	13.7	12.5	
Missing	0.4	0.6	0.3	
Medical history				
Hypertension	61.8	60.1	62.5	0.001
Diabetes mellitus	23.0	20.7	23.9	0.0004
Peripheral arterial disease	6.7	6.3	6.9	0.14
Current/recent smoker	40.6	40.3	40.7	0.45
Dyslipidemia	47.2	49.4	46.4	0.89
Prior MI	20.8	19.6	21.3	0.02
Prior PCI	20.2	19.6	20.5	0.73
Prior CABG	7.7	7.8	7.7	0.69
Prior CHF	7.2	6.2	7.6	0.02
Prior stroke	7.0	5.5	7.5	0.003
Dialysis use	1.0	0.8	1.1	0.12
Presentation features				
Symptom onset to hospital arrival (h)*	1.5 (1.0, 2.9)	1.5 (1.0, 2.9)	1.5 (0.9, 2.9)	0.59
Time from first medical contact to hospital arrival (min)*	27 (11, 36)	29 (20, 37)	25 (6, 35)	0.22
Systolic blood pressure (mm Hg)*	131 (112, 150)	132 (114, 150)	131 (111, 150)	0.87
Heart rate (beats/min)*	77 (64, 93)	77 (64, 92)	78 (64, 93)	0.54
Signs of CHF	16.5	12.9	17.9	<0.0001
ECG findings				<0.0001
Persistent ST-segment elevation	95.2	96.9	94.5	
New LBBB	4.8	3.1	5.1	

Data are expressed as percentages except where indicated. *Expressed as medians (25th, 75th percentiles).
Abbreviations as in Table 1.

tion of pre-hospital ECGs by EMS providers is a key component in the development of STEMI systems of care and reducing reperfusion times, because pre-hospital identification of STEMI patients allows for direct transport of patients to the nearest hospital with primary PCI capabilities as well as early activation of the cardiac catheterization laboratory before the patient arrives at the receiving hospital (3). However, broad adoption of pre-hospital ECGs has not yet occurred in the U.S. as we have shown that fewer than 20% of patients transported by EMS had a pre-hospital ECG performed (7,9). However, practical factors that may have limited the use of pre-hospital ECGs in the U.S., such as the cost of

Table 3	Use of Reperfusion Therapy by Pre- Versus In-Hospital ECG Utilization		
Variable	**Overall (N = 7,098)**	**Pre-Hospital ECG (n = 1,941)**	**In-Hospital ECG (n = 5,157)**
Primary PCI	88.0	92.1	86.3
Fibrinolytic therapy	4.3	4.6	4.2
PCI + fibrinolytic	0.6	0.5	0.7
No reperfusion therapy	6.2	2.4	7.7
Missing	0.9	0.4	1.0

Data are expressed as percentages except where indicated. The p value comparing the distribution of reperfusion therapy options between pre-hospital versus in-hospital ECG use was <0.001.
ECG = electrocardiogram; PCI = percutaneous coronary intervention.

Table 4	Acute (≤24 h) Medications by Pre- Versus In-Hospital ECG Utilization		
Variable	**Overall (N = 7,098)**	**Pre-Hospital ECG (n = 1,941)**	**In-Hospital ECG (n = 5,157)**	**p Value**
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Aspirin	97.5	98.3	97.1	0.03
Clopidogrel	84.8	86.9	83.9	0.02
Beta-blocker	94.5	95.6	94.1	0.99
GP IIb/IIIa inhibitor	77.2	80.7	75.8	0.003
Unfractionated or low-molecular-weight heparin	86.9	86.5	87.1	0.78

Data are expressed as percentages except where indicated.
ECG = electrocardiogram; GP = glycoprotein.

Table 5	Timing of Reperfusion Therapy by Pre- Versus In-Hospital ECG Utilization			
Reperfusion Times	**Overall (N = 7,098)**	**Pre-Hospital ECG (n = 1,941)**	**In-Hospital ECG (n = 5,157)**	**p Value**
Fibrinolytic agents	(n = 239)	(n = 72)	(n = 167)	
Door-to-needle time (min)*	26 (15, 41)	19 (10, 30)	29 (19, 45)	0.003
Door-to-needle time ≤30 min	56.2	72.4	49.1	0.05
Primary PCI	(n = 5,117)	(n = 1,501)	(n = 3,563)	
Door-to-balloon time (min)*	71 (55, 91)	61 (46, 79)	75 (58 95)	<0.0001
Door-to-balloon time ≤90 min	73.6	82.3	70.0	<0.0001

Data are expressed as percentages except where indicated. *Expressed as medians (25th, 75th percentiles).
Abbreviations as in Table 3.

capital equipment purchases for local EMS services, challenges of training of EMS providers in ECG interpretation, and technical limitations regarding transmission of pre-hospital ECG findings to hospitals for physician over-read, will need to be addressed to stimulate more widespread adoption of this technology.

Study limitations. This study has several potential limitations. First, there likely were unmeasured differences in the clinical presentation of patients for whom a pre-hospital ECG was used. Second, we did not collect information on how the pre-hospital ECGs were interpreted (EMS provider interpretation vs. wireless transmission for physician over-read), whether and how the results were transmitted to the ACTION hospital before the patient's arrival, how the pre-hospital ECG impacted catheterization laboratory activation, and whether patients were diverted from a community hospital to a tertiary hospital participating in the ACTION registry based on the pre-hospital ECG results. Third, we cannot comment on the specificity or sensitivity of pre-hospital ECGs for accurately identifying STEMI patients because there was no central core laboratory interpretation of the ECGs and information was not collected regarding the accuracy of the EMS providers' interpretation of the pre-hospital ECGs. Fourth, because patients with a pre-hospital ECG were younger and had fewer comorbidities compared with patients with an in-hospital ECG, the use of pre-hospital ECGs may have been preferentially directed toward patients with a more straightforward presentation and ischemic symptoms that triggered use of pre-hospital ECG. The lower use of reperfusion therapy in the in-hospital ECG group may support this observation. Finally, we excluded a significant proportion of patients, including those who did not present first to the emergency department or cardiac catheterization laboratory, so the impact of pre-hospital ECGs may not have been completely assessed.

Conclusions

Among a contemporary population of STEMI patients in the U.S. transported by EMS, one-quarter received a pre-hospital ECG. Pre-hospital ECG use was associated with a greater use of reperfusion therapy, faster reperfusion times with both fibrinolytic agents and primary PCI, and a trend for a lower adjusted risk of in-hospital mortality. These data provide contemporary evidence supporting a more widespread use of pre-hospital ECGs as a key triage tool for patients with ischemic symptoms and suspected STEMI who are first evaluated by EMS.

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Table 6	In-Hospital Clinical Outcomes by Pre- Versus In-Hospital ECG Utilization					
	Overall	**Pre-Hospital ECG**	**In-Hospital ECG**	**Adjusted Odds Ratio**	**95% Confidence Interval**	**p Value**
Total population	(n = 7,098)	(n = 1,941)	(n = 5,157)			
Death	8.7	6.7	9.5	0.80	0.63–1.01	0.06
CHF	7.5	6.3	8.0	0.81	0.61–1.06	0.12
Cardiogenic shock	8.3	7.2	8.8	0.87	0.70–1.07	0.19
Reperfusion population*	(n = 6,458)	(n = 1,528)	(n = 3,589)			
Death	5.1	4.6	5.2	0.96	0.68–1.35	0.82
CHF	6.0	5.3	6.4	0.75	0.56–1.01	0.06
Cardiogenic shock	7.5	6.7	7.9	0.83	0.64–1.08	0.16

Data are expressed as percentages except where indicated. Variables in the model: age, male sex, white, continuous body mass index, hypertension, diabetes mellitus, current/recent smoker, hypercholesterolemia, prior myocardial infarction, prior percutaneous coronary intervention, prior coronary artery bypass graft, prior congestive heart failure, prior stroke, signs of heart failure, heart rate, and systolic blood pressure on presentation. *Includes only patients who received primary percutaneous coronary intervention or fibrinolytic agents.
  CHF = congestive heart failure; ECG = electrocardiogram.

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