Improving Use of Prehospital 12-Lead ECG for Early Identification and Treatment of Acute Coronary Syndrome and ST-Elevation Myocardial Infarction

Denise H. Daudelin, RN, MPH; Assaad J. Sayah, MD; Manlik Kwong, BSEE, BSCS; Marc C. Restuccia, MD; William A. Porcaro, MD, MPH; Robin Ruthazer, MPH; Jessica D. Goetz, MPH; William M. Lane, BS; Joni R. Beshansky, RN, MPH; Harry P. Selker, MD, MSPH

Background—Performance of prehospital ECGs expedites identification of ST-elevation myocardial infarction and reduces door-to-balloon times for patients receiving reperfusion therapy. To fully realize this benefit, emergency medical service performance must be measured and used in feedback reporting and quality improvement.

Methods and Results—This quasi-experimental design trial tested an approach to improving emergency medical service prehospital ECGs using feedback reporting and quality improvement interventions in 2 cities’ emergency medical service agencies and receiving hospitals. All patients age ≥30 years, calling 9-1-1 with possible acute coronary syndrome, were included. In total, 6994 patients were included: 1589 patients in the baseline period without feedback and 5405 in the intervention period when there were feedback reports and quality improvement interventions. Mean age was 66±17 years, and women represented 51%. Feedback and quality improvement increased prehospital ECG performance for patients with acute coronary syndrome from 76% to 93% (P<0.001) and for patients with ST-elevation myocardial infarction from 77% to 99% (P<0.0001). Aspirin administration increased from 75% to 82% (P=0.001), but the median total emergency medical service run time remained the same at 22 minutes. The proportion of patients with door-to-balloon times of ≤90 minutes increased from 27% to 67% (P=0.006).

Conclusions—Feedback reports and quality improvement improved prehospital ECG performance for patients with acute coronary syndrome and ST-elevation myocardial infarction and increased aspirin administration without prehospital transport delays. Improvements in door-to-balloon times were also seen. (Circ Cardiovasc Qual Outcomes. 2010;3:316-323.)

Key Words: electrocardiography myocardial infarction reperfusion computers cardiopulmonary resuscitation

Emergency medical service (EMS) performance and accurate interpretation of prehospital 12-lead electrocardiograms (PH-ECGs) is central to early identification of acute ST-elevation myocardial infarction (STEMI) in the community.1-5 Timely coronary reperfusion by primary percutaneous coronary intervention (PCI) is the preferred treatment when it can be done soon after the onset of symptoms. American College of Cardiology/American Heart Association (ACC/AHA) guidelines recommend that patients with STEMI should receive PCI within a ≤90-minute door-to-balloon (D2B) time,6 but despite national and local initiatives, only 54% to 58% of patients achieve this time frame.3-9 ACC/AHA guidelines on prehospital chest pain evaluation and treatment recommend that PH-ECGs be performed for all patients with suspected acute coronary syndrome (ACS) and that aspirin be given to those with suspected STEMI.6 When hospitals use PH-ECG results to activate cardiac catheterization labs while the patient is en route, D2B times are shorter than when activation is initiated on emergency department (ED) arrival.10,11 Despite this, currently PH-ECGs are performed on 8% to 27% of patients with STEMI.12,13

Newly emerging regional systems for patients with ACS will increasingly rely on paramedics interpreting PH-ECGs to identify STEMIs before hospital arrival.4 This can allow bypass of non–PCI-capable hospitals when a PCI-capable hospital can be reached in a timely manner or can enable early notification of a community hospital to treat and transfer for PCI.

The primary goal of this study was to improve compliance with evidence-based practices in prehospital care of patients with possible ACS and STEMI, including PH-ECG performance and interpretation and aspirin administration, by providing EMS with feedback on performance measures and support for quality improvement (QI) interventions. Secondary goals were to evaluate factors associated with PH-ECG...
nonperformance, paramedic diagnostic sensitivity for STEMI, and the impact of PH-ECG improvements on D2B times. We also checked for any adverse impact of PH-ECG on time from EMS arrival on-scene to hospital arrival.

**Local Challenges in Implementation**

The challenges met in implementing measurement-based quality improvement of EMS performance measures were common issues for EMS QI, as described by the Institute of Medicine report “Future of Emergency Care: Emergency Medical Services at the Crossroads.” These included lack of defined prehospital ACS performance measures, lack of information systems linking prehospital care and hospital diagnosis or outcome, and lack of measurement-based QI processes in EMS and between EMS and EDs.

PH-ECG performance is cited as a key quality metric for successful STEMI regionalization programs, but there are no agreed-on PH-ECG performance definitions. The EMS agencies participating in this study acknowledged the importance of measurement but had no standard methods for evaluating which patients should have an ECG and whether an ECG was performed.

Data needed to evaluate performance measures were in disparate medical record sources and had to be combined to create an information resource sufficient for performance measurement. EMS agencies attached printed PH-ECGs to paper medical records, but electronic PH-ECGs stored in electrocardiographs were not retained in central databases and were not consistently available for QI. Moreover, the ultimate hospital diagnoses given to patients transported by EMS were infrequently available to EMS, precluding evaluation of accuracy of prehospital clinical impressions and STEMI identification.

EMS agencies did not use QI methods with objective tracking and feedback measures over time. Feedback on clinical care issues typically focused on poor performance or problem cases. Collaboration between EMS and the local receiving hospitals was limited, and PH-ECG use by ED staff for diagnosis and treatment was inconsistent, even when a PH-ECG showed STEMI.

Thus, although desiring to improve their PH-ECG performance in terms of adherence to guidelines and effective communication to receiving hospitals for STEMIs, EMS medical directors found themselves without reliable information about PH-ECG performance and patient outcomes, and with little QI structure to support improvement.

**Design of the Initiative**

**Setting**

The study included the EMS agencies providing all 911 services in 2 Massachusetts cities, the 5 receiving hospitals in those cities, and 3 tertiary hospitals receiving patients in transfer for PCI. Community A’s EMS agency was privately owned and transported to 2 receiving community hospitals. One hospital transferred all patients with STEMI for PCI; the other hospital performed PCI during business hours when the catheterization laboratory was available but transferred patients at other times. Community B’s hospital-based EMS agency was a private-public partnership transporting to 3 receiving hospitals. Of the 3 hospitals, 2 performed PCI and 1 transferred elsewhere for PCI. All hospitals infrequently administered thrombolytic therapy as single therapy for STEMI. Ambulances in both communities transported patients to the closest open ED and provided interhospital transfers. Ambulances were staffed by 2 paramedics or a paramedic with an Emergency Medical Technician-Intermediate (EMT-I), had used PH-ECG equipment for at least 2 years, and used direct paramedic interpretation of PH-ECGs. The institutional review boards at each hospital and at the research Coordinating Center approved the study protocol.

In each community, a team was formed that included the EMS Medical Director, EMS QI coordinator, and nursing and physician representatives from each receiving hospital ED. These teams, in conjunction with Coordinating Center staff and other experts, were responsible for participating in measure development, abstracting and entering data into a centralized database for measure result reporting, setting measure-specific improvement targets, identifying improvement opportunities, and taking actions to improve measure results. Teams collaborated on the development and implementation of a “STEMI alert” protocol. Coordinating Center staff was responsible for providing education and support to EMS and hospitals on the QI process using “plan, do, study, act” cycles.

**Performance Measures**

An expert panel of EMS and emergency medicine clinicians and EMS and ED stakeholders reviewed a list of potential performance measures from scientific literature, clinical practice guidelines, and the state’s prehospital care protocols. The panel rated the measures on importance, reliability, validity, feasibility, and usefulness in improving patient outcomes. The final primary measures included performance of a PH-ECG, documentation of ECG interpretation, and prehospital administration of aspirin for patients with possible ACS. The Joint Commission national hospital performance measure for D2B time was used as a secondary measure for hospital performance.

**Feedback Reporting**

A web-based data collection and reporting system was developed to allow collecting performance measures, viewing electronic PH-ECGs, and reporting feedback to both EMS and the ED. Reports displayed measure performance in monthly intervals using line charts available online and were updated each month during the study intervention period. Information was collected by the sites to identify the patient, paramedic, or EMS run characteristics associated with poor measure performance. To tailor feedback reports and target educational interventions, factors associated with nonperformance of PH-ECGs in the baseline were identified using multivariable analyses. Accuracy of paramedic ECG interpretation was evaluated monthly by EMS Medical Director review of a 20% random sample of paramedic interpreted PH-ECGs plus all ECGs interpreted by paramedics as STEMI. To identify possible STEMI cases overlooked by paramedics, ECGs that generated a computerized interpretation of “acute MI suspected”
were also reviewed. This ECG over-reading and feedback method used a single physician’s ECG interpretation as the gold standard because this was considered most feasible and sustainable in EMS settings. All paramedics participating in the project completed the same online ECG interpretation course before the baseline data collection period or on joining the EMS agency.

**Study Design**

To study the effect of the feedback and QI interventions without causing disruption, we used a before-after quasi-experimental interventional study design. We compared performance measures during the 6-month baseline period (September 2005 to February 2006) with those during the 15-month intervention period (March 2006 to May 2007). Included were all patients over 30 years of age who called 9-1-1 and were transported by EMS for signs or symptoms of possible ACS. Prehospital signs and symptoms of possible ACS include chest, jaw, or left arm pain; acute onset shortness of breath; epigastric pain; history of diabetes or coronary artery disease or age >70 years with symptoms of diaphoresis, syncope, general malaise, or palpitations; abnormal limb leads on cardiac monitor; and self-administered nitroglycerin. Patients were excluded if they had an ECG done before EMS arrival. Patient and EMS run characteristics in the baseline and intervention periods are shown in Table 1.

Predefined data elements were abstracted by trained research assistants from prehospital and hospital medical records and entered into the data collection and reporting system, the EMS Time-Insensitive Predictive Instrument Information System (EMS TIPI-IS, Clinical Care Systems, Inc, Boston, Mass). Prehospital data included patient demographics, symptoms, clinical impression, care provided, transport times, paramedic identifiers, and receiving hospital name. Hospital data included time of hospital arrival and first ECG in the ED, ED diagnosis, hospitalization disposition and in-hospital location, transfer for PCI, D2B time, and ICD-9 discharge diagnoses and procedure codes. Confirmed diagnoses of ACS were based on an ICD-9 discharge diagnosis of MI, and the diagnosis of STEMI was determined by EMS...
Medical Director PH-ECG over-reading or hospital diagnosis of STEMI. Information was collected at the initial receiving hospital, and, when transferred for PCI, at the PCI-capable receiving hospital. ECGs were transmitted from the PH-ECG management systems (Code-STAT Suite, Medtronic/Physio-Control, Redmond, Wash) to the central study database and were matched to the prehospital and hospital patient data for study data collection and QI purposes. Quality control of the data collection process included case reabstraction and validity checking of field values in the data collection system.

**Primary Data Analysis**

The primary analysis evaluated key performance measures of this QI project, including rate of PH-ECG performance, frequency of documented PH-ECG interpretation by EMS providers, and aspirin administration. Secondary analyses included factors associated with PH-ECG nonperformance, paramedic diagnostic sensitivity for STEMI, prevalence of hospital-confirmed STEMI within EMS systems, EMS total run times, and receiving hospital D2B times.

Data were analyzed using SAS software, Version 9.1 of the SAS System for Windows (SAS Institute Inc, Cary, NC). χ² tests were used to test for differences in distributions of categorical variables between baseline and intervention periods. Continuous variables were analyzed for differences between the baseline and intervention populations in 2 ways: (1) segmented into categorical variables and analyzed as above; and (2) described with medians and interquartile ranges and t tests (for normally distributed variables) or Kruskal-Wallis tests (for non-normally distributed variables). Logistic regression was used to measure associations between having a PH-ECG and variables of interest, using odds ratios and probability values.

The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written.

**Implementation of the Initiative**

During the intervention phase (March 2006 to May 2007), we implemented a series of group and individual performance measure feedback reports on the use and accuracy of ECG interpretations, including for STEMI. Feedback reports included the median monthly rate for each measure displayed on line charts and a target improvement goal. Quarterly, individual paramedics received their own rates along with blinded on line charts and a target improvement goal. Logistic regression was used to measure associations between having a PH-ECG and variables of interest, using odds ratios and probability values.

In both communities, “STEMI alert” protocols were developed between the EMS agency and its receiving hospitals, with clear expectations about paramedic and hospital roles during transport of a patient with STEMI. The protocol was for paramedics to issue the “STEMI alert” en route to the hospital and for ED staff to activate the cardiac catheterization laboratory before EMS arrival.

**Success of the Initiative**

We assessed the impact of feedback and improvement activities on our primary goals of improving the rate of PH-ECG performance, frequency of documented PH-ECG interpretation by EMS providers, and aspirin administration. We also evaluated the secondary goals of addressing factors associated with PH-ECG nonperformance, improving paramedic sensitivity in identifying STEMI, identifying prevalence of hospital-confirmed STEMI within EMS systems, and determining changes in hospital D2B times and EMS total run time. To determine the impact of the intervention, we compared performance measure results during the baseline and intervention periods. Data were collected on 6994 patients: 1589 in the baseline period and 5405 in the intervention period. We checked for an interaction between period and site in the final model for our key outcome, PH-ECG performance. There was a slight site-based effect, of borderline significance, and the change in PH-ECG performance was in the same direction at both sites, but of different magnitudes; therefore, as planned a priori, we combined data from both sites for the final analysis.

In comparing PH-ECG performance and aspirin administration between the baseline and intervention periods (Table 3), we found that all of our measures improved, all statisti-
Aspirin administration in patients with symptoms of ACS also increased significantly from 75% to 82% (P=0.001) once feedback was provided. With the intervention, performance of PH-ECGs for women rose from 53% (431/813) to 82% (2241/2742) (P<0.0001) and for men from 62% (480/775) to 87% (2305/2660) (P<0.0001). Thus, despite an increase in PH-ECG for both sexes, the baseline sex difference persisted; women still had a 30% lower odds ratio than men of having a PH-ECG performed (odds ratio, 0.69; 95% confidence interval, 0.59, 0.80). Likewise, PH-ECG performance for patients with a communication barrier increased from 42% (84/201) to 73% (152/201) (P=0.0001), but those with a communication barrier remained 55% less likely to have a PH-ECG than those without barriers. This suggests that factors leading to disparities in PH-ECG performance persisted despite focused interventions.

When PH-ECG measure feedback was provided and STEMI alert protocols were in use, patients with confirmed STEMIs received PH-ECGs more frequently, median D2B times decreased, and the proportion of patients receiving PCI within recommended time frames increased. The proportion of patients with confirmed STEMI who received a PH-ECG increased from 77% to 99% (P<0.0001) (Table 3). The median D2B time decreased from 158 minutes to 80 minutes (P=0.04) (Table 4), and the proportion of patients with STEMI who received PCI at the initial receiving hospital within the recommended 90-minute D2B time, rose from the

### Table 2. Factors Evaluated for Association With PH-ECG Nonperformance During the Baseline Period

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>% Patients Without PH-ECG</th>
<th>Odds Ratio (CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>47% (382/813)</td>
<td>1.44 (1.18–1.76)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Male</td>
<td>38% (295/775)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, linear (odds per 10-y increase)</td>
<td>. . .</td>
<td>0.97 (0.91–1.03)</td>
<td>0.27</td>
</tr>
<tr>
<td>Communication barrier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>58% (117/201)</td>
<td>2.05 (1.52–2.77)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>No</td>
<td>40% (561/1388)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient symptoms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest pain</td>
<td>19% (121/627)</td>
<td>0.17 (0.14–0.22)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Jaw pain</td>
<td>16% (4/25)</td>
<td>0.25 (0.09–0.74)</td>
<td>0.01</td>
</tr>
<tr>
<td>Left arm pain</td>
<td>21% (27/126)</td>
<td>0.34 (0.22–0.53)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Self-administered nitroglycerin</td>
<td>15% (11/71)</td>
<td>0.23 (0.12–0.45)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Epigastric pain</td>
<td>43% (21/49)</td>
<td>1.01 (0.57–1.79)</td>
<td>0.98</td>
</tr>
<tr>
<td>History of CAD with symptoms*</td>
<td>30% (61/203)</td>
<td>0.54 (0.39–0.74)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of DM with symptoms*</td>
<td>50% (93/185)</td>
<td>1.42 (1.04–1.92)</td>
<td>0.03</td>
</tr>
<tr>
<td>Age ≥70 with symptoms*</td>
<td>44% (152/343)</td>
<td>1.09 (0.86–1.39)</td>
<td>0.5</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>52% (352/683)</td>
<td>1.89 (1.55–2.32)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Abnormal limb leads</td>
<td>35% (152/435)</td>
<td>0.64 (0.51–0.81)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Run characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day of week</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekend</td>
<td>42% (171/408)</td>
<td>0.96 (0.76–1.20)</td>
<td>0.7</td>
</tr>
<tr>
<td>Weekday</td>
<td>43% (507/1181)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>44% (346/795)</td>
<td>1.07 (0.88–1.31)</td>
<td>0.5</td>
</tr>
<tr>
<td>Night</td>
<td>42% (322/794)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total run time (odds per 1-min increase)</td>
<td>. . .</td>
<td>0.97 (0.95–0.98)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Paramedic sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>43% (83/191)</td>
<td>1.17 (0.86–1.59)</td>
<td>0.3</td>
</tr>
<tr>
<td>Male</td>
<td>40% (514/1295)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paramedic work status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>39% (497/1265)</td>
<td>0.78 (0.59–1.04)</td>
<td>0.1</td>
</tr>
<tr>
<td>Part-time</td>
<td>45% (100/221)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI indicates confidence interval; CAD, coronary artery disease; and DM, diabetes mellitus.

*Diaphoresis, weakness, malaise, or nausea.

cally significantly. Before ongoing measurement and feedback, only 57% of patients who should be evaluated for ACS had a PH-ECG, compared with 84% (P<0.0001) after receiving feedback. Moreover, in the baseline period, even when a PH-ECG was done, the paramedic documented their interpretation in 84% of the cases, whereas in the intervention period this rose to 95% (P<0.0001). Aspirin administration in

### Table 3. PH-ECG Performance and Aspirin Guideline Adherence During Baseline and Intervention Periods

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Intervention</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH-ECG done by EMS</td>
<td>57% (911/1589*)</td>
<td>84% (4549/5405*)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PH-ECG interpreted by EMS</td>
<td>84% (764/911†)</td>
<td>95% (4334/4549‡)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PH-ECG for patient with STEMI</td>
<td>77% (13/17‡)</td>
<td>99% (92/93§)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PH-ECG for patient with ACS</td>
<td>76% (53/70§)</td>
<td>93% (234/251§)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Aspirin given</td>
<td>75% (315/421[])</td>
<td>82% (1413/1727[])</td>
<td>0.001</td>
</tr>
<tr>
<td>Total run time, min, median (q1-q3)</td>
<td>22 (18–27) n=1525</td>
<td>22 (18–27) n=5328</td>
<td>0.9</td>
</tr>
</tbody>
</table>

*Patients with possible ACS and eligible for PH-ECG.
†Patients with possible ACS and PH-ECG performed.
‡Hospital or EMS medical director–identified STEMI.
§Hospital-identified ACS.
<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Intervention</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2B time, min, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>158 (64–228), n=15*</td>
<td>80 (64–130), n=54*</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>D2B time ≤90 min, %</td>
<td>27% (4/15)</td>
<td>67% (36/54)</td>
<td>0.006</td>
</tr>
<tr>
<td>D2B time ≤120 min, %</td>
<td>40% (6/15)</td>
<td>72% (39/54)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*Excludes patients transferred for PCI.
baseline of 27% to 67% (P<0.0001) (Table 4). Once a STEMI alert protocol was in place, paramedic staff reported greater attention to PH-ECGs by ED staff and the initiation of direct transport to the cardiac catheterization laboratory (however, data on these rates and on inappropriate catheterization laboratory activation were not collected).

Importantly, these improvements caused no increase in the total EMS run time. The median run time from arrival on-scene to hospital arrival remained 22 minutes throughout the project. Paramedics had initially expressed concerns about delaying hospital transport by performing PH-ECGs, but there was no increase in total run time, perhaps becoming more efficient in performing PH-ECGs as they did so more frequently.

There are several limitations in the study intrinsic to its being conducted in a “real world” setting. It was incorporated into daily operations of EMS agencies to acquire, as much as possible, results generalizable to other similar settings. Process measures were collected, but outcome measures were not tracked; a much larger study would be needed to be able to detect direct impact on outcomes. The project participants were not blinded to the intervention and were aware of the aims to improve the care of patients with ACS. Awareness of being observed may have changed performance, although this would be a feature of this approach in the “real world.” Of note, the before-after quasi-experimental interventional study design used in this study provides a less strong demonstration of causality than the fully randomized approach used in other kinds of interventions. The consistency of effect at the 2 sites and that the interventions’ timing linked with the improvement in performance all help compensate for the limitations of this study design. Nonetheless, additional studies confirming our results will be helpful.

Another limitation is that assessment of performance was abstracted from patient care records, and completeness of documentation varied and may have influenced study inclusion. Additionally, documentation of EMS “STEMI alert” notification to the ED was difficult to collect as were cardiac catheterization laboratory activation times. This prevented evaluation of the frequency and impact of the “STEMI alert.” Also, the 2 participating EMS systems were private/private-public entities in suburban/urban settings and may not be broadly representative. Performance measures were developed considering local guidelines; other agencies may choose to develop different measures relevant to their local setting. Despite these limitations, the consistency of this study’s findings in improving prehospital care for ACS suggests that the results are generalizable, although further research will be needed to verify this.

**Summary of the Experience, Future Directions, and Challenges**

In comparing PH-ECG performance and aspirin administration between the baseline and intervention periods, we found that all of our measures improved, all statistically significantly. Both PH-ECG performance and interpretation documentation for patients with prehospital symptoms of ACS and hospital confirmed ACS increased significantly and remained at high levels throughout the intervention period.

The use of PH-ECG interpretations to trigger the activation of the cardiac catheterization laboratory while the patient is en route is one of several successful strategies to reduce D2B times.\(^{11}\) Efforts at activation of the catheterization laboratory by the ED physician and streamlining hospital communications are effective but do not take advantage of the opportunity to activate the laboratory before ED arrival.\(^{17-19}\) In our study, patients with ACS, including those with STEMI, were more likely to have a PH-ECG when paramedics received ongoing feedback on their performance. This enhanced the opportunity posed when the paramedic identified STEMI in the field and could notify the receiving hospital en route—and, in some cases, patients were transported directly to the catheterization laboratory. Importantly, these improvements were achieved without increasing total run time.

The use of EMS to identify STEMI in the field and bypass non-PCI hospitals to go to prenotified PCI centers represents an effective model of STEMI care regionalization that leads to shorter D2B times.\(^{20-25}\) The time duration from first medical contact to PCI balloon inflation,\(^{6}\) EMS-to-balloon time (E2B), is a metric that allows measurement and improvement of the prehospital contribution to timely STEMI care.\(^{26}\) A second model of STEMI systems of care is the “treat and transfer” model, in which patients are rapidly transferred from non-PCI-capable hospitals to PCI-receiving hospitals, using a standardized treatment protocol and integrated transfer system.\(^{27}\) Of importance for these approaches, this study confirmed that programs based on ongoing measurement and QI of PH-ECG performance, along with “STEMI alert” systems, can reduce D2B times. Whether paramedics are making the decision in the field to bypass a non-PCI-capable hospital or to activate a treat and transfer protocol in a community hospital, the paramedic staff must be confident in their ECG interpretation skills and prepared to communicate their interpretation while en route to the hospital.\(^{28,29}\)

The American Heart Association’s “Mission Lifeline” (AHA-ML) campaign includes recommendations for data collection on EMS ECG performance and use of QI with formal feedback across the continuum of STEMI care providers.\(^{15,30,31}\) The findings of this study, which concluded just as Mission Lifeline was launched, are relevant to the primary goals of AHA-ML, and the study demonstrated the technical capability to meet these goals. The information system developed for the project allowed data collection and integration of data and performance measures across prehospital and hospital care. Prehospital metrics included performance and use of PH-ECGs and adherence to aspirin guidelines; hospital metrics included D2B time. For patients transferred between hospitals, time from door of hospital A to door of hospital B to balloon time was calculated. All metrics and the supporting data were available on a web-based system accessible to EMS and hospital staff. There are few national EMS performance measure initiatives, and the ability to collect standardized data has only recently emerged. Although there are many references to improving EMS performance through educational interventions,\(^{32}\) there is little literature that demonstrates measuring, improving, and maintaining paramedic performance over time. The recent emergence of a National EMS information system (NEMSIS) may allow standardiza-
tion of EMS data collection and further development of measures as described here. After this study, the participating communities did not maintain the data collection needed for the feedback reporting system because of resource constraints. Electronic PCR systems and the development of joint EMS and hospital ACS registries should facilitate the kind of comprehensive measurement and improvement efforts tested in this study as well as more integrated and improved EMS-hospital care for ACS and STEMI.

To continue to develop the role of EMS PH-ECG performance and interpretation to improve systems of care for STEMI, the importance of measuring and improving prehospital care and PH-ECG use for care of all ACS will need to increase as well. The approach implemented in this study, supported by health information technology, successfully measured performance, provided feedback on performance, and improved clinical performance measures for care of ACS, including the performance of PH-ECGs. This approach appears to have promise for community-based care of ACS and STEMI and deserves further exploration.

Acknowledgments
The authors thank Drs Judith Hinchin and Richard Hermann and Mic Gunderson for consultation on performance measure development and Dr David Kent for review of the article. Drs Octavio Dias, Richard Herman, Craig Sylvester, and James Fitch provided ED leadership. Martin Tirell, David Lovesky, and Michael Hunter coordinated EMS data collection and improvement. Virginia Mangolds, MS, FNP, Jane Bateman, RN, Patricia Arensault, RN, Pamela Sigel, RN, Kalen Ho, MD, and Benjamin Scirica, MD, coordinated institutional review board approval and hospital data collection.

Sources of Funding
This study was funded by a grant from the Agency for Healthcare Research and Quality (UC1 HS15124). This work was supported in part by the National Institutes of Health, National Heart, Lung, and Blood Institute (U01 HL077821). In-kind support for the project also was provided by Medtronic, Zoll Medical, Clinical Care Systems, and Tufts Medical Center.

Disclosures
D.H. Daudelin received research support from the Agency for Healthcare Research and Quality and has equity in Clinical Care Systems, Inc. M. Kwong received research support from the Agency for Healthcare Research and Quality and the National Heart, Lung, and Blood Institute and has equity in Clinical Care Systems, Inc. R. Ruthazer received research support from the Agency for Healthcare Research and Quality, the National Heart, Lung, and Blood Institute, and the National Library of Medicine. J.D. Goetz received research support from the Agency for Healthcare Research and Quality, the National Heart, Lung, and Blood Institute and has equity in Clinical Care Systems, Inc. Dr Selker received research support from the Agency for Healthcare Research and Quality and the National Heart, Lung, and Blood Institute and has equity in Clinical Care Systems, Inc.

References
Improving Use of Prehospital 12-Lead ECG for Early Identification and Treatment of Acute Coronary Syndrome and ST-Elevation Myocardial Infarction
Denise H. Daudelin, Assaad J. Sayah, Manlik Kwong, Marc C. Restuccia, William A. Porcaro, Robin Ruthazer, Jessica D. Goetz, William M. Lane, Joni R. Beshansky and Harry P. Selker

Circ Cardiovasc Qual Outcomes. 2010;3:316-323
doi: 10.1161/CIRCOUTCOMES.109.895045
Circulation: Cardiovascular Quality and Outcomes is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2010 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-7705. Online ISSN: 1941-7713

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circoutcomes.ahajournals.org/content/3/3/316

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation: Cardiovascular Quality and Outcomes can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation: Cardiovascular Quality and Outcomes is online at:
http://circoutcomes.ahajournals.org//subscriptions/