Grant Final Report

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EMS Based TIPI-IS Cardiac Care QI/Error Reduction System

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Abstract

Purpose: This project developed, implemented, and measured the impact of an emergency cardiac care QI and error reduction information system. The Emergency Medical System Time Insensitive Predictive Instrument Information System, (EMS TIPI-IS) collected and fed back the results of quality measures. ACI-TIPI/TPI decision support assisted paramedics in identifying patients with acute coronary syndrome (ACS).

Scope: The impact of a prehospital/hospital quality improvement and error reduction system was demonstrated in two cities and included the two EMS agencies, five community hospitals and three referral hospitals serving those communities.

Methods: The approach uses multiple information technology strategies including ACI-TIPI capable electrocardiogram(ECG) computation of prehospital patients' 0-100% probability of having ACS and a web-based data collection and feedback reporting system; a before after time series design assessed impact. Information was collected on prehospital and hospital care, combined in to a single database and used for feedback reporting.

Results: To improve quality, TIPI-IS provided real-time decision support, retrospective feedback, and web-based QI review. It electronically collected and distributed clinical information and quality measure results on more than 4,300 prehospital/hospital patients focusing on adherence to ACS treatment protocols. The intervention period showed improvement in prehospital obtainment of ECGs needed for STEMI identification, adherence to treatment protocols, and shorter hospital door-to-balloon times.

Key Words: Feedback reports**,** information technology, QI, ACI, ACS, AMI, unstable angina, STEMI, EMS, clinical decision support, quality measure, ACI-TIPI, TIPI-IS

Final Report

Purpose

This project aimed to develop, implement, and measure the impact of an EMS emergency cardiac care QI and error reduction information system. The Emergency Medical System Time Insensitive Predictive Instrument Information System,(EMS TIPI-IS) was created to collect and feed back the ongoing results of quality performance measures and support tailored improvement interventions. The foundation of the system was based on the real-time and retrospective use of the ACI-TIPI and TPI in the prehospital setting to assist paramedics in identifying patients with acute coronary syndrome (ACS) including those with ST wave elevation myocardial infarction (STEMI). We looked for impact on treatment and avoidable delays in the EMS and hospital settings and on the timeliness of coronary reperfusion treatment (CRT) for patients with STEMI.

Scope

Acute cardiac ischemia (ACI, also known as acute coronary syndromes, ACS), which includes acute myocardial infarction (AMI) and unstable angina pectoris (UAP), which can progress to AMI, represents the largest cause of mortality and morbidity in the US and a major focus of emergency medical service (EMS) systems. Key to saving lives in ACI is timeliness of treatment. In particular, for patients with ACI just evolving into AMI, reflected by electrocardiogram (ECG), ST elevation MI (STEMI), coronary reperfusion therapy (CRT), i.e., thrombolytic therapy (TT) or primary percutaneous transluminal coronary angioplasty (PTCA), can be life-saving, *if given promptly*. Time from ACI symptom onset to CRT is the single greatest determinant of its impact on mortality. In hospitals, appreciation of this and evolving requirements of accrediting and monitoring entities have spawned approaches to improve rapid recognition and treatment of ACI/AMI. These entities have focused on preventing delays and errors in treatment and on data collection for feedback and improvement of care. In EMS settings, there has been appreciation of the importance of identifying patients needing CRT and getting them treatment promptly, but there has not been the requirement for, nor the growth of, error reduction and quality improvement (QI) systems. Based on a system we implemented in hospitals and their emergency departments (EDs), developed, implemented and demonstrated the effective use of a patient safety and QI support system for emergency care for ACI/AMI in EMS systems.

Our approach to QI/error reduction/patient safety for ACI care is based on time-insensitive predictive instruments (TIPIs) built into the clinical tool used to evaluate patients with suspected ACI, the electrocardiograph. The *"time-insensitive"* aspect reflects that the TIPI's computed 0-100% probabilities of key clinical outcomes are valid for use in the *real-time* clinical setting *and* for *retrospective* review of care. Thus, in EMS settings, conventional computerized electrocardiographs with TIPI software can provide the predicted probabilities of key diagnoses and outcomes by printing it on the top of the initial ECG to aid paramedics' immediate decision-making, and that predicted probability can be saved in a TIPI information system (TIPI-IS) database for *retrospective reports* for feedback. Our TIPI for improving use of CRT for STEMI, the thrombolytic predictive instrument (TPI), is implemented in computerized electrocardiographs so that when TPI software detects ST segment elevation of AMI, on the ECG header are printed patient-specific 0-100% predictions of the key outcomes of the use of TT, the potential benefits in terms of 30-day mortality, 1-year mortality, and cardiac arrest, and the probabilities of TT-related hemorrhagic stroke and transfusion-requiring bleeding. In clinical trials, the TPI has been shown to improve care. It increases recognition of patients who should receive CRT and the speed of treatment among those more commonly missed, such as women and those with less obvious AMIs, and in settings where needed expertise is not on-site. In order to take advantage of the decision support provided by ACI-TIPI/TPI and to potentially identify and treat patients with AMI in the filed, a 12-lead ECG must be performed and interpreted by paramedics.

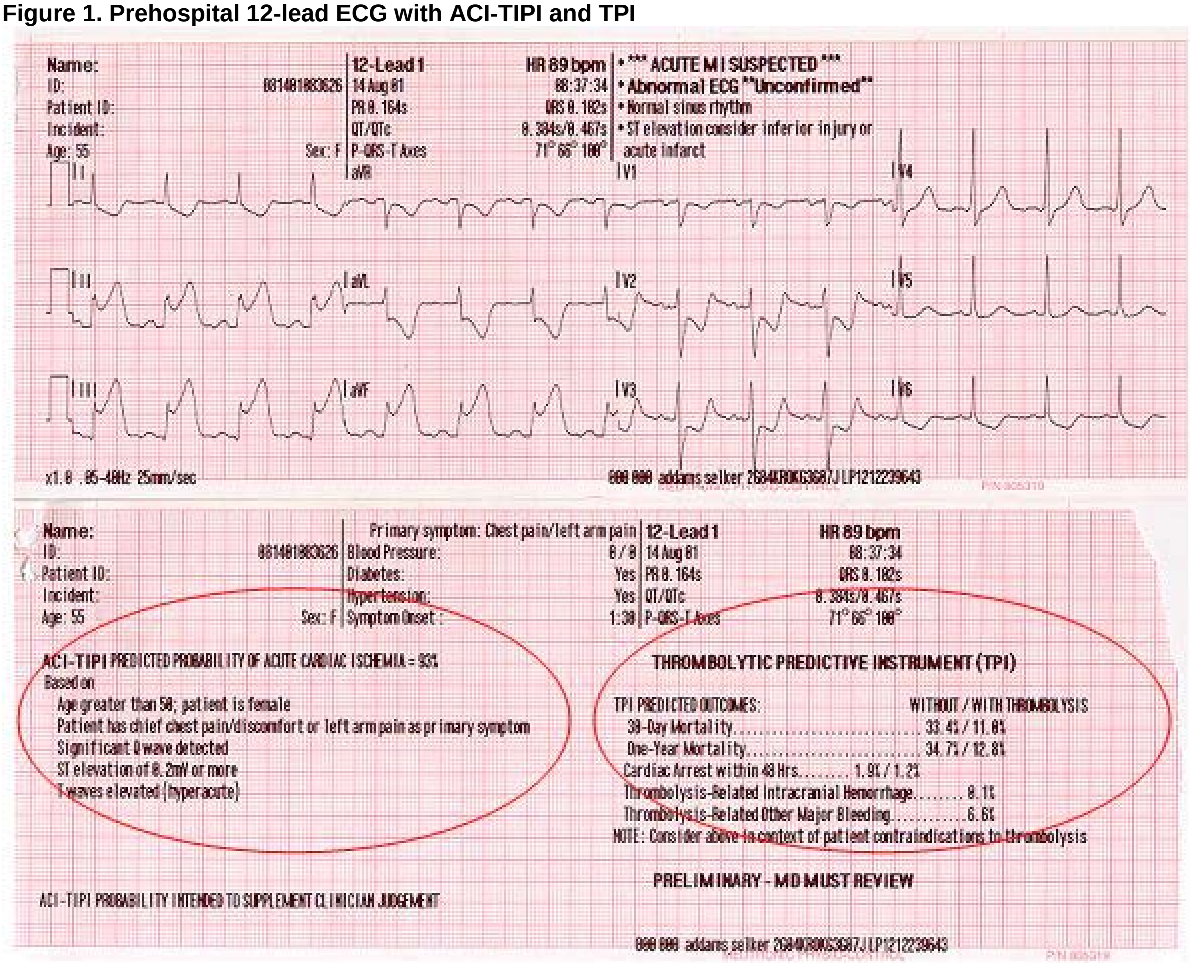
EMS performance and accurate interpretation of a prehospital 12-lead ECG is central to early identification of acute STEMI in the community.[1-3] Timely reperfusion through primary percutaneous coronary intervention (PCI) has become the preferred treatment when it can be done soon after the onset of symptoms. The American Heart Association/American College of Cardiology (AHA/ACC), have recommended that patients with STEMI receive a PCI within a < 90 minute door-to-balloon time standard.[4] For patients who present to non-PCI capable hospitals and require transfer for treatment, only 4.2% will meet this 90-minute goal.[5] When hospitals use prehospital 12-lead ECG results to activate a cardiac catheterization lab while the patient is still en route, door-to-balloon times are shorter than when such activation is initiated upon ED arrival.[6,7] Despite this, currently prehospital 12-lead ECGs are performed on fewer than 10% of patients with STEMI.[8]

Newly emerging regional systems for patients with ACS rely on paramedics interpreting prehospital ECGs and identifying the presence of STEMI for direct transport to a PCI-capable hospital or for early community hospital notification to treat and transfer for PCI. These efforts are modeled after regionalized trauma and stroke care, for which the most critically ill patients are taken directly by EMS to trauma or stroke designated centers, bypassing hospitals without this capability.[9,10] Applying this to the care of patients with STEMI means EMS bypassing non-PCI-capable hospitals when a PCI-capable hospital can be reached in a timely manner. To realize the potential benefits of prehospital identification of and of systems of care for STEMI, there must be appropriate equipment and training and continuous improvement of paramedic 12-lead ECG use through measurement and feedback.[11] Despite numerous national guidelines and local treatment protocols, there are no national agreed upon prehospital 12-lead ECG or ACS performance measures to guide EMS agencies.

The EMS TIPI-IS Quality Improvement Project used multiple information technology strategies to measure and improve the quality of care for EMS patients with ACS. The ACI-TIPI decision support combined with the EMS TIPI-IS system, provided real time support in identifying patients with ACS and retrospective measurement and feedback about the quality of care. The EMS TIPI-IS system collected information about the care provided to patients transported by EMS and combined that information with the prehospital electronic ECG if performed. Hospital assessment and diagnosis information was collected, entered into the system and combined with the EMS data creating a single record of care for the entire prehospital and hospital encounter. Prehospital ACS quality measures were developed based on existing treatment protocols and the aims of the study. The measures were programmed into the

TIPI-IS and the results provided to EMS agencies via web-based feedback reports. Established Hospital AMI measures developed by JCAHO were also programmed into the system and reported through online reports to ED managers. Combining the prehospital and hospital care delivered as well as outcome information collected at the hospital allowed a broader view of the impact of prehospital care on patient outcomes in the hospital. It also allowed EMS providers to evaluate their care in light of the patient's true diagnosis after hospital evaluation, an important but often unattainable process. The purpose of this study was to demonstrate a method by which prehospital care of patients with ACS could be measured and improved including the availability and use of the ACI-TIPI and TPI. To do this we implemented the ACI-TIPI decision support in electrocardiographs at the point of care **(**Figure 1.**),** developed performance measures, and implemented an information system to collect, feedback, and monitor performance, and then we developed feedback reports to EMS and ED managers and staff.

Figure 1. Prehospital 12-lead ECG with ACI-TIPI and TPI



Site Selection

EMS agencies were selected based on their willingness to participate in the project, the existence of a quality improvement program, ability of leadership to effect changes in clinical practice, and a culture receptive to feedback and improvement. Receiving hospitals in each community also needed to be willing to participate and engage in joint EMS/ED improvement efforts. One of the initial sites was dropped when information suggested that the leadership couldn't engage the staff in quality improvement efforts because of internal conflicts.

The selected study sites included EMS agencies providing 9-1-1 services in two Massachusetts cities; the five receiving hospitals in those cities and selected tertiary referral hospitals receiving patients in transfer for PCI also participated. EMS System A included a privately-owned EMS agency staffed by paramedics or a paramedic with an Emergency Medical Technician-Intermediate. Of the two receiving community hospitals, one hospital performed PCI for STEMI or transferred for PCI when the cardiac catheterization lab was unavailable, whereas the other hospital transferred its patients with STEMI for PCI. Three PCI-capable tertiary hospitals who received patients in transfer from one or both of the community hospitals participated. EMS System B included a hospital-based EMS agency staffed by paramedics. Of the three receiving hospitals, two performed PCI and one transferred elsewhere for PCI. All hospitals involved in the project infrequently administered thrombolytic therapy as single therapy. The institutional review board (IRB) at each hospital and at the research coordinating center approved the study protocol.

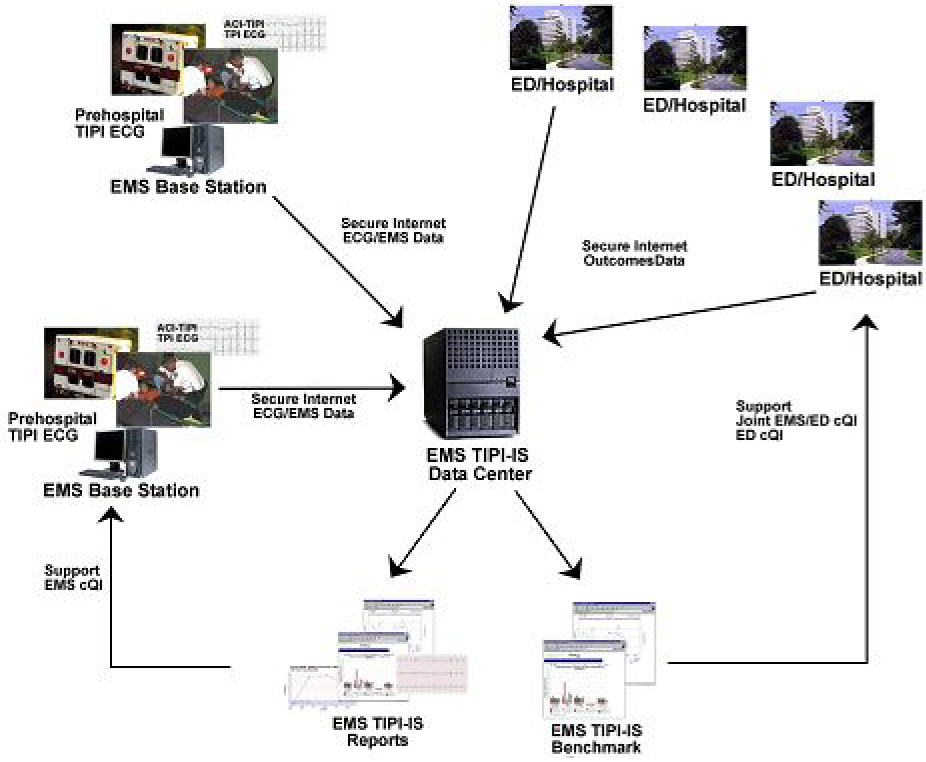
Selection of Study Participants

In each city, the patient care records for all patients who called 9-1-1 and were transported by EMS were screened for signs and symptoms suggestive of ACS (chest, jaw, or left arm pain; acute onset shortness of breath; epigastric pain; history of diabetes or coronary artery disease or age >70 with symptoms of diaphoresis, syncope, general malaise, or palpitations; abnormal limb leads noted on cardiac monitor; and self administered nitroglycerin). If one or more such symptoms were present, the patient was included in the project. Patients were excluded if they had an ECG prior to their encounter with EMS or were less than 30 years old.

Methods

Data from each prehospital patient care record (PCR) were abstracted by research assistants and entered into a web-based data collection and reporting system, EMS TIPI-IS (Clinical Care Systems, Boston, MA). **(**Figure 2.**)** Electrocardiograms were transmitted from the prehospital ECG management system (Code-STAT Suite, Medtronic/Physio-Control, Redmond WA) to the central database and matched to the prehospital patient data**.** Each receiving hospital entered patient care information into the web-based system for their same patients. If a patient was transported to a non-PCI-capable hospital and then required transfer to a PCI-capable hospital, the second receiving hospital also entered information into the system. Baseline and intervention period data were collected at each site. The baseline and intervention periods were six months and eight months at EMS System A, and were two months and six months at EMS System B.

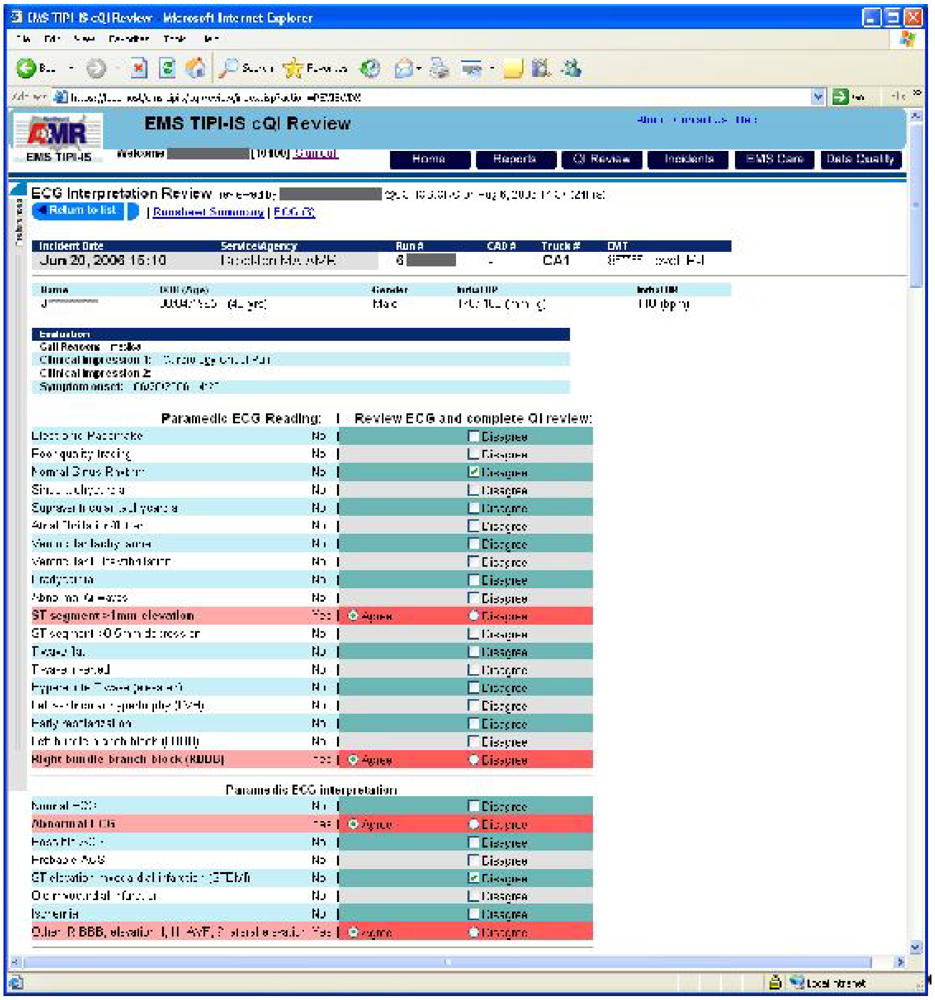
Figure 2. TIPI-IS diagram



Prehospital data included patient demographics, the results of assessments, treatments provided, prehospital event times, paramedic identifiers and receiving hospital name. Paramedic's ECG interpretations were coded, entered into the database and matched to the corresponding electronic ECG records. Hospital medical record data were abstracted and entered into the data collection system, including the times of hospital arrival, first ED ECG, ED diagnosis, admission status and location and transfer for PCI, door-to-balloon time and ICD-9 discharge diagnoses and procedure codes. A separate, but related study tracking paramedic 12-lead ECG performance was conducted at one site following this project.

The accuracy of paramedic ECG interpretation, one of the quality measures, was checked through monthly EMS medical oversight by physician review of a random sample of paramedic ECG interpretations. Electrocardiograms that paramedics interpreted as showing STEMI and ECGs that generated computer interpretations of "acute MI" were also included in the over-reading process. An EMS physician Medical Director reviewed the prehospital ECG and paramedic interpretation via the web-based system and identified interpretations as "correct," "incorrect," or "missed". **(**Figure 3.)

Figure 3. EMS TIPI-IS ECG over-reading screen



Performance Measures

We developed metrics to track adherence to local ACS treatment protocols, including the performance of a prehospital ECG. Analysis over the baseline period revealed factors associated with less frequent performance and interpretation of ECGs; this was used to develop additional measures.

Intervention: Performance Measure Feedback and Improvement Cycles

The intervention period included a series of feedback reports on performance measures. Reports included the frequency of ECG performance during the baseline period and each subsequent month **(**Figure 4**.)** as well as feedback on the other quality measures**.** Reports were posted in a central location and results discussed during staff meetings. The EMS Medical Directors communicated the importance of the project to their staff and participated in individual

ECG case reviews. Performance on the measures was displayed on a line chart along with the median monthly rate for each measure and the target rate. Quarterly, individual paramedics were presented their own rate along with blinded results for others. **(**Figure 5.) Data from the baseline period were analyzed to identify patient, paramedic, and EMS run characteristics associated with a lower likelihood of 12-lead ECG performance. These findings were used to create additional feedback reports during the intervention period. The target measures included: chest pain assessment, 12-lead ECG performance and interpretation, and ACS treatment protocol compliance.

Figure 4. 12-Lead ECG performance feedback report

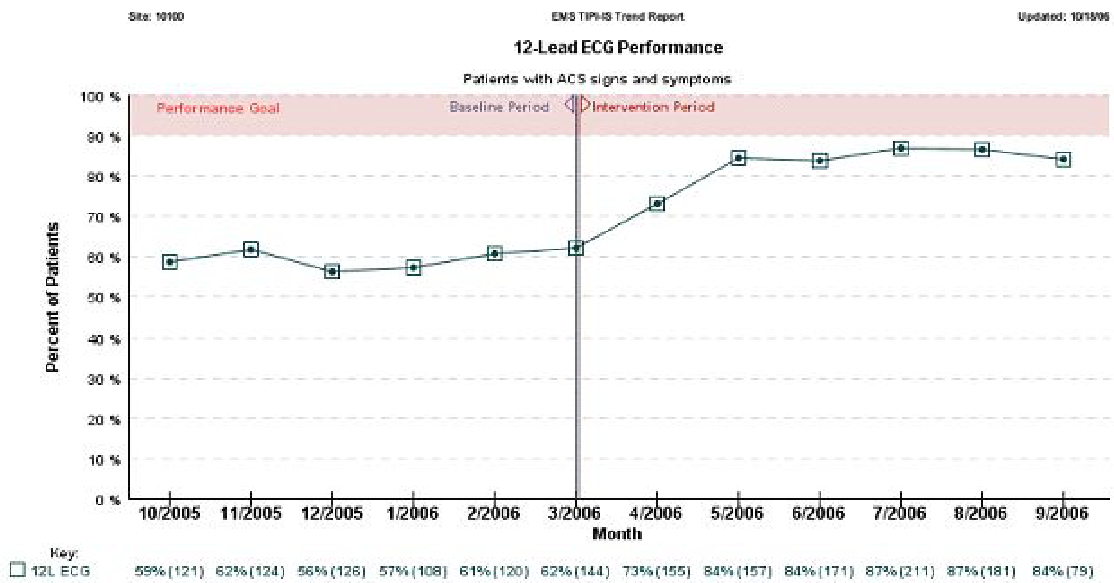
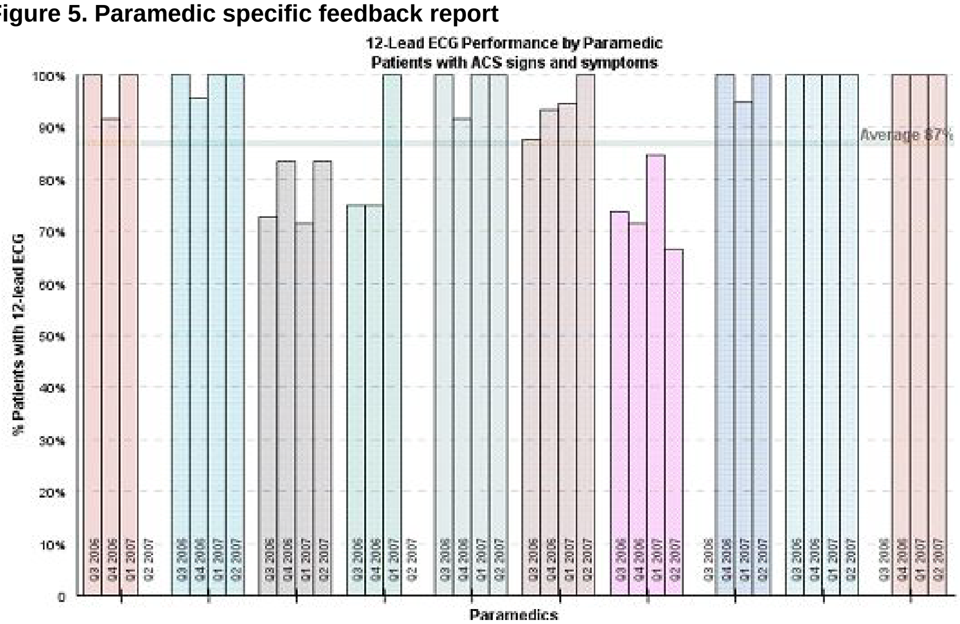


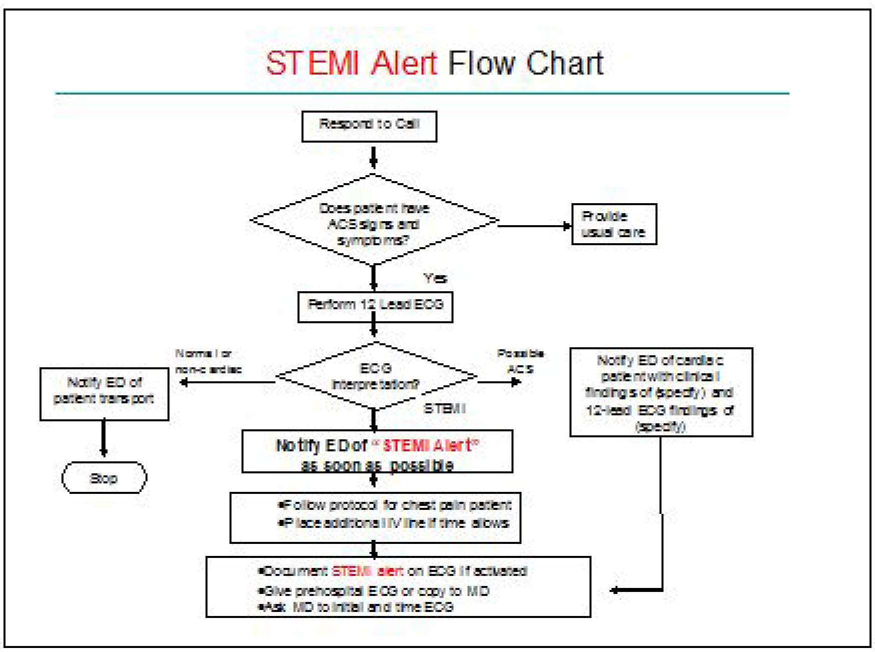
Figure 5. Paramedic specific feedback report



A series of quality improvement cycles with small tests of change were used to improve the measures. Process changes were developed and implemented at EMS agencies based on the results of the baseline and ongoing performance measures, and analysis of cause and effect diagrams. Group and individual paramedic interventions included: 1) education about when to perform an ECG and how to document the interpretation; 2) raising staff awareness about the types of patients for whom an ECG was indicated but not performed; 3) providing focused ECG interpretation education based on the results of medical director over-reading; 4) addressing technical problems with electrocardiograph equipment; 5) communicating clearly the role of the paramedic in identifying patients with STEMI for ED prenotification and cardiac catheterization lab activation. All paramedics participating in the project completed the same online ECG interpretation module prior to the baseline data collection period or when they joined the EMS agency.

In one community, a "STEMI Alert" protocol was developed by the EMS agency and its receiving hospitals establishing clear expectations about paramedic and hospital roles for transport of a patient with STEMI. (Figure 6.) Emergency physicians became aware that the paramedic would issue the "STEMI Alert" en route to the hospital and that they should activate the cardiac catheterization lab. When the paramedic was unsure if the ECG represented a STEMI, "Possible STEMI" notification was made. Paramedics were expected to provide the ECGs directly to the ED physician and to discuss the interpretation.

Figure 6. STEMI Alert protocol flowchart



The second community participated in the implementation of a regional STEMI Alert protocol, developed in parallel and implemented during the project's intervention phase. This regional plan included a computer aided dispatch system enhanced notification process that allowed the paramedic to reach an ED based medical control physician while transporting patients with suspected STEMI. This led to development of hospital specific STEMI Alert protocols.

A Project Assessment Survey was used to understand and improve the attractiveness and utility for all users of the TIPI-IS error reduction system and prepare for the wide dissemination of the TIPI-IS approach. The survey was designed to identify the barriers to implementation as well as the factors that make attractive and lead to the successful use of the TIPI-IS. A combination of a mail-in survey followed up by a semi-structured telephone interview was used. The results were summarized and used to make improvements in the user interface and reports.

Results

Data Analysis

To assess the effect of the feedback and improvement activities on the performance measures, we compared the baseline and intervention periods based on their proportions of patients who received the target assessment or treatment. We evaluated the rates of ECG performance, as well as other measures, between the two periods and the variables associated with likelihood of an ECG being done. We also compared physician agreement with paramedics' ECG interpretations between the two periods. The volume of ECGs performed during the last three months of the intervention period was compared to the volume of ECGs performed over three months one year after the project.

All data were analyzed using SAS software, Version 9.1 of the SAS System for Windows (SAS Institute Inc., Cary, NC, USA.) Categorical variables were described with frequencies and percentages. Chi-square tests were used to test for any differences in the distribution of categorical variables between the baseline and intervention periods. Continuous variables were analyzed in two ways: 1) They were segmented into categorical variables and analyzed as described above; 2) They were described with medians and inter-quartile ranges and t-tests (for normally distributed variables) or Kruskal-Wallis tests (for non-normally distributed variables) were used to test for differences between the baseline and intervention populations. Logistic Regression was used to measure associations between having a 12-lead ECG and the variables of interest. Odds ratios and p-values produced by the logistic models are reported. A survey of the attractiveness and usefulness of the TIPI-IS was conducted with participating sites and stakeholders. The results were summarized and changes made to the system throughout the project.

We collected data on a total of 4,412 patients (2,851 in EMS System A, and 1,561 in EMS System B), including 1,592 patients in the baseline periods and 2,820 in the intervention periods. The baseline and intervention periods for EMS System B were shorter than for System A. System B contributed 21% of the baseline data and 44% of the intervention data. **Table 1** summarizes patient, EMS run, and paramedic characteristics for each EMS System during the baseline and intervention periods.

Table 1. Patient, paramedic, and run characteristics

Table 1a. Patient characteristics

Cohort/ Outcome	**EMS System A: Baseline (n=1,263)**	**EMS System A: Intervention (n=2,755)**	**EMS System A: P value**	**EMS System B: Baseline (n=326)**	**EMS System B: Intervention (n=2,647)**	**EMS System B: P value**
Gender (%Men)	48 (607)	47 (1,285)	0.4	52 (168)	52 (1,375)	0.9
Age, mean ± SD	66, +/-17.0 (1263)	65, +/- 16.4 (2,755)	0.6	67, +/- 16.0 (326)	66, +/-16.6 (2,650)	0.9
Communication Barrier (% Yes)	14.0% (177)	14.2% (390)	0.9	7.4% (24)	5.8% (154)	0.27

Table 1b. EMS clinical impression

Cohort/ Outcome	**EMS System A: Baseline (n=1,263)**	**EMS System A: Intervention (n=2,755)**	**EMS System A: P value**	**EMS System B: Baseline (n=326)**	**EMS System B: Intervention (n=2,647)**	**EMS System B: P value**
EMS clinical impression	N=1,263	N=2,755	<.0001	N=326	N=2,650	0.0007
Cardiology	40.9% (517)	41.9% (1155)		40.2% (131)	44.3% (1173)	
Musculoskeletal	4.8% (61)	2.9% (80)		2.5% (8)	3.2% (85)	
Neurology	11.6% (146)	11.3% (312)		4.6% (15)	7.4% (197)	
Respiratory	21.4% (270)	20.9% (576)		17.8% (58)	15.2% (404)	
Other	21.4% (269)	22.9% (632)		24.8% (114)	29.7% (791)	

Table 1c. Run characteristics

Cohort/ Outcome	**EMS System A: Baseline (n=1,263)**	**EMS System A: Intervention (n=2,755)**	**EMS System A: P value**	**EMS System B: Baseline (n=326)**	**EMS System B: Intervention (n=2,647)**	**EMS System B: P value**
Day of Week (% Weekday)	N=1,263 74.1% (936)	N=2,755 75.2% (1,272)	0.5	N=326 75.2% (245)	N=2,650 73.6% (1,950)	0.5
Time of Day (%Day)	N=1,263 50.3% (635)	N=2,755 50.4% (1,389)	0.9	N=326 49.1% (160)	N=2,650 48.0% (1,271)	0.7
Total Run time Median, min <q1-q3> (n)	23 < 19-27> (1,213)	23 < 19-28> (2,703)	0.007	20 < 16-24> (312)	20 < 17-25> (2,625)	0.002

Table 1d. Paramedic characteristics

Cohort/ Outcome	**EMS System A: Baseline (n=1,263)**	**EMS System A: Intervention (n=2,755)**	**EMS System A: P value**	**EMS System B: Baseline (n=326)**	**EMS System B: Intervention (n=2,647)**	**EMS System B: P value**
Gender (% Men)	88.4% (1,045)	91.2% (1,311)	0.02	83.7% (278)	81.9% (1,002)	0.5
Paramedic work status (% Full Time)	86.8% (1,026)	88.9% (1,279)	0.09	80.4% (267)	87.0% (1,064)	0.003

We performed multivariable analyses to identify factors associated with nonperformance of ECGs in the baseline period in order to tailor feedback reports and target educational interventions. In both communities, women were less likely to have an ECG, and in Community A, patients with a communication barrier were less likely to have an ECG performed. Day of the week and time of day were not associated with a lower likelihood of ECG performance. **(**Table 2.)

Table 2. Factors associated with 12-Lead ECG performance

Table 2a. All

	EMS System Community A: % patients with 12L ECG	EMS System Community A: Odds Ratio (CI)	EMS System Comm-unity A: p-value	EMS System Community B: % patients with 12L ECG	EMS System Community B:Odds Ratio (CI)	EMS System Comm-unity B:p-value
ALL	57% (716 / 1,263)			60% (195/326)		

Table 2b. Patient characteristics

	EMS System Community A: % patients with 12L ECG	EMS System Community A: Odds Ratio (CI)	EMS System Comm-unity A: p-value	EMS System Community B: % patients with 12L ECG	EMS System Community B:Odds Ratio (CI)	EMS System Comm-unity B:p-value
Gender: Men	61% (371/607)	1.4 (1.13-1.77)	0.002	65% (109/168)	1.6 (0.99-2.41)	0.05
Gender: Women	53% (345/655)	Ref.		54% (86/158)	Ref.	
Age – linear (odds per 1 yr increase)		1.0 (0.99-1.00)	0.6		.99 (0.98-1.00)	0.8
Communication barrier: Yes	38%(68/177)	0.4 (0.30-0.58)	<.0001	67% (16/24)	1.4 (0.57-3.31)	0.9
Communication barrier: No	60%(648/1,086)	Ref.		59% (179/302)	Ref.	

Table 2c. Patient symptoms

	EMS System Community A: % patients with 12L ECG	EMS System Community A: Odds Ratio (CI)	EMS System Comm-unity A: p-value	EMS System Community B: % patients with 12L ECG	EMS System Community B:Odds Ratio (CI)	EMS System Comm-unity B:p-value
Chest pain	79%(396/502)	5.15 (3.98-6.66)	<.0001	88% (110/125)	10 (5.45-18.4)	<.0001
Left arm pain	79%(93/117)	3.25 (2.05-5.17)	<.0001	67% (6/9)	1.4 (0.33-5.51)	0.7
Jaw pain	83%(20/24)	3.9 (1.33-11.48)	0.005	100% (1/1)	-	
Self admin ntg	85% (60/71)	4.5 (2.32-8.56)	<.0001	-	-	
Cocaine Use	100% (5/5)			100% (3/3)		
Epigastric pain	63% (19/30)	1.3 (0.63-2.81)	0.5	47% (9/19)	0.6 (0.23-1.48)	0.26
History of CAD*	68% (125/183)	1.8 (1.28-2.49)	0.0005	85% (17/20)	4.07 (1.17-14.2)	0.01
History of DM *	51% (83/163)	0.8 (0.55-1.06)	0.11	41% (9/22)	0.4 (0.18-1.06)	0.06
Age > 70 *	57% (164/286)	1.03 (0.79-1.35)	0.8	47% (27/57)	0.5 (0.30-0.96)	0.4
Acute onset SOB	51% (301/592)	0.6 (0.51-0.80)	<.0001	33% (30/91)	0.21 (0.12-0.35)	<.0001
Abnormal limb leads	65% (281/432)	1.7 (1.33-2.15)	<.0001	67% (2/3)	1.35 (0.12-15.0)	0.8

* includes symptoms of diaphoresis, weakness, malaise or nausea

Table 2d. Run characteristics

	EMS System Community A: % patients with 12L ECG	EMS System Community A: Odds Ratio (CI)	EMS System Comm-unity A: p-value	EMS System Community B: % patients with 12L ECG	EMS System Community B:Odds Ratio (CI)	EMS System Comm-unity B:p-value
Day of week: Weekend	58% (191/327)	1.10 (0.85-1.42)	0.5	57% (46/81)	0.9 (0.51-1.41)	0.5
Day of week: Weekday	56% (525/936)	Ref.		61% (149/245)	Ref.	
Time of day: Day	55% (352/635)	0.9 (0.72-1.13)	0.4	61% (97/160)	1.07 (0.69-1.66)	0.8
Time of day: Night	58% (364/628)	Ref.		59% (98/166)	Ref.	
Total run time: Under 20min	44% (168/382)	Ref.	<.0001	50% (74/149)	Ref.	0.002
Total run time: 20-30min	63% (404/639)	2.19 (1.69-2.83)		69% (98/143)	2.21 (1.37-3.56)	
Total run time: Over 30min	59% (113/192)	1.8 (1.28-2.59)		70% (14/20)	2.4 (0.86-6.48)	

Table 2e. Paramedic characteristics

	EMS System Community A: % patients with 12L ECG	EMS System Community A: Odds Ratio (CI)	EMS System Comm-unity A: p-value	EMS System Community B: % patients with 12L ECG	EMS System Community B:Odds Ratio (CI)	EMS System Comm-unity B:p-value
Gender: Men	60% (633/1,047)	Ref.	0.11	67% (348/520)	Ref.	0.26
Gender: Women	53% (73/137)	0.8 (0.52-1.07)		71% (66/93)	1.21 (0.74-1.96)	
Work hours: Full time	61% (624/1,028)	1.4 (0.99-1.95)	0.06	68% (343/502)	1.22 (0.79-1.87)	0.26
Work hours: Part time	53% (82/156)	Ref.		64% (71/111)	Ref.	

In both communities, ECG performance and interpretation for ACS signs and symptoms increased significantly in both men and women and remained at a high level throughout the intervention periods. Despite the increase for women, men continued to be more likely to have an ECG performed (men:women odds ratios of 1.29 [CI 1.07, 2.05] and 1.64 [CI 1.29, 2.09] in communities A and B respectively) Patients with hospital confirmed STEMI received a prehospital ECG more frequently in the intervention period. (Table 3.) Of note, in the subsequent year after the study intervention was withdrawn, follow-up information showed a 25% decline in the number of ECGs performed.

Table 3. 12-Lead ECG and chest pain protocol adherence before and during intervention period

Measure, % (n)	Community A: Baseline N=1,263	Community A: Interv. N=2,755	Community A: p value	Community B: Baseline N= 326	Community B: Interv. N=2,650	Community B: p value
Chest Pain assessed*	78% (989)	80% (2,211)	0.15	100% (325)	97% (2,567)	0.004
12-lead ECG done by EMS*	57% (716)	80% (2,203)	<.0001	60% (195)	89% (2,346)	<.0001
12-lead ECG interpreted*	81% (582/716)	94% (2,065/2,203)	<.0001	93% (182195)	97% (2,269/2,346)	0.01
12-lead ECG for pt with STEMI	73% (8/11)	100% (30/30)	0.01	83% (5/6)	98% (54/56)	0.18
12-lead ECG for pt with ICD9-CM code = MI	74% (36/49)	88% (99/112)	0.02	77% (10/13)	97% (131/135)	0.001
Pulse oximetry* used	83% (1,051)	89% (2,450)	<.0001	96% (321)	98% (2,606)	0.4
Oxygen administered*	84% (1,060)	89% (2,435)	<.0001	84% (275)	93% (2,455)	<.0001
IV Attempted*	83% (994)	92% (2,380)	<.0001	88% (283)	96% (2,507)	<.0001
Aspirin administered**	72% (237/330)	73% (588/804)	0.7	86% (78/91)	89% (825/923)	0.28
Any Med Administered	28.6% (361)	32.2% (887)	0.02	39.6% (129)	53.2% (1,410)	<.0001
Time, minutes, median <Q1-Q3> (n): Total Run time	23 <19-27> (1,213)	23 <19-28> (2,703)	0.007	20 <16-24> (312)	20 <17-25> (2,625)	0.002

*Patients with ACS signs and symptoms **Patients with EMS ACS clinical impression.

Compliance with local ACS treatment protocols also changed during the intervention period, with significant increases in pulse oximetry use, oxygen administration, and intravenous access. This was done without clinically significant transport delays; median total transport time for patients from scene to hospital remained at 23 minutes in EMS System A and increased from 20 minutes to 21 minutes in EMS System B. Patients without an ECG performed had transport times two to three minutes shorter than patients with an ECG in both time periods. Women with an ECG had longer transport times than men with an ECG by one minute. Administration of aspirin was one protocol treatment that did not increase despite educational interventions to increase its use. We were unable to identify the barriers to increasing aspirin administration.

The ACI-TIPI/TPI was introduced in a second phase of the intervention period in both communities and was available on all 12-lead electrocardiograms. Due to technical problems and paramedic compliance with ACI-TIPI and ECG downloading protocols, not all ECGs were produced with the ACI-TIPI or TPI during the period the software was available. For patients with an ACI TIPI., we analyzed protocol adherence based on an ACI-TIPI risk group of low (0-10%), moderate (11-54%) and high or $\geq$55%. (Table 4) There was higher compliance with protocol care for patients with higher probabilities of ACS. It is unclear whether the presence of these higher probabilities influenced the care or reflected the paramedics' existing ability to identify patients at higher risk and provide appropriate care.

Table 4. ACS protocol adherence by ACI-TIPI risk group

	Comm. A: <10	Comm. A: 10-55	Comm. A: >=55	Comm. A: P value	Comm. B: <10	Comm. B: 10-55	Comm. B: >=55	Comm. B: P value
Aspirin administered	12% (12/103)	41% (68/168)	74% (20/27)	<.0001	23% (24/103)	54% (105/194)	69% (35/51)	<.0001
Oxygen administered	84% (86/103)	95% (159/168)	96% (26/27)	0.006	88 (91/103)	94% (183/194)	100% (51/51)	0.01
IV attempted	95% (93/98)	95% (155/163)	100% (26/26)	0.76	97% (100/103)	100% (19%4/194	98% (50/51)	0.04
Pulse oximetry	91% (94/103)	92% (155/168)	81% (22/27)	0.19	98 % (101/103)	99 (192/194)	100% (51/51)	0.79

In a separate prehospital study using the ACI-TIPI/TPI and being conducted our research center, approximately 84% of patients with a prehospital ACI-TIPI/TPI of ≥75% had ACS on hospital follow-up, with 95% of ACS patients having AMI and 81% of AMI being STEMI. Using this 75% cut point, we see that in the EMS TIPI-IS project, 71% of patients at both sites with an ACI-TIPI or ≤ 75% received aspirin as compared to 32% in Community A and 46% in community B for patients with < 75% probability. **(**Table 5.) Whether the ACI-TIPI/TPI assisted paramedics in selecting patients to receive aspirin is unclear. What is certain is that there continues to be substantial improvement opportunity in providing this evidenced based treatment in the prehospital setting.

Table 5. Protocol adherence by ACI-TIPI probability above or below 75%

	Comm A: <75 %	Comm A: ≥75%	Comm A:	Comm B: <75 %	Comm B: ≥ 75%	Comm B:
Aspirin administered	32% (90/284)	71% (10/14)	0.006	46% (154/334)	71% (10/14)	0.06
Oxygen administered	90% (257/284)	100% (14/14)	0.62	93% (311/334)	100% (14/14)	0.61
IV attempted	95% (261/274)	100% (13/13)	.99	99 % (330/334)	100% (14/14)	.99
Pulse oximetry	91% (259/284)	86% (12/14)	0.37	99% (330/334)	100% (14/14)	.99

Inter-rater reliability testing was conducted among the three physicians over-reading paramedics' ECG interpretations. A random sample of 25 paramedic interpreted ECGs were selected and reviewed by all three ED physicians. For key ECG interpretation findings of ST segment elevation or depression and left bundle branch block (LBBB), the kappa values were 0.7, 0.7, and 1.0. Overall, 71% of the key findings resulted in kappa values in the substantial (kappa between 0.6 - 0.79) or almost perfect (kappa ≥0.8) agreement categories.

We categorized physician agreement with a paramedic's impression of ACS at four different levels: disagree; partially agree; agree; and insufficient information. These determinations differed significantly in distributions between the baseline and intervention periods in Community A (p=0.001) and Community B (p=0.05). Physician agreement with paramedics' ECG interpretations in Community A increased from 63% to 77%, and the proportion of cases with insufficient ECG interpretation information decreased from 16% to 7%. In community B, respectively, the increase was 38% to 52% with no change in the proportion with insufficient information.

The proportion of patients who received CRT within recommended timeframes increased between the baseline and intervention periods in both communities. (Table 6.) The joint development of a STEMI Alert protocol between the EMS agency and participating hospitals in Community A resulted in cardiac cath lab activation from the field for the first time and patients being transported directly to the cath lab for intervention rather than remaining in the ED for evaluation. Community B also implemented a STEMI Alert protocol and saw significant reduction in door to balloon times. Patients who require transfer for cardiac cath and CRT experience the longest times due to, in part, cumbersome protocols in the initial hospital and long delays in getting an ambulance to transport the patient to the next hospital. EDs also refer patients to interventional cath labs with whom they have an affiliation rather than the closest available lab.

Table 6. Cardiac catheterization and PCI door to treatment times in baseline and intervention periods

Time, minutes, median <Q1-Q3> (n)	Comm. A: Baseline	Comm. A: Intervention	Comm. A: p value	Comm. B: Baseline	Comm. B: Intervention	Comm. B: p value
≤ 90 min, 1st hospital	75% (3/4)	85% (11/13)	0.66	25% (1/4)	71% (25/35)	0.06
≤ 90 min, transfer or 1st hospital	30% (3/10)	58% (11/19)	0.15	20% (1/5)	71% (25/35)	0.02
≤ 120 min, 1st hospital	75% (3/4)	85% (11/13)	0.66	50% (2/4)	80% (28/35)	0.17
≤ 120 min, transfer or 1st hospital	40% (4/10)	58% (11/19)	0.15	40% (2/5)	80% (28/35)	0.05
Door to cath, 1st hospital	49 <40 – 132> (4)	50 <44-59> (18)	0.86	234 <91-323> (7)	64 <43-129> (58)	0.03
Door to emergent PCI, 1st hospital	57 <47-96> (4)	79 <68 – 81> (3)	0.1	206 < 75 – 313> (4)	73< 57-95> (35)	0.15
Door to transfer for cardiac cath	153 <80-203) (18)	111 <70 – 130> (10)	0.14	na	na	
Door, 1st hospital, to cath at transfer hospital	159<137-286> (11)	190 <157-270)> (8)	0.59	na	na	
Door, 1st hospital, to emergent pci at transfer hospital	198 <158-217> (6)	218 <176-251> (6)	0.42	na	na	
Door at transfer hospital to cath at transfer hospital	23<13-57> (11)	17 <10.5-99> (8)	0.90	na	na	
Door at transfer hospital to emergent PCI at transfer hospital	56 <26-75> (7)	49 <41-90> (5)	0.68	na	na	

An evaluation of the attractiveness and utility of the EMS TIPI-IS and the ACI-TIPI/TPI was conducted through a survey of project participants and used to improve the system during the course of the project. A combination of a mail-in survey followed up by a semi-structured telephone interview was completed by 6 of 12 participants solicited from the two communities. He respondents included representatives from EMS agencies and Emergency Departments.

Survey respondents were asked about changes in the level of interest for quality improvement and use of clinical decision support and health IT since they began the project. From the EMS perspective, 80% responded that the level of interest had changed some or a lot for the use of predictive instruments in the prehospital setting, joint EMS/Hospital QI Activities, and using health IT for improving care. All noted that it had changed from some or a lot for improving the care of patients with ACS in light of other improvement priorities. From the hospital perspective, 75% thought that the level of interest had changed some or a lot for improving the care of patients with ACS in light of other improvement priorities, joint EMS/Hospital QI Activities, and use of Health IT since the beginning of the project. Please note that three of the four that responded from the hospital perspective also had a hospital role in addition to their EMS role, and, therefore, were able to comment from both the hospital and the EMS perspectives.

When asked to rate factors in their organization contributing to progress in the project, ECG interpretation education was rated as having the largest contribution followed by paramedic participation and the STEMI Alert Protocol. Physician participation, sharing data with stakeholders, the EMS/TIPI-IS System overall and its feedback reports followed behind. Table 7 provides a breakdown of how respondents rated the factors contributing to the project's progress.

Table 7. Factors contribution to project progress

Contributing Factors	Large Contribution	Moderate Contribution	Small Contribution	No Contribution
ECG interpretation education	100% (6/6)	---	---	---
STEMI Alert Protocol	83% (5/6)	17% (1/6)	---	---
Paramedic participation	83% (5/6)	17% (1/6)	---	---
Data shared with stakeholders	80% (4/5)	20% (1/5)	---	---
Physician participation	66% (4/6)	33% (2/6)	---	---
Data shared regularly with leadership	20% (1/5)	60% (3/5)	20% (1/5)	---
Feedback Reports	66% (4/6)	50% (2/4)	---	---
EMS TIPI-IS overall	66% (4/6)	17% (1/6)	17% (1/6)	---
ECG over-reading	50% (2/4)	66% (4/6)	---	---
Leadership support	33% (2/6)	50% (3/6)	17% (1/6)	---
ACI TIPI/TPI	25% (1/4)	75% (3/4)	---	---

Survey respondents were asked about barriers to implementation. "Getting People to Change the Way They Work" created a moderate to large barrier to implementation. Coordinating care across settings, staffing time required, and other competing priorities, followed. Some examples of cultural or operational obstacles that have prevented improvement or change in the care of patients since the onset of the project included changing culture, putting the ACI-TIPI/TPI into the ECG, teaching paramedics how to use the TIPI-IS, data collection, issues of priorities and multi-tasking, and interfacing with hospital IS Systems. The TIPI-IS impact on overall quality and organizational performance is summarized in Table 8.

Table 8. TIPI-IS impact on quality and organizational performance

Quality & Organizational Performance	Significant	Some	Minimal	None	Don't Know
Measuring quality of clinical care provided to patients	100% (5/5)	---	---	---	---
Understanding areas of ACS care needing improvement	80% (4/5)	20% (1/5)	---	---	---
Focusing educational efforts to improve performance	100% (5/5)	---	---	---	---
Timeliness of reperfusion for patients	20% (1/5)	80% (4/5)	---	---	---
Teamwork within EMS agencies (or ED Dept)	40% (2/5)	60% (3/5)	---	---	---

Table 8. TIPI-IS impact on quality and organizational performance (continued)

Quality & Organizational Performance	Significant	Some	Minimal	None	Don't Know
Teamwork across EMS and ED providers	60% (3/5)	40% (2/5)	---	---	---
Responding to external questions about quality	20% (1/5)	60% (3/5)	20% (1/5)	---	---
Holding staff accountable	40% (2/5)	60% (3/5)	---	---	---
Responding to organizational expectations	40% (2/5)	40% (2/5)	20% (1/5)	---	---
Reducing potential malpractice claims	---	40% (2/5)	---	20% (1/5)	40% (2/5)
Improving efficiency of care	60% (3/5)	40% (2/5)			
Responding to regulatory requirements	40% (2/5)	20% (1/5)	20% (1/5)		20% (1/5)
Reducing unnecessary care		40% (2/5)	20% (1/5)	40% (2/5)	
Performing your job better	100% (5/5)				
Demonstrating the value of services	40% (2/5)	40% (2/5)			20% (1/5)

The Physician ECG Over-Reading Process was noted to be of the most value to users and participants. Feedback Reports on Overall ECG Performance and Adherence to Chest Pain Protocol was also deemed to have a high value. Four of the respondents completely agreed with the statement "EMS TIPI-IS System provides you with enough information to measure and improve the quality of care for cardiac patients." And, 83% believed that this technology will have a large impact on long term improvements to patient care for ACS patients.

In general, the survey respondents from the two communities involved in the EMS TIPI- IS Project found the TIPI-IS System to be helpful in improving paramedic performance, interpretation of ECGs, and improving relationships between the hospital and ED staff. The TIPI-IS provided a framework for EMS agencies to systematically collect and review the care that they provide in the pre hospital setting for the ACS patient population. In considering ways to expand the system for wider dissemination, it will be important to include an electronic PCR in order to reduce the burden of manual data collection and to find ways to better engage the hospital in working with EMS. These will be important steps forward in helping to coordinate care across treatment settings.

Limitations

A limitation of this study is that the indications for inclusion in the project were abstracted from patient care record text and completeness of documentation varied among paramedics and between EMS agencies and may have influenced the inclusion of cases in the study. Also, the participating agencies were both located in suburban/urban settings and were private/private-public entities; their results may not be representative of other types of EMS settings. Moreover, the prehospital performance measures used in the study were developed based on existing local guidelines since there are no nationally accepted performance measures for EMS. Other agencies may choose to develop different measures relevant to their local setting. Follow-up after-study information available for one of the EMS agencies suggests that the rate of 12-lead ECG performance declined once the feedback intervention was stopped. Nonetheless, the consistency of the effects we saw suggests that the results are generalizable, although further research will be needed to verify this.

Discussion

In this study, we developed measures to evaluate EMS systems' ability to perform and accurately interpret prehospital 12-lead ECGs and to provide protocol assessment and treatment of patients with possible signs and symptoms of ACS. A web-based system to collect prehospital and hospital data and patient outcomes was implemented to compile the measures and to regularly feed back the results to support quality improvement (QI). When provided in the intervention period with education on ECG interpretation, feedback on performance measures, and physician online ECG over-reading, compared to the baseline period with ECG education alone, paramedic performance and interpretation of ECGs improved and was sustained during the intervention period. Once the intervention was removed, however, as found in the one-year after-study follow-up, ECG performance declined, reaffirming the need to maintain quality measurement and feedback systems.

Women and patients with a language barrier were less likely to have an ECG performed during the baseline period. Patients with acute myocardial infarction (AMI), including those with STEMI, were more likely to have an ECG when paramedics received ongoing feedback on their performance. When the paramedic identified STEMI, the hospital was notified en route, and in some cases, patients were transported directly to the catheterization lab. These improvements were achieved without a clinically significant increase in the total transport time to the hospital.

The use of prehospital ECG interpretations to trigger the activation of the cardiac catheterization lab while the patient is en route is one of several successful strategies to reduce door to balloon times.[7] Physician activation from the ED of the catheterization lab and streamlining hospital communications are also effective, but cannot take advantage of initiation prior to ED arrival.[12-14] In this study, we found that without ongoing measurement and feedback on prehospital ECG performance, only 57- 60% of patients who deserved evaluation for ACS received a 12-lead ECG. With the intervention of group and individual feedback on performance measures, ECG performance increased to 80-89%. The proportion of patients with a hospital confirmed STEMI who received a prehospital ECG increased from 73% to 100% in community A, and from 83% to 98% in community B.

The use of EMS to triage patients in the field and bypass to prenotified PCI centers represents one effective model of STEMI care regionalization leading to shorter door-to-balloon times.[15-18] A second model of STEMI systems of care is the "treat and transfer" model, in which patients are rapidly transferred from PCI-referral hospitals to PCI-receiving hospitals, using a standardized treatment protocol and integrated transfer system.[20] Importantly for this approach, our study confirmed that paramedics could accurately identify STEMI in the field. Correct identification of STEMI improved in the intervention period when paramedics were receiving feedback on whether their interpretations of STEMI were correct or incorrect. This process of identifying STEMI diagnoses that were false negative, false positive, and true positive enabled timely and affirmative feedback on correctly identified STEMIs and timely constructive feedback on incorrectly identified cases. Whether paramedics are making the decision in the field to bypass a non-PCI-capable hospital, or to set in motion a treat and transfer protocol in a community hospital, the paramedic staff must be confident in their ECG interpretation skills and prepared to communicate those results while en route to the hospital. [19]

The AHA recently launched its "Mission Lifeline" campaign, with a series of recommendations that include data collection of EMS ECG performance metrics and use of quality improvement systems with formal feedback across the continuum of STEMI care providers.[21-23] This study demonstrated the technical capability to meet the goals described by AHA. The information system developed for the project allowed data collection and integration of data and performance measures between prehospital and hospital care. Individual case feedback reflected the entire episode of care across both settings. Prehospital metrics included prehospital performance of ECGs and the interpretation accuracy; hospital metrics included door-to-ECG and door-to-balloon 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 the hospital staff and EMS agency.

There are few national EMS performance measure initiatives, and the ability to collect standardized data has only recently emerged. While there are many references to improving EMS performance through educational interventions,[24,25] there is little literature that shows how to measure, improve and maintain paramedic performance over time. The recent emergence of a National EMS information system (NEMSIS) may allow standardization of EMS data collection and further development and validation of measures like those described here. As more EMS agencies adopt electronic data collection systems they will have the ability to measure and improve their performance more efficiently and effectively. Electronic PCR systems and the development of joint EMS and hospital ACS registries will allow comprehensive measurement and improvement by harnessing the power of health information technology. All these advances should result in better and more integrated EMS-hospital care for ACS and STEMI.

As the role for EMS performance and interpretation of ECGs expands with development of systems of STEMI care, the importance of measuring and improving ECG performance will increase. In this study we describe an improvement effort, supported by health information technology, that successfully measured, fed back performance results, and improved clinical performance measures for ACS care including ECG performance and interpretation. This approach appears to have promise for community based care of ACS and STEMI, and deserves further exploration.

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List of Publications and Products

Daudelin DH, Sayah A, Kwong M, Restuccia M, Porcaro W, Ruthazer R, Goetz J, Lane W, Beshansky J, Selker P Improving Use of Prehospital 12-lead Electrocardiography for Early Identification and Treatment of Acute Coronary Ischemia and ST-segment Elevation Myocardial Infarction. (Submitted for publication, *Annals of Emergency Medicine*, July 2008)