Using Prehospital Electrocardiograms to Improve Door-to-Balloon Time for Transferred Patients With ST-Elevation Myocardial Infarction

A Case of Extreme Performance

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A 45-year-old man was walking his dog at 5:30 AM in June 2009 and developed crushing 10/10 substernal chest pain. He called 911 at 6:05 AM after his symptoms persisted for 35 minutes. Emergency medical services (EMS) paramedics arrived at the scene at 6:09 AM and obtained a brief history and examination showing a diaphoretic man, pulse of 92 bpm, blood pressure of 170/140 mm Hg, normal respiratory rate, and no rales or murmurs. Treatment was initiated including supplemental oxygen, sublingual nitroglycerin, and aspirin. A 12-lead prehospital (PH) ECG was acquired at the scene at 6:16 AM and interpreted by paramedics as showing acute ST-elevation myocardial infarction (STEMI) (Figure 1). On the basis of the PH ECG, paramedics made a single phone call to the closest community hospital emergency department and activated the PH ECG STEMI protocol at 6:17 AM. The closest community hospital was located within 5 miles and did not have capability for percutaneous coronary intervention (PCI). The STEMI protocol activation consisted of autolaunching helicopter transport to intercept the patient at the community hospital and alerting the cardiac catheterization team at the tertiary PCI center located 50 miles away with the estimated patient arrival time. The patient arrived at the community hospital emergency department (door 1) by ground ambulance at 6:26 AM. Helicopter transport picked up the patient and departed the community hospital at 6:37 AM with a door 1 in–to–door 1 out time of 11 minutes. The patient arrived at the tertiary PCI center (door 2) at 7:10 AM and was transported directly to the cardiac catheterization laboratory. During transport from the helipad to the cardiac catheterization laboratory, the patient had ventricular fibrillation in the elevator, and a shock was delivered with 120 J of selected energy. Coronary angiography showed a thrombotic occlusion of the left anterior descending artery that was successfully treated with a drug eluting stent (Figure 2A and 2B). The time metrics from symptom onset to reperfusion with first PCI device are shown in Table 1. In summary, the door 1–to–first PCI device time was 61 minutes, first EMS contact–to–first PCI device time was 82 minutes, and symptom onset–to–first PCI device time was 117 minutes. The peak troponin level was 1.8 ng/mL, and ECG immediately after PCI is shown in Figure 3. There were no complications during the hospitalization, and cardiac MRI on hospital day 3 showed a large area of infarction involving the entire anterior wall and apex with a left ventricular ejection fraction of 39% and moderate delayed myocardial enhancement. The patient was discharged on hospital day 4 with referral to cardiac rehabilitation and the following medications: aspirin, clopidogrel, simvastatin, nicotine patch, lisinopril, and metoprolol. At 30-day follow-up, he was asymptomatic and compliant with his medications, and an echocardiogram showed left ventricular ejection fraction had improved to 52%.

Goals and Vision of the Program

Timely reperfusion therapy with fibrinolytic therapy or primary PCI is the cornerstone of treatment to reduce infarct size and improve outcomes in patients with STEMI.[1,2] Current guidelines recommend first medical contact–to–balloon times <90 minutes for both nontransferred and transferred patients with STEMI.[3] However, recent analyses have demonstrated that fewer than 10% patients with STEMI who are transferred for primary PCI achieve this goal of <90 minutes.[4,5]

Improving access to and timeliness of primary PCI for patients who require transfer to a STEMI receiving center has been the focus for the American Heart Association Mission Lifeline Initiative.[6,7] PH ECG can provide earlier identification and triage of patients with STEMI[8–11] and potentially improve access to and timeliness of primary PCI if the information from the PH ECG is integrated with downstream systems of care.[12] Although PH ECG programs have been described for urban hospital networks,[9,11] a "rural hybrid system" to coordinate prehospital triage and helicopter inter-

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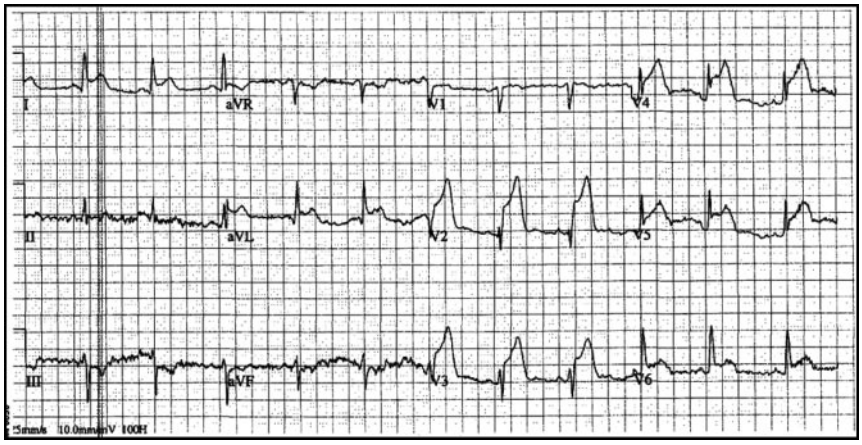

Figure 1. PH ECG obtained by EMS at the scene.

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cept for rural populations where STEMI referral hospitals and STEMI receiving centers are separated by long distances have not been reported. Current challenges for implementing PH ECG into systems of care have included:

1. Low utilization of PH ECG among patients with acute coronary syndrome transported by EMS.
2. Processes of care to enable rapid interpretation of PH ECG by EMS personnel or wireless transmission for remote physician interpretation.
3. Coordinating downstream systems of care such as activating the cardiac catheterization laboratory while ambulance is en route, bypassing the emergency department, or bypassing non-PCI capable STEMI referral hospitals.

Local Challenges in Implementation

We implemented the PH ECG program at a 77-bed rural community hospital without PCI capability in February 2009. This STEMI referral hospital is located 50 miles from the STEMI receiving center (Saint Mary's Hospital) and connected by a 2-lane rural road. This rural road system leads to delays in ground ambulance transport, particularly during winter and inclement weather. Historically, patients who were transferred to Saint Mary's Hospital for primary PCI have an observed median door 1–to–first PCI device time of 116 minutes.[13] The main challenges we sought to address included:

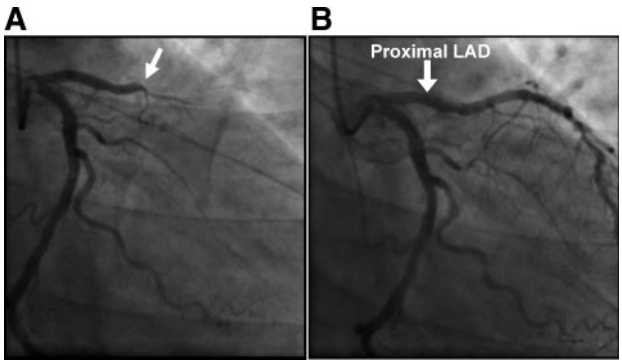

Figure 2. A, Coronary angiography of proximal left anterior descending (LAD) total occlusion. B, Coronary angiography of proximal LAD after stent placement.

1. Training EMS personnel to acquire and interpret PH ECG for STEMI.
2. Developing a protocol for EMS personnel for what clinical situations to acquire a PH ECG.
3. Developing a process for EMS personnel to activate the STEMI protocol that included autolaunching helicopter transport to intercept the patient and alerting the cardiac catheterization team at Saint Mary's Hospital.
4. Developing a diversion protocol for when it was and was not appropriate to bypass the emergency departments at the STEMI referral hospital and STEMI receiving center.
5. Developing a process to minimize the door 1 in-to-door 1 out time at the STEMI-referral hospital.
6. Developing a process to provide immediate feedback to all clinical providers.

Design of the Mayo Prehospital ECG Protocol

The Mayo PH ECG program for patients with STEMI transferred from rural community hospitals is distinct from the previously reported interhospital transfer approach.[13] Before implementing the PH ECG program, paramedics were

Table 1. Time Intervals

Description	Time	Time Interval, min
Symptom onset	05:30	0
911 call	06:05	35
EMS on-scene	06:09	4
PH ECG acquired	06:16	7
STEMI protocol activation	06:17	1
Transport to local community hospital	06:22	5
Arrival at door 1	06:26	4
Departure from door 1	06:37	11
Arrival at door 2	07:10	33
First PCI device	07:27	17
Time intervals		
Door 1 in to door 1 out		11
Door 2 to first PCI device		17
Door 1 to first PCI device		61
First EMS contact to first PCI Device		82
Symptom onset to first PCI device		117

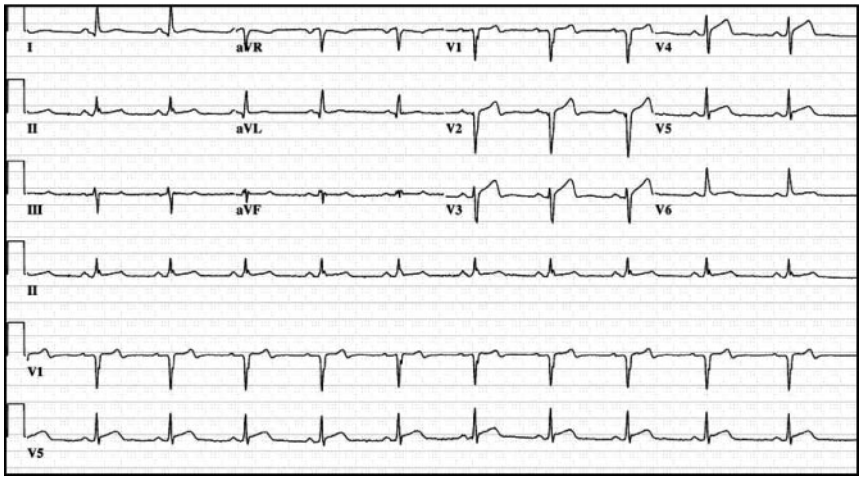

Figure 3. ECG after left anterior descending stent.

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required to take a 1-day course on how to acquire and interpret PH ECG as well as to pass an examination to identify ST-elevation among 50 unknown ECG tracings. Ambulances were equipped with PH ECG equipment and were typically staffed by 1 paramedic and 1 intermediate-level EMS provider. A protocol was developed for what clinical situations to acquire a PH ECG for patients with suspected acute coronary syndrome (Appendix 1). The protocol limited the number of PH ECG to 2 attempts in order not to delay care or transport. The EMS personnel were educated to classify a PH ECG into 3 categories:

1. *Definite STEMI* was defined as when EMS paramedics and computer interpretation were concordant for presence of acute ST elevation.
2. *Possible STEMI* was defined as the presence of left bundle-branch block or when EMS paramedics and computer interpretation were discordant for acute ST elevation.
3. *Not STEMI* was defined as when EMS paramedics and computer interpretation were concordant for the absence of acute ST elevation.

In cases in which a definite STEMI was identified at the scene from a PH ECG, the paramedics were instructed to make a single phone call to the rural community hospital emergency department to activate the STEMI protocol. While the patient is en route by ground ambulance to the community hospital, helicopter transport has already been autolaunched to intercept the patient at the community hospital and the cardiac catheterization team at Saint Mary's Hospital is alerted of the estimated patient arrival time. To achieve rapid door 1 in–to–door 1 out time at the STEMI referral hospital, the following processes were implemented: the patient was kept on the ambulance stretcher; the patient was not registered unless treatment was indicated; no emergency department evaluation, laboratory tests, repeat ECG, or other diagnostic tests were performed; adjunctive medications were administered by the paramedics and helicopter nurses; the patient was jointly monitored by the paramedic and emergency department nurses; and the patient was immediately transported to the STEMI receiving center when the helicopter arrived.

The helicopter nurses transported the patient directly to the Saint Mary's Hospital catheterization laboratory for emergent coronary angiography and bypassed the Saint Mary's Hospital emergency department. However, if the patient was noted to have a diversion criterion, then full emergency department evaluation at the STEMI referral hospital or STEMI receiving center was performed. Standard diversion criteria were used by both paramedics and helicopter nurses, including respiratory distress requiring intubation, hemodynamic instability, suspected aortic dissection, suspected intracranial hemorrhage, or patients with "do not resuscitate" status (Appendix 2). In addition, EMS did not activate the STEMI protocol or helicopter autolaunch for patients with "do not resuscitate" status.

A standardized process provided feedback to every provider (EMS, nurses, and physicians) involved in the clinical case within 24 to 48 hours, including all the time metrics shown in Table 1. Every PH ECG was reviewed for technical and clinical accuracy by a cardiologist (H.H.T.).

Implementation of the Initiative

Before implementation, multiple meetings were undertaken to achieve commitment and consensus from all stakeholders to implement the PH ECG program at the community hospital. A clear vision to improve access to and timeliness of primary PCI was defined and agreed on. Three critical pillars for success included having top leadership commitment, local clinical champions to sustain the momentum when barriers arose, and engagement of front-line staff who provided the actual patient care. These pillars needed to be aligned across all disciplines (cardiology, emergency medicine, nursing, and EMS). To implement major change initiatives, the organizational culture and readiness for change is equally or more important than the specific strategy.[14]

During the first 6 months (February to August 2009) of the program, a total of 60 PH ECG were acquired for patients with suspected acute coronary syndrome; the time metrics for prehospital care are shown in Table 2. One patient was identified with a definite STEMI as reported in the clinical case and performance measures were provided to EMS personnel, nurses, and physicians involved in the case via

Table 2. Time Intervals

Time Intervals	Median (Quartile 1, Quartile 3), min
911 call to EMS on scene	5.0 (4.0, 9.0)
EMS on scene to PH ECG acquired	15.0 (7.9, 21.7)
PH ECG acquired to door 1	9.5 (3.0, 18.2)

electronic mail using the format shown in Table 1. The remaining 59 cases were categorized as not STEMI.

Success of the Initiative

The clinical case demonstrates a first medical contact-to-balloon time of 82 minutes and symptom onset to balloon time of 117 minutes, both of which are within ideal, guideline-recommended performance measures for a patient with STEMI transferred for primary PCI. The door 1 in–to–door 1 out time at the STEMI referral hospital was 11 minutes. An opportunity for improvement for EMS was the median on-scene–to–PH ECG acquired time of 15 minutes. This exceeded an analogous benchmark for door-to-ECG time <10 minutes for patients with suspected myocardial infarction who present directly to the emergency department. At 30-day follow-up, the patient did not have any adverse outcomes such as recurrent angina, readmission to any hospital, or death. His left ventricular function ejection fraction improved from 39% during the index event to 52% at 30-day follow-up. This improvement in left ventricular function probably reflects achieving a short total ischemic time from onset of symptoms to reperfusion therapy of <2 hours.

Summary of the Experience, Future Directions, and Challenges

This clinical case demonstrated that it is possible to achieve the guideline-recommended goal of first medical contact–to–balloon time of <90 minutes for patients transferred for primary PCI from a rural STEMI referral hospital located 50 miles from a STEMI receiving center. This high level of performance required educating EMS paramedics to acquire and interpret PH ECG, developing standard protocols for STEMI activation and transport, and optimizing transitions of care from ground ambulance to helicopter transport to cardiac catheterization laboratory.

The potential for PH ECG to improve outcomes in patients with STEMI will hinge on integrating the PH ECG with downstream systems of care for urban and rural networks of STEMI referral hospitals and STEMI receiving centers. A rural hybrid system will require unique models for paramedics to coordinate prehospital triage as well as systems to integrate helicopter autolaunch and intercept at the STEMI referral hospital or en route. We are interested in evaluating whether the ground ambulance could bypass the rural community hospital and coordinate helicopter intercept of the ground ambulance while en route to the STEMI receiving center. This coordination of ground ambulance and helicopter intercept is currently being used for motor vehicle accident and trauma victims in the region.

We plan to extend this "rural hybrid system" for prehospital triage and helicopter intercept to 30 STEMI referral hospitals located in rural Minnesota, Iowa, and Wisconsin that transfer patients with STEMI to Saint Mary's Hospital (STEMI receiving center). Our evaluation will focus on precomparisons and postcomparisons of process and outcome measures[15] for this system of care, which would include metrics such as first medical contact–to–balloon time, door 1 in–to–door 1 out time, door 1–to–needle time for instances when transfer for primary PCI is not possible due to weather, percentage of patients with STEMI treated with any reperfusion therapy, percentage of false alarms,[16] prehospital delay time from symptom onset to hospital arrival, percentage of patients referred to cardiac rehabilitation, left ventricular ejection fraction, and mortality.

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Disclosures

None.

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SUPPLEMENTAL DATA

Appendix 1

INDICATIONS

For patients with suspected cardiac ischemia or acute myocardial infarction, obtain a 12-lead ECG utilizing the following selection criteria and procedures.

SELECTION CRITERIA

Complete the 12-lead ECG procedure whenever a potential cardiac event is suspected.

Criteria which should be considered in determining the presence of a potential cardiac event and acquiring a 12-lead ECG include, but are not limited to, the following:

- Generally, the patient should be 35 years or older
- The patient exhibits ongoing chest discomfort or symptoms similar to previous angina or myocardial infarction
- Symptoms have been present for less than 24 hours if they are continuous
- The patient should be hemodynamically stable
- Acquisition of the 12-lead would not interfere with or delay emergent or life saving care

PROCEDURE, following initial assessment and care:

1. Acquisition of the 12-lead ECG should take precedence over interventions such as insertion of intravenous catheter, aspirin, nitroglycerin, or beta blocker. Simultaneous interventions are acceptable.

2. Print the 12-lead ECG and identify if it is a technically acceptable tracing. If unacceptable, correct any problems and attempt a second acquisition. Do not delay treatments or transport for additional attempts beyond two.

3. If the tracing is acceptable, review the computer interpretation for ST-elevation.

4. If the device interpretation includes "***Acute Myocardial Infarction***" and EMS confirms ST-segment elevation >1mm in 2 contiguous leads, then categorize this event as a "DEFINITE STEMI".

5. If "DEFINITE STEMI", immediately contact community hospital to activate the STEMI protocol. This will auto-launch helicopter transport and alert the cardiac catheterization team at Saint Marys Hospital.

6. Prepare patient for immediate transport with indicated medications administered en route to hospital. Attempt to limit the scene time to the shortest time possible.

7. On arrival at the hospital, a printed copy of the 12-lead PH ECG should be presented to the receiving nurse or physician staff as part of the patient transfer report.

8. Keep the patient on ambulance stretcher and await the arrival of helicopter transport team.

Appendix 2

"EMS CHECKLIST" for STEMI identified on Prehospital ECG

- **Obtain prehospital 12-lead ECG as soon as possible after patient contact**
- **If DEFINITE STEMI, contact Emergency Communication Center to activate STEMI protocol**
- **Pick up patient identification wristband from Emergency Department**

Information Needed for Registration:
- Full Name
- Date of Birth
- Mayo Clinic Number (If available)
- Address
- Spouses (or ex-spouses) First Name
- Maiden Name

- **"Diversion Criteria" for full Emergency Department physician evaluation**

"Diversion Criteria" for Emergency Department physician evaluation
- Patient has active DNR order
- Chest trauma or motor vehicle accident victim
- Suspect aortic dissection
- Patient with acute neurologic symptoms or confusion
- Hemodynamic compromise (SBP<90, HR<50)
- Ongoing or recurrent VT or VF
- Respiratory distress and need for airway control or intubation

- **Obtain clinically important information as follows:**

#	INFORMATION	YES	NO
1.	Does this patient have previous history of MI, PCI, or CABG?		
2.	Severe allergy to contrast dye or Iodine (e.g. anaphylaxis)?		
3.	Bleeding disorder (e.g. GI Bleed, CVA), or recent surgery?		
4.	Does the patient use coumadin (warfarin)?		
5.	Has family been contacted? Family contact:_____		

Last set of vital signs: BP_____/_____ HR_____ Spo2_____

Meds Given (Circle): Nitro - SL/IV ASA Metoprolol Morphine