Implementation and Integration of Prehospital ECGs Into Systems of Care for Acute Coronary Syndrome

A Scientific Statement From the American Heart Association Interdisciplinary Council on Quality of Care and Outcomes Research, Emergency Cardiovascular Care Committee, Council on Cardiovascular Nursing, and Council on Clinical Cardiology

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Clinical case: A 58-year-old woman called 9-1-1 with acute onset of chest pain that had persisted for 30 minutes. She had a history of hypertension, hyperlipidemia, and type 2 diabetes mellitus but no previous history of myocardial infarction or heart failure. Her medications included aspirin, atorvastatin, lisinopril, and metoprolol. Paramedics were dispatched, and a prehospital ECG demonstrated 3- to 4-mm ST-segment elevation in leads I, aVL, and V_2 through V_6 (Figure 1). Her examination revealed a regular pulse of 90 bpm, a blood pressure of 100/60 mm Hg, clear lungs, and normal heart sounds with no murmurs. Paramedics interpreted the prehospital ECG and activated the catheterization laboratory en route to the hospital. On hospital arrival, the patient was transported directly to the catheterization laboratory. Coronary angiography demonstrated an occluded proximal left anterior descending artery, which was successfully treated with balloon angioplasty and a stent. The pertinent time intervals were as follows: paramedic dispatch to balloon time, 56 minutes; paramedic arrival at the scene to balloon time, 46 minutes; hospital door to balloon time, 23 minutes. Her biomarkers revealed a peak troponin T of 2.42 ng/mL and a peak creatine kinase muscle-brain isoenzyme of 26.8 ng/mL. An echocardiogram demonstrated normal left ventricular ejection fraction of 55%, with mild anterior hypokinesis, and the patient was discharged on hospital day 3.

Current Guidelines for Prehospital ECGs Among Patients With ST-Segment–Elevation Myocardial Infarction

American Heart Association national guidelines,[1–3] as well as other consensus and scientific statements,[4–11] recommend that emergency medical services (EMS) acquire and use prehospital ECGs to evaluate patients with suspected acute coronary syndrome. Despite these recommendations, prehospital ECGs are used in fewer than 10% of patients with ST-segment–elevation myocardial infarction (STEMI),[12,13] and this rate has not substantially changed since the mid-1990s. Furthermore, even when a prehospital ECG is acquired, the information is often not effectively translated into action and coordinated with hospital systems of care to decrease delays in reperfusion therapy.[13] The purpose of this article is to summarize evidence concerning the benefits of using prehospital ECGs, review barriers and challenges to routine use, and recommend approaches to enhance their effectiveness for improving quality of care for patients with acute coronary syndromes.

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This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on July 2, 2008. A single reprint is available by calling 800-242-8721 (US only) or by writing the American Heart Association, Public Information, 7272 Greenville Ave, Dallas, TX 75231-4596. Ask for reprint No. 71-0454. A copy of the statement is also available at http://www.americanheart.org/presenter.jhtml?identifier=3003999 by selecting either the "topic list" link or the "chronological list" link. To purchase additional reprints, call 843-216-2533 or e-mail kelle.ramsay@wolterskluwer.com.

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(***Circulation.*** **2008;118:1066-1079.**)

Circulation **is available at http://circ.ahajournals.org** **DOI: 10.1161/CIRCULATIONAHA.108.190402**

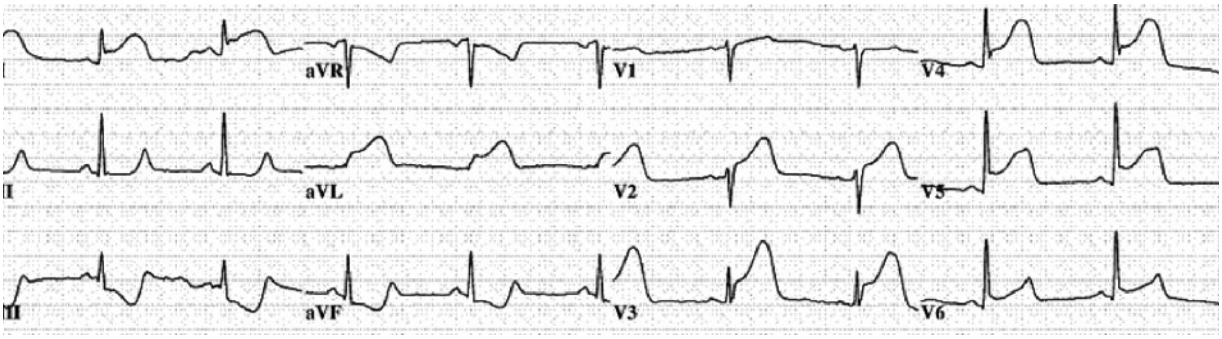

Figure 1. Prehospital ECG.

What Are the Benefits of Using Prehospital ECGs in Patients With STEMI?

Multiple studies have demonstrated the benefits of prehospital ECGs for decreasing door-to-drug time and door-to-balloon time in patients with STEMI.[12–30] The direction and magnitude of the time savings are clinically relevant, resulting in an approximately 10-minute decrease in door-to-drug time and 15- to 20-minute decrease in door-to-balloon time.[12,13] However, these time savings may not reflect the full potential of prehospital ECGs to decrease delays in reperfusion therapy. In fact, studies have shown further reductions in door-to-balloon time when prehospital ECGs are used to activate the catheterization laboratory while the patient is en route to the hospital.[31–37]

For patients transported by EMS without prehospital ECG, delay from symptom onset to reperfusion therapy, which reflects the overall period of ischemic injury, can be divided into 4 time intervals: (1) symptom onset to EMS arrival, (2) EMS arrival to hospital arrival, (3) hospital arrival to ECG, and (4) ECG to reperfusion. Prehospital ECG programs, if effectively implemented and coordinated with hospital systems of care, would be expected to decrease the latter 3 time intervals (Figure 2). The second interval is composed of time from first medical contact by EMS to hospital door, and EMS personnel may behave with more urgency if a diagnosis of STEMI has been made in the field. The third interval is essentially eliminated with a prehospital ECG. The fourth interval can be decreased by advanced notification of the hospital to receive and evaluate the patient, to activate the catheterization laboratory while the patient is en route, or to bypass the emergency department and transport the patient directly to the catheterization laboratory. Scholz and colleagues reported the impact of prehospital ECGs on these time intervals from 114 patients with STEMI treated within an integrated system of care.[38] The system consisted of acquiring a prehospital ECG by emergency responders (in Germany, this was generally a physician), transmitting the prehospital ECG to a fax machine at the percutaneous coronary intervention (PCI) hospital cardiac intensive care unit, activating the catheterization laboratory en route if STEMI was diagnosed, and bypassing the emergency department when the catheterization laboratory team was on-site. Pertinent time intervals were collected for 1 year. Comparing performance in the last quarter of implementing this system with the first quarter (reference group), the time spent at the scene decreased from 25 to 19 minutes, time spent in the

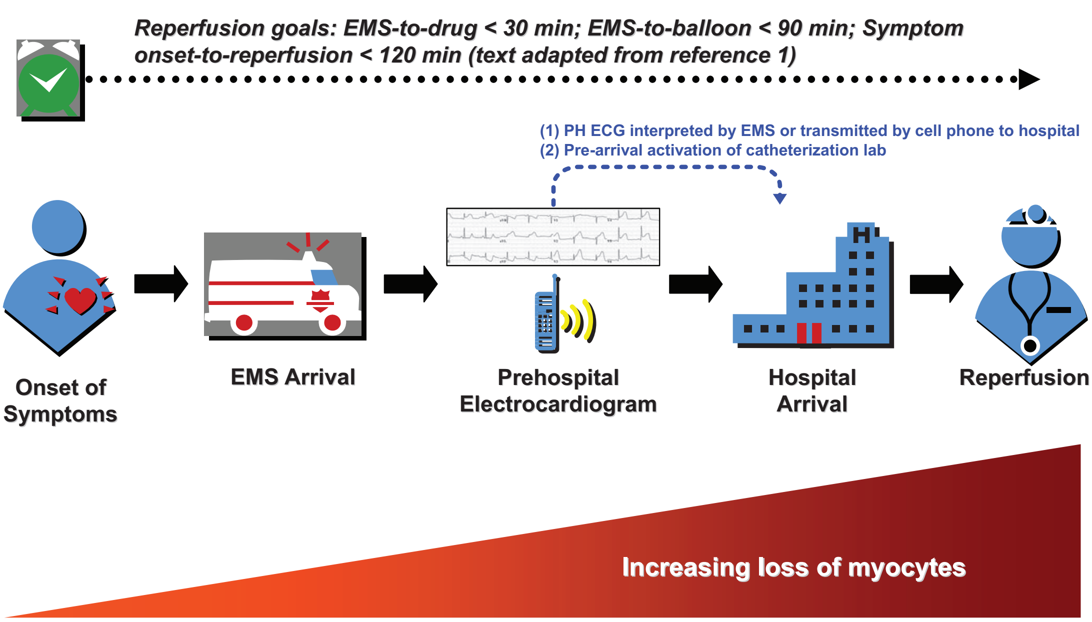

Figure 2. Reperfusion time goals for patients with ST-segment–elevation myocardial infarction.

'Table 1. Models for interpreting Prehospital ECGs

Method of Interpreting Prehospital ECG	Pros	Cons
Computer algorithm interpretation	Rapid, easy No wireless network or technology requirements	False-positive and false-negative rates higher than physician interpretation
Paramedic interpretation	Rapid, easy No wireless network or technology requirements	Requires intensive education and quality assurance program More complex in communities with multiple EMS providers and agencies
Wireless transmission and physician interpretation	Theoretically, lowest rate of false-positives and false-negatives Medical oversight can provide guidance on destination hospital and treatment en route	New technology requirement for EMS providers and hospital Reliable wireless network Transmission unit on ambulance Receiver station unit at hospital Smartphones for physicians Requires system to ensure immediate interpretation by physician Transmission failures

EMS indicates emergency medical services.

emergency department decreased from 14 to 3 minutes, time from arterial access to balloon decreased from 21 to 11 minutes, door-to-balloon time decreased from 54 to 26 minutes, and first medical contact to balloon time decreased from 113 to 74 minutes. The authors also concluded that systematic, quarterly feedback on performance to cardiology, emergency department, and EMS stakeholders was an important component in improving prehospital and hospital processes of care.[38]

Can EMS Providers Acquire Prehospital ECGs?

A survey found that 90% of EMS systems serving the 200 largest cities in the United States had 12-lead ECG equipment available in their ambulance systems.[39] EMS providers can rapidly acquire diagnostic-quality prehospital ECGs with an average increase of 5 to 6 minutes in the on-scene time interval.[14–16,28,40–49] To acquire diagnostic-quality prehospital ECGs, a valuable strategy is to educate EMS providers about the importance of careful patient positioning and lead placement. Movement artifact, lead misplacement, and poor skin contact can result in poor-quality tracing that can be misinterpreted by algorithms or EMS providers.

One study, which used data from the National Registry of Myocardial Infarction between 1994 and 1996, found that patients with prehospital ECGs had time intervals that were 20 minutes longer from symptom onset to hospital arrival.[12] This finding was difficult to interpret, however, as there was no measure of how long the prehospital ECG required and potential selection bias in who received a prehospital ECG. For example, patients who had a longer transport distance may have received a higher rate of prehospital ECGs as compared with those with a shorter transport distance. An analysis of the National Registry of Myocardial Infarction between 2000 and 2002 found that patients with prehospital ECGs did not have longer times from symptom onset to hospital arrival.[13]

Can EMS Providers Reliably Interpret or Communicate Prehospital ECGs?

Several studies have examined the feasibility of EMS providers identifying STEMI using prehospital ECGs with or without wireless transmission.[20,36,50–58] The pros and cons for computer algorithm interpretation, paramedic interpretation, and wireless transmission for physician interpretation of prehospital ECGs are summarized in Table 1. There are no data to compare the effectiveness of these different approaches for diagnostic accuracy or quality of reperfusion therapy delivered to patients with STEMI. The choice of which option to use may also be limited by the specific resources available in the community or its local geography.

Studies have also shown that paramedics with specific ECG training can reliably interpret prehospital ECGs without transmitting to a hospital or physician. Trained paramedics can identify STEMI with sensitivity ranging from 71% to 97% and specificity ranging from 91% to 100%,[15,16,59–65] and with good agreement between paramedics and emergency department physicians (κ ranging from 0.59 to 0.73).[20,60,64] The sensitivity (97%) and specificity (91%) of trained paramedics to interpret prehospital ECGs and diagnose STEMI was particularly high in one study, which included a 2-day training seminar.[62] A study of this issue, conducted in the United States with 151 patients with suspected acute myocardial infarction transported by a large urban EMS system, found that trained paramedics had 80% sensitivity and 97% specificity in diagnosing STEMI with prehospital ECGs, with good agreement between paramedics and emergency physicians (κ=0.73).[64]

Alternatively, prehospital ECGs can be transmitted by EMS for physician interpretation to drive decision making, but this approach has been limited by technology requirements for rapid and reliable transmission of prehospital ECGs. Two pilot studies have demonstrated that wireless transmission of prehospital ECG is feasible.[36,55] In the Timely Intervention in Myocardial Emergency–Northeast Experience (TIME-NE) conducted in Concord, NC, 24 patients with STEMI had successful wireless transmission of prehospital ECGs to a hospital receiving station and the on-call cardiologist's smartphone.[55] The on-call cardiologist then decided whether to activate the catheterization laboratory on the basis of the prehospital ECG. Median door-to-balloon time decreased in this study to 50 minutes as compared with 101 minutes for historical controls; however, there were 19 patients with STEMI who experienced failed wireless transmission. In the ST-Segment Analysis Using Wireless Technology in Acute Myocardial Infarction (STAT-MI) study conducted in Newark, NJ, 80 patients had prehospital ECGs transmitted using a wireless cellular phone network to a secure hospital central server and to the on-call cardiologist's smartphone.[36] This model had no transmission failures; median time from prehospital ECG acquisition to availability on the remote server was 2 minutes and on the smartphone was 4 minutes. The door-to-balloon time was 80 minutes with use of prehospital ECGs, as compared with 146 minutes for historical controls without use of prehospital ECGs. In geographic regions with reliable wireless network coverage, wireless transmission of prehospital ECG for physician interpretation is feasible and reliable; however, current wireless networks can fail to transmit or encounter significant delays in up to 20% to 44% of cases as a result of wireless "dead zones" in a moving ambulance or in rural areas with sparse coverage.[50,55,62,66,67]

Wireless transmission prehospital ECG systems are commercially available from Medtronic[36,57] (Minneapolis, Minn), Welch Allyn[55] (Beaverton, Ore), Zoll Medical[30] (Chelmsford, Mass), and Phillips Healthcare (Andover, Mass). These systems acquire the prehospital ECG and automatically transmit the data using Bluetooth protocol to a nearby cellular phone. The cellular phone functions as a router to transmit the data to a central receiving station and smartphones via a wireless cellular network or wireless local area network (IEEE 802.11).[68–71] A novel approach using camera phones with multimedia messaging service has been proposed and tested in 10 patients.[72] A camera phone obtains a digital picture of the prehospital ECG paper printout and wirelessly transmits the picture to an e-mail account, and the ECG image can be viewed on any multimedia messaging service–capable device, such as a computer or smartphone. This approach may be a simple, low-cost, and innovative technology[73] to communicate diagnostic image data and warrants further study for feasibility in real-world practices.

Can EMS and Hospitals Organize Systems to Effectively Use Prehospital ECGs?

EMS and hospitals should organize efficient systems of care for patients with STEMI from the prehospital phase of care to hospital arrival and reperfusion therapy in the hospital phase of care. The typical current process[2] for emergency cardiac care initiated by a 9-1-1 call is contrasted with the ideal process in Figure 3. Historically, EMS providers have been trained to follow these steps in evaluating patients with chest pain in the field: (1) assess airway, breathing, circulation, and

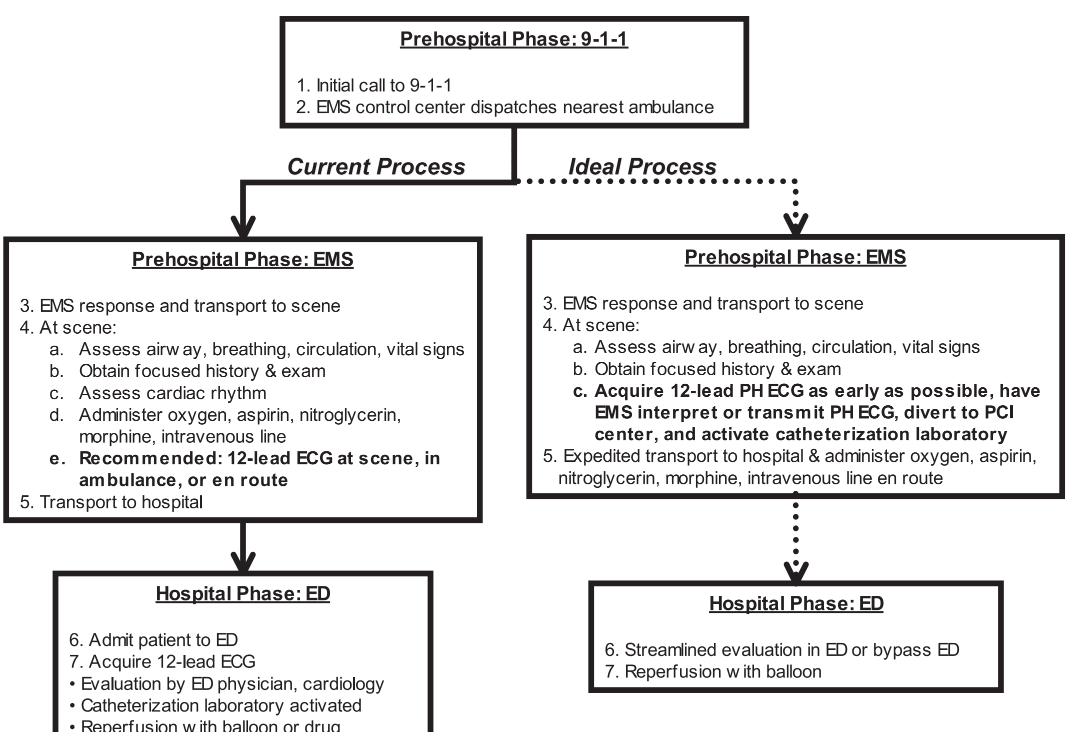

Figure 3. Current versus ideal processes to integrate prehospital ECGs into systems of care.

vital signs; (2) obtain focused history and examination; (3) assess cardiac rhythm; (4) initiate treatment with oxygen, aspirin, nitroglycerin, and morphine and insert intravenous line; (5) recommended: acquire 12-lead prehospital ECG at the scene, after the patient is transferred to the ambulance, or while en route to the hospital. Because the 12-lead ECG represents the critical data for diagnosis and decision making in patients with chest pain, it should be prioritized and performed as early as possible at the scene. If a STEMI is identified on the prehospital ECG, then scene times should be minimized, with expedited transport to the hospital. Moreover, if the prehospital ECG is communicated to the destination hospital shortly after first medical contact with EMS providers, then the hospital will have more time to prepare for the patient.

The information from a prehospital ECG and advanced notification should lead to efficient action by hospital systems of care to deliver prompt reperfusion therapy, including preparing to receive and evaluate the patient, activating the catheterization laboratory while the patient is en route, or bypassing the emergency department and transporting the patient directly to the catheterization laboratory.[32,37,74] If patients are evaluated in the emergency department, the evaluation should be streamlined by having a physician and necessary resources (eg, translators, nurses) ready before patient arrival, following a standard protocol for treatment, and minimizing physical movement, such as transferring between stretchers. Although bypassing the emergency department may be intuitively faster, concerns have been raised about processes for obtaining informed consent, patient safety, and consideration of alternative diagnoses (eg, aortic dissection, intracranial hemorrhage) or other false-positives that may account for the ST-segment elevation on the ECG in up to 10% to 15% of patients.[75–77] Furthermore, during off hours,[78,79] the catheterization team may not have arrived at the hospital before the ambulance, and the patient will need to be observed in a critical care setting until the catheterization laboratory is ready to receive the patient.

Can Regional Networks of Hospitals Organize Systems to Effectively Use Prehospital ECGs?

Patients with STEMI who require interhospital transfer experience substantial delays with a median first hospital door-to-balloon time of 180 minutes.[80] In the United States, regional networks of hospitals and systems of care have been implemented and evaluated to improve time to reperfusion therapy for patients who initially present to a community hospital without on-site PCI capability.[35,81–83] Similar, but broader systems of optimizing reperfusion therapy across populations have also been in place in Europe for several years.[24,84,85] European systems often have a physician in the ambulance, a central dispatch center for ambulances, and highly organized regional prehospital care, which stands in contrast to the disorganized, competitive environment in the United States.

Prehospital ECGs can play an important role for triage of patients in a regional network of hospitals, and the two models proposed include prehospital triage versus interhospital transfer.[3,11,74,86–89] The prehospital triage model transports patients with STEMI to the closest PCI center and bypasses hospitals without PCI capability. The interhospital transfer model focuses on advanced notification and efficient transfer of patients from non-PCI hospitals to PCI centers.[11] Several key factors, including distance, urban versus rural location, collaborative versus competitive relationships between hospitals, and variability of EMS providers, influence which model is best suited for specific regional populations. An analysis of the US Census Survey and the American Hospital Association Annual Survey showed that 80% of the adult population live within 60 minutes of a PCI-capable hospital, and only 5% live farther than 90 minutes from one.[90] However, there are still 20% of the adult population and large geographic areas that do not meet this standard. One model of regionalized STEMI care does not preclude the other. Both can coexist within a single network and are often driven by specific resources available within a community and local geography. No data comparing the models exist, and potential unintended consequences, such as exceptionally long delays to reperfusion, should be monitored.[10,91]

Table 2. Comparison of Existing Prehospital ECG Programs

Location	Prehospital ECG Interpretation	Activate Catheterization Lab en Route to Hospital	Bypass Non-PCI Hospitals
Boston[64,92]	Paramedic interpretation	Yes (activation by emergency department physician based on paramedic interpretation)	Yes (for all patients with "definite STEMI" or "possible STEMI")
Los Angeles County[76,87]	Computer algorithm interpretation	Yes (activation by emergency department physician based on computer algorithm interpretation)	Yes (for all patients with acute MI)
North Carolina[83]	Mixed (used computer algorithm interpretation, paramedic interpretation, or wireless transmission)	Mixed (activation by paramedics or emergency department physician)	Mixed (paramedics occasionally diverted patients with STEMI to nearest PCI hospital)
Ottawa[65,96]	Paramedic interpretation	Yes (activation by paramedic through a central page operator)	Yes (for all patients with STEMI)

PCI indicates percutaneous coronary intervention; MI, myocardial infarction; and STEMI, ST-segment–elevation myocardial infarction.

How Have Prehospital ECGs Been Incorporated Into Existing Systems of Care?

Many communities are implementing prehospital ECG programs that are in varying stages of development, and Boston, Los Angeles, North Carolina, and Ottawa (Canada) provide important contrasts (Table 2). The Boston EMS program, one of the country's first, involves municipal paramedics trained to interpret and categorize prehospital ECGs as definite STEMI, possible STEMI, or nondiagnostic.[9,64,92] Patients with definite STEMI or possible STEMI are triaged to the closest PCI hospital, and the former are brought directly to the catheterization laboratory and the latter are evaluated in the emergency department. The emergency physician decides whether to activate the catheterization laboratory on the basis of the paramedic interpretation while the patient is en route to the hospital. The Boston EMS program covers a relatively small geographic area (<50 square miles) with 60 to 70 municipal paramedics, and private EMS providers do not participate in the program.

In contrast, the Los Angeles County EMS program includes all EMS providers, an area of >4000 square miles with approximately 2500 paramedics working for 27 agencies.[76,87] The variability and sheer numbers of EMS providers to train in ECG interpretation were considered an insurmountable obstacle. The Los Angeles County EMS program therefore relies on computer algorithm interpretation that identifies ***ACUTE MI*** to prompt EMS transport of patients to the closest PCI center (or STEMI receiving center). The emergency physician decides whether to activate the catheterization laboratory on the basis of the computer algorithm interpretation while the patient is en route to the hospital. A few hospitals in Los Angeles County have started to pilot the feasibility of transmitting prehospital ECGs for physician interpretation. Both the Boston and Los Angeles programs are undergoing formal evaluation. There are also ongoing clinical trials in other parts of the United States evaluating the effectiveness of prehospital ECGs to decrease first medical contact to balloon/drug times.[93–95]

The Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments (RACE) Investigators implemented a statewide approach to improve timeliness of reperfusion therapy for patients with STEMI.[83] The use of prehospital ECGs was high, and prehospital ECGs were acquired in 61% and 43% of patients with STEMI transported by EMS to PCI hospitals and non-PCI hospitals, respectively. However, the RACE program did not have standardized procedures for when to acquire a prehospital ECG, who would interpret the prehospital ECG, and how to integrate the prehospital ECG with systems of care. Each hospital and region decided how to interpret and integrate the prehospital ECG based on available resources, geography, and decisions by regional leadership.

The Ottawa citywide system, which included 1 PCI center and 4 non-PCI hospitals located within 7 miles of the PCI center, reported their 1-year experience in 344 patients with STEMI.[96] The first hospital door-to-balloon time was 69 minutes when paramedics acquired and interpreted a prehospital ECG and bypassed non-PCI hospitals as compared with 123 minutes when a prehospital ECG was not performed and the patient was initially brought to a non-PCI hospital and required interhospital transfer for primary PCI.

What Are the Barriers to Implementing Successful Prehospital ECG Programs?

What Are the Costs and Benefits for Prehospital ECG Programs?

Currently, there are no cost-effectiveness models to evaluate this diagnostic technology from the different perspectives of patients, hospitals, payors, and society.[97] One study reported that the incremental cost to upgrade prehospital ECG equipment to wireless capability was $16 100, which consisted of $11 000 for a receiving station, $600 for cell phones, and $4500 for data cables.[57] The direct cost for prehospital ECG equipment with monitoring and defibrillation capability ranges from $9000 to $25 000, but this does not take into account other direct and indirect costs for training, quality assurance, and organizing complex EMS and hospital systems.[8,98] Developing and implementing STEMI systems require substantial investment of resources that impact on the value of acquiring and using the information provided by prehospital ECGs. Comparative cost models for efficiently acquiring, interpreting, and transmitting prehospital ECGs within the context of STEMI systems will be informative and valuable. Additionally, it will be important to compare the development of STEMI systems of care with other healthcare priorities, both in cardiovascular medicine and other disciplines.

What Training and Maintenance of Competency Do EMS Providers Need?

In the United States, EMS providers are trained to several competency levels. Although the federal government (http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.2a0771e91315babbbf30811060008a0c/) has defined a standard curricula for each of 4 levels (first responder, emergency medical technician [EMT]–basic, EMT-intermediate, and EMT-paramedic),[99] many states use definitions and regulations that vary significantly between states as well as within a single state (rural versus urban areas). The National Registry of EMTs (www.nremt.org), the nation's de facto "board" for certification, currently certifies EMS personnel at the first responder, EMT-basic, EMT-intermediate/1985, EMT-intermediate/1999, and EMT-paramedic levels.

First responder roles are often provided by firefighters or law enforcement officers.[9] EMT-basic personnel provide basic life support, including first aid, cardiopulmonary resuscitation, oxygen, and early defibrillation. EMT-intermediate and EMT-paramedic personnel provide advanced life support, including intubation and intravenous medications. Prehospital ECG acquisition has historically been limited to EMT-paramedic. The current EMT-paramedic national standard curriculum[99] includes the following objectives intended to provide paramedics with a basic understanding of the pathophysiology and ECG features of acute myocardial infarction:

5–2.9 Identify the arterial blood supply to any given area of the myocardium.

5–2.22 Discuss the pathophysiology of cardiac disease and injury.
5–2.34 Relate the cardiac surfaces or areas represented by the ECG leads.
5–2.48 Recognize the changes on the ECG that may reflect evidence of myocardial ischemia and injury.
5–2.78 Identify the ECG changes characteristically seen during evolution of an acute myocardial infarction.

The National Association of EMS Educators (www.naemse.org) is presently revising all of the existing national standard curricula for EMS with new standards. The initial draft of this document, released in June 2007, includes 12-lead ECG interpretation as a required competency for paramedics. Currently, no standards exist regarding how much initial and subsequent periodic education is required to achieve and maintain competency in prehospital ECG interpretation. Also, there are no standard protocols for when and what patient subsets to obtain a prehospital ECG, as well as what to do with the data.

It has been proposed that prehospital ECG acquisition be extended to EMT-basic and EMT-intermediate levels.[9] A preliminary study showed that EMT-basic personnel could acquire, but not interpret, ECGs in a comparable amount of time as compared with EMT-paramedics.[100] Although rural geographic areas without paramedic coverage could benefit by extending prehospital ECG acquisition skills to EMT-basic personnel, this would require significant changes in current curriculum, training, protocols, and policy.

EMS systems vary substantially with regard to configuration and structure, each using some combination of EMS providers to deliver emergency medical care for rural, suburban, or urban communities. Physician oversight also varies, with only a small number of large EMS systems having full-time physician medical directors. Given the challenges with EMS training, maintenance of competency,[101–103] quality management, and medical oversight, there is no "one size fits all" or even "one size fits most" solution.

How Will Patients With Acute Coronary Syndromes Use EMS?

The reluctance of patients with acute coronary syndromes to call 9-1-1 is a major obstacle to realization of the full public health benefits of prehospital ECGs and organizing systems of care. Prior studies have shown that 10% to 59% of patients with chest pain use EMS[104–111] and less than half of patients with STEMI use EMS versus self-transport to the hospital.[8,110] Studies have demonstrated that patients with STEMI arriving by ambulance receive faster reperfusion therapy than those who arrive by self-transport, particularly in busy, overcrowded emergency departments.[112,113] Unfortunately, educational and media efforts to increase EMS use have had limited success.[114] Conversely, if substantially more patients with chest pain call 9-1-1, EMS and emergency department systems may need to grow to provide adequate access and capacity.[113,115–117] Efforts to increase the reach of prehospital ECG programs will need to address the limited use of EMS by patients with STEMI and the need to expand EMS capacity to meet increased demand.

What Areas of Future Research Need to Be Addressed?

How Will the Use of Prehospital ECGs Be Measured and Assessed?

For the most part, current measures for assessing the use and timeliness of reperfusion therapy in STEMI (eg, door-to-balloon time) are hospital-based and therefore inadequate for evaluating the effectiveness of prehospital ECGs. To evaluate the incremental benefit of this technology, current hospital-based measures (door-to-balloon time) would need to evolve to patient-centered measures, such as first medical contact to reperfusion or symptom onset to reperfusion. Current STEMI guidelines recommend that the pertinent metric for quality of reperfusion therapy are first medical contact to balloon $<$90 minutes and first medical contact to drug $<$30 minutes.[3] Furthermore, we need to assess patient responsiveness after onset of symptoms, appropriate use of EMS and EMS responsiveness, EMS scene time to acquire prehospital ECGs, and effective communication of this data to destination hospitals and its use in decision making about reperfusion therapy. There needs to be careful analysis of the denominator or eligible population who should have received a prehospital ECG versus those who actually received a prehospital ECG. For providers to adopt the technology, an improved understanding of how potential gains in rapid reperfusion translate into improved clinical outcomes would be ideal, as well as an understanding of the frequency of false alarms and other unintended consequences. Real-world examples are particularly helpful in this regard, given the wide-ranging approaches that different types of healthcare systems—for example, urban versus rural—may require. These examples would also be important for assessing the overall value of this technology relative to the financial investment in equipment, training, and organizing STEMI systems.

How Will Prehospital ECGs Be Performed and in Whom Should They Be Used?

There remains a poor understanding of who will acquire and interpret prehospital ECGs and in whom these tests should be performed. A direct comparison of diagnostic accuracy and times for ECG interpretation by computer algorithm, paramedics, and emergency physicians or cardiologists would be valuable. Most regions that use prehospital ECGs have standard protocols for what types of symptoms should prompt acquisition of the test, but the false-positive and false-negative rates have been poorly characterized in general. It would be valuable to understand the frequency of ST-segment elevation from other causes,[118] such as early repolarization, left ventricular hypertrophy, left bundle-branch block, pericarditis, hyperkalemia, atrial flutter, Brugada syndrome, pulmonary embolism, and Prinzmetal angina, as prehospital ECG programs are implemented.

It has been reported that approximately 5% of patients with chest pain who are evaluated by EMS have STEMI.[59,76] The incremental value of this technology when the number needed to treat is 20 for 1 patient who benefits needs to be verified and elucidated in patients with more atypical symptoms, such as shortness of breath, dizziness, or other atypical symptoms.

How Will Prehospital ECGs Be Integrated Into Practice Without Unintended Consequences?

An important area of investigation is how the prehospital ECGs can optimize decision making to triage patients to destination hospitals with and without PCI capability. The broad and diverse population of the United States poses several challenges to establishing effective systems of care for incorporating prehospital ECGs into routine clinical practice. It is apparent that a one-size-fits-all approach is neither practical nor ideal. The use of this technology requires a careful assessment of the local needs and resources within each community, with the overarching goal to improve patient care and access, timeliness of reperfusion therapy, and the proportion of eligible patients who receive reperfusion.

A better understanding of the precise role of different providers in the design of systems that use prehospital ECGs is needed. How will the roles of EMS and emergency physicians evolve for activating the catheterization laboratory? How will safeguards be established so that patients with other life-threatening conditions that may mimic or complicate STEMI are not missed and care is not delayed? Investigators should be encouraged to explore both the benefits and pitfalls of implementing a prehospital ECG program. There may be unintended deleterious effects to patients, such as longer scene times and overall longer time from symptom onset to reperfusion.

Table 3. Requirements for an Integrated Prehospital ECG System of Care

EMS
Training and ongoing quality assurance for EMS providers and medical control physicians
Acquiring prehospital ECG as early as possible during initial scene evaluation
Minimize scene time when STEMI is diagnosed
Advanced notification of destination hospital
Activation of catheterization laboratory by EMS providers or emergency physician while patient is en route to hospital
PCI Hospital
Organize reliable wireless networks and technologies
Advanced preparation to receive and evaluate patient
Activation of catheterization laboratory by emergency physician while patient is en route to hospital
Streamline emergency department evaluation or bypass emergency department
Prehospital triage for regional hospital networks to bypass non-PCI hospitals
Research and Quality Assurance
Monitor quality measures, including first medical contact to drug/balloon
Monitor false-positive and false-negative rates
Evaluate whether EMT-basic and EMT-intermediate can acquire prehospital ECG reliably and efficiently
Promote systematic and routine feedback of performance to all stakeholders, including EMS, emergency department, and cardiology

EMT indicates emergency medical technician.

What Policy Measures Should Be Adopted to Encourage Use of Prehospital ECGs?

The healthcare system within the United States is not currently organized in a way that encourages the adoption of prehospital ECGs or regional systems of care for STEMI.[90,119,120] Numerous providers in the prehospital and hospital settings make it challenging to foster cooperation. For example, in many regions, there are several private, for-profit EMS that are responsible for evaluating and transporting patients. Successful implementation will require the inclusion of these providers and may necessitate that prehospital ECGs are required by regulation and are reimbursed. Currently, EMS reimbursement is typically based on 2 levels of care as well as distances traveled, but EMS is not reimbursed for specific services delivered, including a prehospital ECG. However, it also is unclear whether expansion of reimbursement for prehospital ECGs may lead to overuse and misuse.

Issues surrounding reimbursement are also fundamental to hospitals. Cardiac patients are seen as lucrative, given the high rate of invasive procedures associated with these conditions, and represent prestigious service lines for the institution.[121] Encouraging EMS systems to use prehospital ECGs as part of protocols that divert patients from community hospitals to STEMI destination hospitals will be challenging, because the loss of profitable cardiac patients may impact the financial viability of a rural, critical access hospital. EMS providers, emergency physicians, and cardiologists will need to engage and work together to implement an ideal, integrated prehospital ECG system of care for patients with acute coronary syndrome.

Additionally, it is unclear what regulatory oversight is needed to assess quality of prehospital ECG programs. These issues raise the concern of accountability after their establishment. Much of the daily work required for these systems will be done at the local healthcare system level, with groups of expert providers from the community participating in the design and implementation of these programs. However, authority and funding for these programs may need to come from higher levels of government, such as county, state, or regional health agencies. Increasingly, health agencies at these regulatory levels are recognizing the importance of timely therapy for patients with STEMI and categorizing them similar to trauma patients. This emphasis on rapid treatment and the expansion of primary PCI to more hospitals may allow for funding of programs for prehospital ECGs to be tied in as well.

Summary

Prehospital ECG programs have the potential to improve the way care is delivered to patients with STEMI in the United States. Current American Heart Association guidelines recommend that paramedics perform and evaluate a prehospital ECG routinely on patients with chest pain suspected of having STEMI (Class IIa, Level of Evidence B).[1,3] The central challenge for healthcare providers is not to simply perform a prehospital ECG, but to use and integrate the diagnostic information from a prehospital ECG with systems of care. The potential savings in time from first medical contact to reperfusion therapy by integrating prehospital ECGs with hospital systems of care are considerable and clinically relevant. However, the gaps between use under ideal circumstances and in routine practice remain substantial (Table 3). There are many logistic barriers, including the need for increased patient use of EMS; increased EMS capacity; improved education and quality assurance for EMS providers; improved collaboration among EMS, emergency departments, and cardiology; improved organization of hospital systems and providers; and improved coordination of regional hospital networks to provide the ideal patient care rather than optimize market share. It also is apparent that several financial barriers, including reimbursement and cost-effectiveness of this diagnostic technology, will need to be overcome for prehospital ECGs to gain widespread support across payors, providers, and healthcare systems. But these barriers are not insurmountable and can be overcome with dedicated efforts to improving systems of care. Future investigations and policy measures are needed to encourage EMS, hospitals, and healthcare systems to adopt and maximize the full potential of this technology, as well as monitor unintended consequences.

Many of the barriers to the widespread implementation of prehospital ECGs are being addressed by the American Heart Association's Mission: Lifeline, a national initiative launched in 2007 to improve systems of care for patients with STEMI.[11] Mission: Lifeline's initial phase includes Emergency Medical Services System Assessment and Improvement. Working in collaboration with EMS organizations on national and local levels, Mission: Lifeline is conducting a comprehensive survey to determine EMS capability, policy, infrastructure, and resources, including prehospital ECG capability and protocols for care of patients with STEMI. On the basis of the above assessment, the American Heart Association plans to build and evaluate the appropriate infrastructure to ideally serve patients with STEMI that is tailored at the local, regional, or state level. The implementation phase will address funding, training, the potential for overuse of STEMI services or procedures, and identification of underserved populations and development of strategies to mitigate disparities in access to care, as well as evaluation of existing process measures and patient outcomes.[91]

Disclosures

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Name	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Ownership Interest	Consultant/ Advisory Board	Other
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(*Continued*)

Continued

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This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

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This table represents the relationship of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit.

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KEY WORDS: AHA Scientific Statements ■ acute care ■ medical services, emergency ■ emergency medicine