Chapter 3

The future of STEMI response: Implementing field-to-cardiologist ECG transmission to accelerate reperfusion in acute MI

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INTRODUCTION

Medic 6 arrives at the home of a 68-year-old male with chest pain. After conducting a complete assessment, obtaining a 12-lead electrocardiogram (ECG) and starting initial interventions, the crew sends the 12-lead directly from their monitor to the personal digital assistant (PDA) of a cardiologist. The physician hears the device’s alert tone, checks the PDA and evaluates the ECG in real time.

The cardiologist evaluates the patient’s ECG to determine if it meets criteria for emergency reperfusion therapy in the facility’s cardiac catheterization (cath) lab. It does, so he advises the crew to bypass the emergency department (ED) and proceed directly to the cath lab where he and his team will meet the patient.

The crew acknowledges the cardiologist’s orders and then notifies the ED. The patient arrives at the hospital 12 minutes later and within another seven minutes is under the care of the specialized catheterization team.

Sound far-fetched? It’s not. Technology has begun to make this scenario happen in emergency medical service (EMS) systems throughout the world. This article describes the protocol used to study this clinically important and innovative technology.

BACKGROUND

An estimated 2 million annual hospital discharges in the United States are for acute coronary syndromes, and one-third of these patients have ST-elevation myocardial infarction (STEMI) (1). The underlying cause of STEMI is typically an acute occlusion of a coronary artery (e.g., thrombosis).

The rapid identification of STEMI should be of highest priority to EMS crews because reperfusion treatments (e.g., thrombolytic medications or mechanical intervention in the cath lab) can save cardiac muscle and potentially even the patient’s life if treatment is administered rapidly (2-5). To reduce the time from onset of acute thrombosis to reperfusion therapy, clinicians have employed numerous strategies, including patient educational initiatives (6-8), specific acute myocardial infarction (MI) protocol development for EDs (9-15), prehospital ECG transmission from EMS vehicles to EDs (16-19) and prehospital thrombolysis (20-25).

Cellular transmission of ECGs to receiving hospitals has been in use by EMS systems since 1987 (26). In the TIME 1 (Timely Intervention in Myocardial Emergency 1) trial in Guilford County, N.C., Wall et al documented a 27% time reduction (109 to 80 minutes) from hospital arrival to percutaneous coronary intervention (PCI) by implementing prehospital ECG transmission to the ED (19). However, a follow-up study revealed that the initial decrease in door-to-balloon time was not sustained over a 10-year period (27).

These results stimulated the discussion of whether door-to-balloon times could be
consistently reduced for patients with clearly abnormal ECGs by increasing direct communication between paramedics and cardiologists. Such a system would involve paramedics evaluating 12-lead ECGs for ST-elevation and directly contacting the cardiologist when STEMI was present. [Note: A study found that the true-positive rate of STEMI diagnosis by paramedics is high in patients presenting without confounding factors, e.g., prior myocardial infarction (MI), poor-quality ECG, bundle branch block, left ventricular hypertrophy and pacemaker, but decreases when the ECG has confounding factors (28)]

ECG transmission directly from a prehospital ECG monitor to a handheld digital device has only recently become an option (29). This system can now provide parallel ECG transmission to the ED and an on-call cardiologist for patients with both symptoms and ST-segment changes that most strongly suggest an MI.

Testing of this technology has been performed in both Europe and the United States (30,31). The hypothesis of these studies is that the time to reperfusion therapy will be reduced when the assigned cardiologist has immediate access to a 12-lead ECG and other patient data directly from paramedics in the field. It’s further hypothesized that earlier treatment will result in increased myocardial salvage as estimated by previously validated ECG scoring techniques described below (32-35).

Technical aspects
In the studies referenced, paramedics obtain a 12-lead ECG for patients experiencing symptoms suggestive of acute coronary syndrome. If a probable STEMI is indicated by at least 1 mm ST elevation in two or more contiguous leads, the ECG is transmitted from the ambulance to a central computer at the EMS headquarters or a hospital, using a cellular connection or digital wireless network (36). The ECG can be transmitted to a fax machine at the ED, a receiving station or a PDA. Systems with a receiving station can forward the ECG to a cath lab or other location.

Notification can also be sent to an on-call cardiologist’s PDA. The small, handheld device alerts the physician of an incoming ECG. Using proprietary software, the cardiologist can download the ECG from the central computer and view it on the PDA screen. The software provides a view of the six limb leads, the six precordial leads and a more detailed zoom view of each individual lead. If the cellular connection to the PDA fails, the ECG is faxed to the hospital ED. The fax system is maintained as a back-up to the electronic transfer system. In addition, the ECGs are stored on the central computer, which facilitates their use for computing the predicted final MI size.

RESULTS
The method described was developed by investigators at Guilford County (N.C.) and Duke Clinical Research Institute in response to an absence of sustained reduction in time to
reperfusion for STEMI patients (27). This ECG transfer method has been implemented in TIME studies in both Copenhagen, Denmark (TIME-C), and Cabarrus County, N.C. (TIME-NE), and is now the basis for multi-center TIME studies of two commercial prehospital ECG manufacturers (Figure 1) (30,37).

In addition, a study in Durham, N.C. (TIME-HL) has shown a significant decrease in door-to-balloon time when paramedics called the coronary care unit directly to activate the cath lab using a dedicated “hotline” (38). This intervention did not involve ECG transmission and relied solely on paramedic recognition of STEMI.

**Figure 1:** Evolution of the Timely Intervention in Myocardial Emergency (TIME) Studies

![Figure 1](image)

**The ideal environment for implementation**

A community interested in implementing this technology must have a well-organized EMS system and hospital health system that provides primary coronary intervention and/or intravenous thrombolytic therapy on a 24-hour basis. Both EMS and the health system must have resources for collecting patient data into a computerized database. A relationship must be established with a study coordination center capable of designing the ECG transfer protocol, managing the data and determining the study outcomes. The cellular network must support messaging/paging services, as well as data and voice transmission services.

**EMS involvement:** Paramedics involved in remote transmission programs must be well-educated in the interpretation, recording and transmission of 12-lead ECGs, as well as in the advanced patient treatment associated with cardiac chest pain (28). The ambulances must be equipped to transmit the ECG via cellular or wireless technology.

An EMS research coordinator should be appointed to ensure the education of the paramedics and be responsible for testing, introducing, and maintaining the necessary tech-
nology. The coordinator would be responsible for monitoring and ensuring the correct functioning of the ECG transmission system and EMS data collection after the technology has been implemented.

**Participating hospital involvement:** Participating hospitals must provide reperfusion therapy on a 24-hour basis using thrombolytic therapy or PCI. Protocols must be established regarding the responsibilities of the paramedics, ED physicians and cardiologists. A research coordinator within the hospital must be appointed and given responsibility for obtaining data on patients with reperfusion therapy.

**Study coordination center:** A study coordination center should oversee the study progress, determining the requirements of each of the participants before the technology can be implemented in the community. The center must be experienced in coordinating clinical research studies and the testing of new technologies, and have facilities to maintain and analyze patient data in a study database and experts to analyze the ECGs.

A study coordinator establishes a system for data collection and analysis from the different sources and for direct communication between the participants. The coordinator appoints a Data Safety and Monitoring Board (DSMB) to approve the study design and monitor patient safety (39).

**Communications flow**
In our system, paramedics transmit an ECG for patients meeting STEMI criteria to a cardiologist’s handheld digital device on a 24-hour basis. The cardiologist receives and views the ECG, and contacts the paramedic by phone. Assuming primary medical control, the cardiologist decides what emergency treatment is indicated and discusses the plan with the paramedic.

The paramedic then establishes contact with the ED charge nurse, providing information regarding the cardiologist’s decision of treatment and transport site. Depending on local EMS capability and treatment protocols, the paramedic initiates field thrombolytics, transports the patient directly to the cath laboratory for PCI or transports the patient to the hospital ED, either for thrombolytic therapy or to hold until the cath lab is ready (Figure 2).

A protocol is followed for the patient to bypass the ED when the cath lab is operational, and a shortened admission protocol is followed when it’s not operational so the patient can be transported to the cath lab as soon as it’s available. If the patient will be transported directly to the cath lab, the cardiologist will notify the cath lab nurse directly. The cardiologist then meets the patient at the arrival site—the ED or the cath lab.

**Data collection & analysis**
To safely introduce this technology and monitor the ongoing study, it is essential to have a well-functioning data collection system. The study coordination center gathers the in-
formation (Figure 3). Reports from these computerized databases provide information on patient flow and study progress. This database can then be queried for quality control and outcome research.

An ECG analyst calculates myocardial salvage by analyzing and comparing the transmitted and hospital discharge recordings (32,33,40-42). Automated ECG analysis programs facilitate this process by providing the required digital measurements.

The analysis includes demographic data, medical history, presenting patient characteristics, diagnosis and procedure utilization, delay and treatment time intervals, and hospital outcomes. Thus, patients with and without ECGs transmitted to the cardiologist can be compared.

**LESSONS LEARNED**

Before making the decision to implement this technology, control data on current time to treatment and transportation should be collected from the community regarding the patient population. In addition, the paramedics should be sufficiently trained in 12-lead ECG acquisition and diagnosing STEMI.

**Technology:** There are various methods of transmitting the ECG to a cellular device; there are also different types of devices. When making a choice between the technology options one should consider the availability, dependability (especially software reliability)
Transmission methods: To view a transmitted ECG on a cellular device as an electronic file requires specially designed software. Commercially available software and technology can also fax the ECG via a cellular device, although the quality of the ECG when displayed on the device needs to be verified (43,44).

Factors that should be evaluated are the image resolution, size and the number of leads that can be displayed on the cellular device at one time. The current technology is capable of displaying and transmitting ECGs but often has too many software issues to be sufficiently dependable.

Data entry & collection: Data should be entered as it becomes available, and appropriate edit checks should be applied. Separate databases can be used to analyze the ECGs and to

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<th>Technical &amp; Procedural Data to Monitor Reliability</th>
<th>From EMS/paramedic:</th>
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<td>Time of prehospital ECG transmission</td>
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<td>Transmission information</td>
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<td>Communication with cardiologist and ED</td>
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<td>From cardiologist carrying receiving device:</td>
<td>Notification of ECG received</td>
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<td>Ability to view ECG</td>
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<td>Treatment decision</td>
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<td>Communication with paramedic and cath lab</td>
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<td>From ECG recorder:</td>
<td>Prehospital ECG</td>
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<th>Information from Paramedics</th>
<th>Dates &amp; times of:</th>
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<td>Symptom onset</td>
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<td>EMS arrival on scene</td>
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<td>ECG recording</td>
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<td>Hospital arrival</td>
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<td>Patient baseline characteristics</td>
<td>Date of birth, sex, race, etc.</td>
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<td>Risk factors</td>
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<td>Medical history</td>
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<td>Success of transmission</td>
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<td>Communication and treatment decision</td>
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<th>Patient Care Information from Hospital</th>
<th>Dates and times of:</th>
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<td>Hospital admission (arrival at ED, arrival at cath lab)</td>
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<td>Treatment (administration of thrombolytics or start of PCI)</td>
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<td>Hospital discharge</td>
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<td>Patient baseline characteristics (for matching with EMS data)</td>
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<td>Post-treatment assessment</td>
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<td>Complications and survival</td>
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and capability of the cellular devices.

Figure 3: Key Data Elements to be Recorded
track the transmissions. Establishing a central database that stores all patient data appears to be the most efficient setup. Because the number of study patients at a single site is limited, standardization of the data elements would be valuable for facilitating multi-center data analysis, providing stronger results.

**Communication:** The number of participating sites and organizations involved necessitates a structured feedback plan. Feedback from weekly visits of the study coordinator to the study sites and regular conference calls should be presented to all study participants in a newsletter.

An institutional review board (IRB) should monitor the study results and, if called for, terminate the study. A list of responsibilities for solving specific problems should also be established, and the study coordinator should refer to this list to gather information and set up conference calls to resolve any issues.

**CONCLUSION**

Based on our results, we recommend the implementation of this system be done in three phases:

**Phase one:** After developing an initial plan, the technology to be used is chosen and, if necessary, clinically tested. This applies to the treatment possibilities as well. Existing data from the community is evaluated.

**Phase two:** The communication lines and protocols are finalized and tested together with the technology. At the same time, data collection is started. Patient safety is ensured via an established backup system and a Data Safety and Monitoring Board that approves the study protocol. Final adjustments, based on testing results, are made to the technology and protocols.

**Phase three:** The technology is applied, allowing the cardiologists to make prehospital treatment decisions. The IRB monitors patient safety and study progress. The data are analyzed and compared with other communities.

Implementing this advanced technology requires a long-term commitment from all participants. Technology will always be changing, so clear communication protocols must form a framework for introduction of newer technologies.

**REFERENCES**


3. Newby LK, Rutsch WR, Califf RM, et al: “Time from symptom onset to treatment and outcomes after throm-


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