The Need for Regional Integrated Care for ST-Segment Elevation Myocardial Infarction
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Case 1 presentation: A 57-year-old man suffered a sudden cardiac arrest at home, witnessed by his son, who called 911 and began cardiopulmonary resuscitation immediately. Emergency medical services (EMS) were activated and arrived on the scene within 10 minutes. The patient was found to be in ventricular fibrillation and was defibrillated 5 times by EMS. He was intubated in the field, and an ECG revealed inferior ST-segment elevation. The Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments protocol was initiated. He was transported across county lines, past a non-percutaneous coronary intervention (PCI) hospital, directly to a PCI facility, where the preactivated catheterization laboratory was awaiting arrival (Figure 1). On presentation, he was comatose with a pulse of 90/min, blood pressure of 90/70 mm Hg, and had pulmonary edema with distant heart tones.

Case 2 presentation: A 76-year-old man was driven by his family to his local emergency department after having 1 day of worsening shortness of breath and 2 hours of substernal chest pain. On arrival to this non-PCI facility, he was found to be in respiratory failure, requiring mechanical ventilation, and developed cardiogenic shock. An ECG revealed anterior ST-segment elevation, and laboratory analysis revealed an initial hematocrit of 24%. Because of the distance from the closest PCI facility, he was given fibrinolytic therapy. Despite fibrinolytic therapy, there was failure of resolution of the ST-segment elevation. Approximately 6 hours later, the patient was transferred via helicopter to a PCI center for immediate coronary angiography and rescue PCI.

Overview
Much progress has been made over the last several decades in improving reperfusion therapies for acute myocardial infarction. However, significant challenges remain in ensuring that all eligible patients are treated in a timely fashion. For those with ST-segment elevation myocardial infarction (STEMI), multiple studies have demonstrated that primary PCI is superior to fibrinolytic therapy in reducing mortality and morbidity when performed in a timely fashion. However, the widespread use of primary PCI is restricted by the lack of timely access to PCI-capable hospitals in many regions of the country. Some of this lack of access is due to system barriers involving lack of coordination between EMS, non-PCI, and PCI hospitals. This has led to substantial variations in the treatment of STEMI with regard to reperfusion strategy and administration within the recommended time windows. Currently, ≈25% of STEMI patients receive no reperfusion therapy, despite a lack of contraindications. Of those treated, <50% receive fibrinolytics within the recommended door-to-needle time of 30 minutes, and <40% receive PCI within the recommended 90 minutes, particularly when patients need to be transferred to a PCI center. This delay takes place despite unequivocal data that have demonstrated that any delay in reperfusion, either with fibrinolytics or primary PCI, is associated with an increase in mortality.

There are system-related reasons for delays in reperfusion therapy. They include patient delay in contacting the healthcare system, lack of or delay in calling 911, transportation time to the hospital and between hospitals, time required for triage and diagnosis, and time required to implement the chosen reperfusion strategy. Only approximately half of patients use 911 at all.

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Rapid transportation of a STEMI patient to the most appropriate hospital may be limited by failure to recognize the diagnosis because of a lack of prehospital 12-lead ECG capabilities, requirements to transport the patient to the nearest facility even if PCI is not available at that hospital, or long transportation times on rural roads. Overcoming these barriers requires coordination of care among many levels of providers to work toward the common goal of rapid reperfusion.

To address the obstacles, the American Heart Association (AHA) developed an Acute Myocardial Infarction Advisory Working Group to develop recommendations to increase the number of STEMI patients who receive reperfusion within the recommended time windows. In 2006, the American College of Cardiology (ACC) launched the D2B Alliance, a nationwide initiative targeting 1000 PCI hospitals to achieve door-to-balloon times of 90 minutes in at least 75% of their patients.

The concept of STEMI Receiving Center Networks with integrated and regionalized systems of care was developed to regionalize STEMI care and addressed interhospital transfers and prehospital care. The goals of these programs are to accelerate the diagnosis of ST-segment elevation and to minimize the time from diagnosis to reperfusion (Figure 2). They encourage prehospital ECGs by emergency medical personnel, early activation of the cardiac catheterization laboratory based on this information, direct transportation to a PCI-center when feasible, and expedited transfer from a non-PCI hospital. The ACC/AHA 2009 Joint STEMI/PCI Focused Guidelines Update gives a class I, level of evidence C recommendation for each community to develop a STEMI system of care that includes a process for prehospital identification of STEMI, destination protocols for PCI centers, and transfer protocols for non-PCI centers. Several programs like this have already been put into place and have resulted in impressive improvements in processes of care.

**Prehospital ECG**

For many patients with an acute myocardial infarction, first medical contact occurs outside of the hospital with emergency medical personnel. It is at this moment that the triage, diagnosis, and management of STEMI should begin. Prehospital ECGs performed and interpreted by EMS have been shown to reduce door-to-balloon times and are endorsed by organizations such as the AHA and the ACC. However, recent implementation of prehospital 12-lead ECG capability has not consistently been accompanied by systems that routinely activate the catheterization laboratory when ST-segment elevation is detected.

An analysis of the National Cardiovascular Data Registry Acute Coronary Treatment and Intervention Outcomes Network registry demonstrated low use of prehospital ECG, with only approximately one quarter of eligible patients receiving one. Among those who did, however, there was an increased use of reperfusion therapy and faster reperfusion times for both fibrinolytics and primary PCI. Similarly, an analysis of the National Registry of Myocardial Infarction-4 also demonstrated low use of prehospital ECG (4.5%) but a significant improvement in door-to-needle and door-to-balloon times when used. Use of prehospital ECG has even demonstrated reductions in door-to-balloon times in rural areas where EMS can use the ECG to activate a helicopter “auto-launch” to

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Figure 1. This map shows the emergency medical services route for the patient in case 1. Emergency medical services arrived at the patient’s home (A) and transported him directly to a primary percutaneous coronary intervention center (C), bypassing a non–percutaneous coronary intervention hospital (B). Map created with the use of www.mapquest.com on November 22, 2010.
intercept patients at a landing point (such as a local emergency department) and transport them to the PCI center.\textsuperscript{15}

**Fibrinolytic Therapy Versus Primary Percutaneous Coronary Intervention**

The overriding goal for STEMI treatment is to restore myocardial perfusion as quickly and safely as possible. A goal is to have as many patients as possible reach a catheterization laboratory for primary PCI within 90 minutes and to recognize those in whom this is not feasible. Depending on risk of fibrinolysis, size of myocardial infarction, and time from symptom onset, fibrinolytic therapy should be considered for patients with an additional delay of >60 minutes to primary PCI compared with when fibrinolytic therapy could be given. Because of the heterogeneity of EMS and hospital systems, there is no single algorithm that can be applied to all systems. However, a single and simple reperfusion plan for each hospital is desirable. In general, timely primary PCI is favored over fibrinolytic therapy, especially in those who are higher-risk patients, have cardiogenic shock, or present late after the onset of symptoms.\textsuperscript{6} When a patient initially presents to a facility with 24-hour PCI capabilities, the decision to proceed to PCI immediately is straightforward. However, when patients present to non-PCI centers, a decision must be made quickly about administering fibrinolytics versus transfer for PCI, with understanding of the system goals of door-to-needle time within 30 minutes and first door-to-balloon time within 90 minutes.

In general, if the time difference between when fibrinolytic therapy can be given and when PCI can be performed is >1 hour, fibrinolytics should be favored. In many rural and outlying communities, fibrinolytics are standard of care because of the distance from a primary PCI center. The focus in these centers should be on initiating this therapy as quickly as possible. The 2009 ACC/AHA Focused Update of the STEMI guidelines gave a new class IIa, level of evidence B recommendation (and the European guidelines a class I, level of evidence A) to transfer high-risk patients who receive fibrinolytic therapy at a non-PCI center to a PCI center as soon as

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**Figure 2.** Goals for early reperfusion therapy. Patients are encouraged to call 911 no later than 5 minutes after the onset of symptoms. Emergency medical services (EMS) is encouraged to perform a prehospital 12-lead ECG and, in some instances, administer prehospital fibrinolytics. Patients should be preferentially transported to a percutaneous coronary intervention (PCI)–capable hospital when possible, often bypassing a non-PCI hospital, with an EMS-to-balloon time of <90 minutes. If transported to a non-PCI hospital, that facility may administer fibrinolytics with a door-to-needle time of <30 minutes or transfer to a PCI-capable hospital. The goal is a total ischemic time of <120 minutes. STEMI indicates ST-segment elevation myocardial infarction. Image adapted with permission from the following: Elliott M. Antman, MD, FACC, FAHA, Chair; Daniel T. Anbe, MD, FACC, FAHA; Paul Wayne Armstrong, MD, FACC, FAHA; Eric R. Bates, MD, FACC, FAHA; Lee A. Green, MD, MPH; Mary Hand, MSPH, RN, FAHA; Judith S. Hochman, MD, FACC, FAHA; Harlan M. Krumholz, MD, FACC, FAHA; Frederick G. Kushner, MD, FACC, FAHA; Gervasio A. Lamas, MD, FACC; Charles J. Mullany, MB, MS, FACC; Joseph P. Ornato, MD, FACC, FAHA; David L. Pearle, MD, FACC, FAHA; Michael A. Sloan, MD, FACC; Sidney C. Smith, Jr, MD, FACC, FAHA. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction—executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 1999 Guidelines for the Management of Patients With Acute Myocardial Infarction). J Am Coll Cardiol. 2004;44:761–719.
Possible where coronary angiography (and PCI) should be performed 3 to 24 hours after fibrinolytic administration as a pharmacoinvasive strategy.10

In many areas of the country, the closest hospital may not have 24-hour PCI capabilities, but a PCI center can be reached within 90 minutes. Expediting patient transfer to the catheterization laboratory has been one of the goals of regionalized systems of STEMI care. Prehospital detection of STEMI and activation of the catheterization laboratory allow for direct transportation to the PCI center, bypassing the local non-PCI facility. Alternatively, this strategy allows for expedited transfer from the local hospital to the PCI center by activating transfer even before arrival, as has been demonstrated by a helicopter auto-launch program to intercept patients and expedite transfer.15

Out-of-Hospital Cardiac Arrest

Out-of-hospital cardiac arrest occurs in ≈300,000 people in the United States each year, with the outcomes of these patients varying widely across the country. For example, survival with good neurological recovery following out-of-hospital ventricular fibrillation arrest is 40% in Seattle but only 8% in Alabama.16 There are several reasons why this is the case. Many communities lack a standardized and coordinated approach to cardiac arrest care occurring outside of the hospital. Rates of bystander cardiopulmonary resuscitation vary considerably. Among those resuscitated and transported to the hospital with spontaneous return of circulation, in-hospital treatments such as therapeutic hypothermia, primary PCI for STEMI, and eventual implantable cardioverter-defibrillators are often underutilized.17–19 Better survival has been observed in systems with formalized postresuscitation algorithms.20 This has led to a policy statement from the AHA calling for the development of regional systems of care for out-of-hospital cardiac arrest.21

Traditionally, much of the emphasis to improve survival from out-of-hospital cardiac arrest has focused on intra-arrest care such as early activation of 911, bystander cardiopulmonary resuscitation, and early defibrillation.22 It is now understood that postarrest care within the hospital can also substantially improve outcome.23 When appropriate, these measures should include liberal use of therapeutic hypothermia, early coronary angiography when ischemia is implicated as the cause of the arrest, an experienced intensive care unit care, and consideration for an implantable cardioverter-defibrillator before hospital discharge.21

Induction of therapeutic hypothermia (32°C to 34°C) for 12 to 24 hours after resuscitation from a ventricular tachycardia or ventricular fibrillation arrest has been shown to improve survival and neurological recovery in 1 randomized and 1 quasi-randomized (allocation by day of the week) trial.24,25 In the study by Bernard et al,24 there was a significant improvement in survival with hospital discharge to home or a rehabilitation facility in those treated with hypothermia versus those not treated with hypothermia (adjusted odds ratio = 5.25; 95% confidence interval, 1.47 to 18.76; P = 0.011).17 The Hypothermia After Cardiac Arrest Study Group25 reported similar results after administering therapeutic hypothermia over 24 hours. The risk ratio for a favorable neurological outcome in the hypothermia group compared with the normothermia group was 1.40 (95% confidence interval, 1.08 to 1.81). A similar trend was noted in a study of hypothermia applied to patients with cardiac arrest due to asystole or pulseless electric activity.26 Despite these data, the availability of therapeutic cooling is not uniform and remains underutilized in many regions of the country.

A substantial proportion of out-of-hospital cardiac arrests are due to acute myocardial ischemia.27 Although the presence of ST-segment elevation on an ECG after resuscitation is strongly correlated with occlusive coronary disease, its absence does not accurately predict a lack of an acute coronary occlusion on angiography. This critical observation is the basis for ongoing research into whether routine immediate coronary angiography might improve outcomes. Primary PCI for patients with STEMI after an arrest, when combined with therapeutic hypothermia, has demonstrated good outcomes.20,21

Case Resolution

Case 1

The patient arrived directly at the catheterization laboratory, where angiography revealed a right coronary artery occluded at the ostium. It was successfully opened with 3 bare metal stents with a door-to-balloon time of 46 minutes and a first ECG-to-balloon time of 91 minutes. An intra-aortic balloon pump was placed for hemodynamic support for cardiogenic shock, and therapeutic hypothermia was initiated. Left ventricular ejection fraction was initially estimated at 35%, and echocardiography showed right ventricular dilation and hypocontractility. With standard acute myocardial infarction and heart failure therapies, the patient made a complete recovery with normal neurological function and was discharged home on day 8. After cardiac rehabilitation, the patient reported feeling “better than in years.” At his 6-month follow-up visit, his ejection fraction had returned to normal, and > 1 year after the event, he continues to do well.

Case 2

On arrival at the catheterization laboratory, an intra-aortic balloon pump was placed, and PCI was performed on a 90% left anterior descending artery lesion with Thrombolysis in Myocardial Infarction grade 1 flow. Despite this, the patient remained in persistent cardiogenic shock requiring inotropic and balloon pump support. Shortly thereafter, his hemoglobin dropped to 4.8 g/dL, and an upper gastrointestinal bleed was diagnosed. He ultimately...
developed heparin-induced thrombocytoppenia and multiorgan failure and died 6 days after admission.

Conclusion
In the first case, there was expedient recognition of the diagnosis and rapid and coordinated care, including rapid reperfusion and cardiac arrest interventions that resulted in an excellent outcome. In the second case, late presentation without use of EMS, use of fibrinolytics despite relative contraindications, and delays in transfer may all have contributed to the poor outcome. The cases presented here illustrate examples of achievements in improved STEMI care through regionalized systems and also highlight ongoing challenges and improvements that still need to be made.

STEMI and out-of-hospital cardiac arrest remain among the leading killers in the United States. Despite advances in therapies for both conditions, there is widespread underuse (and suboptimal use) of these therapies. Professional organizations like the AHA and the ACC have issued statements calling for the development of regionalized systems of care to enhance the delivery of life-saving therapies in a timely fashion. To achieve this, substantial coordination must occur among EMS personnel, emergency physicians, nurses, cardiologists, and hospital administrators who work toward a common goal of promoting the health of the patient. Significant improvements have been made in regions of the country where STEMI and cardiac arrest protocols and systems have been implemented, but much work remains to be done.

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