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The Diagnosis And Treatment Of STEMI In The Emergency Department

A 66-year-old man is wheeled into a community hospital's emergency department by EMS on a Saturday morning. He appears anxious, with beads of sweat on his forehead and pale skin. The paramedics indicate that the patient called 9-1-1 and reported chest pain that lasted for 30 minutes. They arrived on the scene 12 minutes after the call to find him doubled over. He described his discomfort as a "worse version of the pains that I've been having over the past few weeks," adding "I'm scared that I might be having a heart attack." The patient was given 325 mg of aspirin to chew at the scene and 2 sublingual nitroglycerin tablets that have not had any effect on his symptoms. Upon arrival, he is 55 minutes into this episode of chest pain. You have IV access, are providing him with supplemental oxygen, and have connected him to a cardiac monitor. The only lead shown is V2, and you see what look like depressions of the ST segment. You request a 12-lead ECG, and a clinical assistant begins to connect the leads. The nurse draws up basic labs, troponin I and CK-MB, and asks, "What would you like to do, doctor?" just as the 12-lead ECG prints out, showing 1.0- to 1.5-mm ST-segment elevations in leads II, III, and aVF. You are asking yourself the same question...

Acute myocardial infarction (MI) is the leading cause of death in the United States[1] and in much of the developed world. It is also a rising threat in developing countries.[2] Rapid diagnosis and treatment of MI is one of the hallmark specializations of emergency medicine (EM) because (1) emergency departments (EDs) are a common health care entry point for patients experiencing MI-associated

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CME Objectives

Upon completion of this article, you should be able to:
1. Manage STEMI in the ED setting using evidence-based practices.
2. Use a methodological approach to patients with chest pain who are at high risk of infarction.

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symptoms, (2) MI is a life-threatening condition, and (3) the emergency medical system has developed tools to manage it effectively. A patient whose MI is missed on evaluation has a 25% likelihood of a very poor outcome,[3] which makes this a "can't miss" diagnosis for the EM clinician. It is worth noting that missed MI has long been the most common justification for monetary awards in EM litigation.[3]

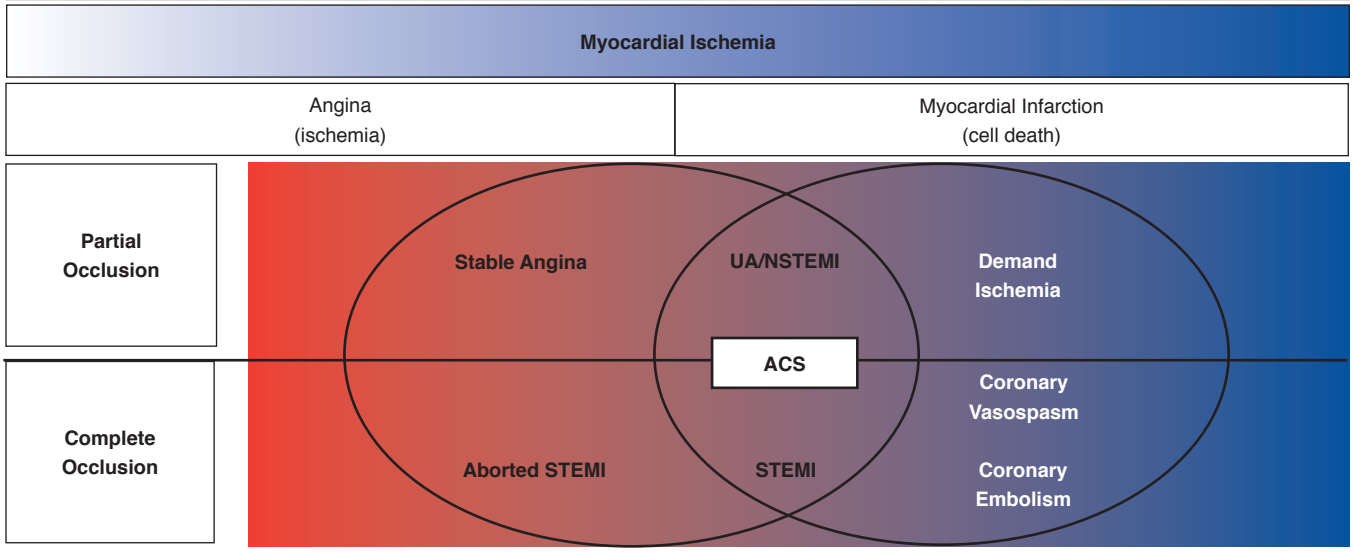
Acute coronary syndrome (ACS) is one of many causes of MI and describes cardiac ischemia that results when a blood clot, or thrombus, acutely narrows an artery supplying myocardial cells with blood. Specifically, ACS is ischemia due to atherosclerotic plaque rupture. Blood clotting factors interact with the plaque's contents and trigger the formation of a superimposed blood clot that narrows or, in the case of an ST-segment elevation myocardial infarction (STEMI), fully occludes the blood vessel lumen. ACS includes unstable angina and non-ST segment elevation myocardial infarction (UA/NSTEMI) as a combined phenomenon, as well as STEMI, but it is differentiated from other forms of cardiac ischemia such as demand ischemia or coronary vasospasm.

In UA/NSTEMI, a clot narrows the lumen enough to limit blood flow and cause myocardial ischemia. This ischemia often leads to chest pain or chest pain-equivalent symptoms (**see the History section**) of a different pattern from the patient's baseline experience. This can be chest pain of a different quality or frequency for a patient with a history of angina or new chest pain in a patient who has never experienced these symptom before. ECG changes may or may not be seen with ischemia alone. Ischemia may lead to infarction that involves the myocardial tissue but falls short of affecting the full thickness of the myocardial wall as is the case with STEMI. The infarction is evidenced by eventual elevation of cardiac enzymes (troponin and/or creatine kinase isoenzyme MB [CK-MB]) and ECG changes including ST-segment depressions, inverted T waves, or (the most common finding) non-specific ST-segment changes. (**See Figure 1.**)

In contrast, a STEMI typically occurs when this same process leads to complete occlusion of a coronary artery with transmural, or full thickness, myocardial wall infarction. (**See Figure 1.**) The ECG will show ST-segment elevations in the area of the heart fed by the affected blood vessel. Any ST-segment elevation is suggestive of a STEMI. However, ECG changes must meet STEMI criteria (**see the Emergency Department Evaluation section**) in order for this diagnosis to be made. [4-6]

In all cases of cardiac ischemia, treatment objectives are to increase the delivery of blood to myocytes beyond the obstructive lesion and to limit the myocytes' demand for oxygen-carrying and metabolite-removing blood. What differentiates STEMI therapy from treatment of other cardiac ischemic

Figure 1. Characteristics Of Myocardial Ischemia



Stable Angina	UA/NSTEMI	STEMI	Other MI
Chest pain[a] (-) ECG changes (-) Cardiac enzymes	Chest pain[a] Nonspecific ECG changes (+/-) Cardiac enzymes	Chest pain[a] ECG ST elevations[b] (+/-) Cardiac enzymes	(+/-) Chest pain (+/-) ECG changes (+) Cardiac enzymes

Abbreviations: ACS, acute coronary syndromes; ECG, electrocardiogram; MI, myocardial infarction; STEMI, ST-segment elevation myocardial infarction; UA/NSTEMI, unstable angina and non–ST-segment elevation myocardial infarction; [a] It is possible to have angina or myocardial infarction without chest pain. (See Common Pitfalls and Medico-Legal section.); [b] ST elevations must meet STEMI criteria in order to be diagnostic. (See Diagnosis section.)

Note: To view full color versions of the figures in this article, visit www.ebmedicine.net/topics.

conditions is the primary focus on immediate reperfusion with percutaneous coronary intervention (PCI) performed in a cardiac catheterization laboratory or with fibrinolytic agents given intravenously.[7]

Critical Appraisal Of The Literature

Ovid MEDLINE, the Cochrane Database of Systematic Reviews, and the National Guideline Clearinghouse were searched for articles relating to STEMI, with a focus on publications and consensus statements published after January 1, 2000. The references were then searched for related articles. Secondary references that were used by committees to develop consensus statements and guidelines were also reviewed. After the primary draft of this article was completed, focused follow-up literature reviews were conducted in August 2008 and March 2009 to identify articles published after the December 2007 release of the American College of Cardiology (ACC) and American Heart Association (AHA) Focused Update for the Management of Patients with STEMI.[8]

Cardiac Anatomy And MI Pathophysiology

As noted above, STEMI occurs when a thrombus forms in a coronary artery, completely occluding the vessel and preventing blood from flowing effectively to distal tissues. Under normal conditions, the depolarizing signal sent through the heart "zeros out" at the ST segment, which corresponds with the time between ventricular depolarization (the QRS complex) and ventricular repolarization (the T wave). As tissue dies, or infarcts, potassium leaks out of the cells, altering the charge over this portion of the heart. In the setting of ischemia, one may find a range of abnormalities including T-wave inversions and alterations of ST-segment levels and morphology. The change that is most specific to STEMI is an elevation of the ST segment on ECG results. This is due to transmural tissue infarction, which causes significant potassium leakage. The excess potassium creates a positive local tissue charge, reflected by the elevation of the ST segment.[9-11]

Blockage of particular coronary arteries leads to predictable regions of infarction. The pacer (or Purkinje) cells that run within these locations may also be involved. Death of Purkinje cells can create predictable rhythm disturbances.[12]

Identification of the anatomic distribution of ischemia and/or infarction is not an essential step in the diagnosis of a STEMI. It is important, however, to recognize that specific areas of infarction increase the likelihood of certain complications and that this information should be factored into treatment and monitoring decisions.[14]

Table 1 shows ECG changes and the associated major coronary artery branches, with the likely anatomical areas of damage and potential complications of each. Matching ECG changes with the anatomy is helpful in mapping out the distribution of involved tissue by the presence of strain patterns (T-wave inversions, ST depressions) or infarction (ST-segment elevations with or without contiguous depressions). Caution should be taken when applying this concept in patients with severe coronary heart disease who are likely to have significant collateral circulatory flow. Rarely, congenital anatomical variations can also make it difficult to infer the distribution of damage and likely consequences.

Out-Of-Hospital Care

In the prehospital system, the management of patients with a suspected STEMI is driven by three goals: (1) delivering patients to an appropriate health care facility as quickly as possible, (2) preventing sudden death and controlling arrhythmias by using acute cardiac life support (ACLS) protocol when necessary, and (3) initiating or continuing management of patients during interfacility transport. Patients who arrive via an emergency medical services (EMS) transport vehicle often have already received some level of care. Basic life support ambulance crews are likely to have administered aspirin and oxygen, used an automated external defibrillator in the event of cardiac arrest, and obtained a basic history from the scene. Advance life support ambulances are additionally capable of providing nitroglycerin and ACLS protocol medications if necessary. Critical care transport vehicles have trained paramedics and nurses who are capable of providing intensive care–level management en route. In some EMS systems, 12-lead ECGs can be produced en route and the results sent to the receiving facility for evaluation before arrival. In regions where transport times are long, EMS teams may be trained and equipped to provide fibrinolytic therapy to STEMI patients before arrival without apparent contraindications. In areas with tertiary care centers within a reasonable distance, EMS teams may bypass small hospitals and deliver patients to facilities with PCI capability. (**See Controversies and Cutting Edge section.**) In addition, patients may be transported to or from a facility after fibrinolytic therapy for further management or when reperfusion is unsuccessful.

In all cases, direct sign-out from the EMS team to the treating emergency clinician is an important time-saving practice. A helpful checklist to get from the EMS team includes the following information.

1. The person who initiated EMS involvement (patient, family, bystander, transferring hospital) and why
2. Complaints at the scene
3. Initial vital signs and physical examination results, as well as notable changes

4. Therapies given prior to arrival and the patient's response
5. ECGs done at an outside hospital or en route, noting the context in which notable ECGs were printed
6. The patient's code status (if known)
7. Family contacts for supplemental information and family members who may be on their way to the ED, as they may be helpful in completing or verifying the history

Emergency Department Evaluation

Diagnosis

All patients with chest pain suggestive of ACS should have an ECG completed within 10 minutes of arrival at the ED and an early evaluation by an emergency clinician. Unlike most medical conditions, STEMI can be diagnosed with a single test before a patient's evaluation is complete.[18] Criteria for the diagnosis of STEMI have been proposed by the ACC/AHA and are in agreement with those of the European Society of Cardiology (ESC). The ACC/AHA and the ESC concur that STEMI exists when the ECG of the patient presenting with acute chest pain shows (1) ≥ 1-mm ST-segment elevation in at least 2 anatomically contiguous limb leads (aVL to III, including -aVR), (2) ≥ 1-mm ST-segment elevation in a precordial lead V4 through V6, (3) ≥ 2-mm ST-segment elevation in V1 through V3, or (4) a new left bundle branch block.[19] (**Figures 2 and 3.**) Laboratory tests, such as troponin and CK-MB measurements, are not a component of a STEMI diagnosis. However, they are helpful in the event that a STEMI is not diagnosed and other forms of MI are still suspected. (**See Figure 1, page 2.**) Every effort should be made to begin reperfusion immediately when ECG changes that are diagnostic for a STEMI are present.[20,21]

History

The patient's history should be taken while the ECG is being performed and initial therapies are being administered. Remember that time is myocardium. Ask the patient if he or she is having chest pain, when it started, what it feels like (stabbing, crushing, pressure, aching), and if it radiates to other parts of the body. Chest pain is the cardinal symptom of MI, but it is not always present, so be sure to ask about jaw/shoulder/neck/arm pain, dizziness, nausea, and shortness of breath. It is also important to elicit whether or not the patient has felt anything like this before, how it was similar or different, if he or she did anything that made it better or worse, or if he or she took anything at home to help with the discomfort. Information about past medical problems, past surgical procedures (when performed), medications taken (if the patient remembers), and any allergies is also helpful.

Historically, clinicians have been taught to review with these patients the major risk factors for cardiovascular disease: hypertension, known coronary artery disease, diabetes, hyperlipidemia, smoking, male sex, and an MI or early cardiac death in a first-degree family member before age 45 in men and 55 in women. Although colleagues in cardiol-

Table 1. Infarction Distribution With ST-Segment Elevation Myocardial Infarction And Consequences[4,15-17]

ST Elevations	Affected Coronary Artery	Area of Damage	Complications
V_1 through V_4	Left coronary artery: Left anterior descending	Anterolateral heart wall Septum Left ventricle His bundle Bundle branches	Left ventricular dysfunction: Decreased carbon dioxide, congestive heart failure Left bundle-branch block Right bundle-branch block Left posterior fascicular block Infranodal block (2˚or 3˚)
V_5 through V_6, I, aVL	Left coronary artery: Left circumflex branch	Left lateral heart wall	Left ventricular dysfunction: Decreased carbon dioxide, congestive heart failure Infranodal block (2˚or 3˚)
II, III, aVF, V_4R	Right coronary artery: Posterior descending branch	Inferior heart wall Right ventricle	Hypotension (particularly with nitroglycerin and morphine, which can decrease preload) Supranodal 1˚ heart block Atrial fibrillation/flutter, premature atrial contractions Infranodal block (2˚and 3˚) Papillary muscle rupture (murmur)
V_8 and V_9 (or ST depressions in V_1 and V_2)	90% Right coronary artery: Posterior descending branch 10% Left coronary artery: Left circumflex branch (will see elevations in V_5 through V_6)	Posterior heart wall	Hypotension Supranodal 1˚ heart block Infranodal block (2˚and 3˚) Atrial fibrillation/flutter, premature atrial contractions Papillary muscle rupture (murmur)

ogy and internal medicine may be interested in these details, they do not affect management in the ED. Active chest pain syndrome or a diagnostic ECG trump all other risk factors in a workup for MI. Time is best spent administering initial therapies and/or mobilizing resources for reperfusion.[25]

If the patient's ECG shows a STEMI, immediately ask about contraindications to fibrinolytic therapy, as this information will aid decisions about the appropriate reperfusion therapy. (**See Table 2.**)

Physical Examination

Aside from the vital signs, which are a critical dashboard in managing a STEMI or other ACS, a physical examination has limited usefulness in the diagnosis and initial treatment plan for patients with a STEMI. However, a focused physical examination can be helpful in identifying causes or complications of MI. If an ECG is diagnostic for a STEMI, the examination should be brief to evaluate for the signs listed in Table 3 (**page 8**) while the focus remains on initiating immediate reperfusion.

If the ECG is not diagnostic for a STEMI or other ACS condition, the examination can be more extensive. The information gathered can help emergency clinicians to sort through and prioritize items on the differential diagnosis.[25] However, it is important to note that even with the most careful evaluation, 1% to 5% of patients with an MI will have completely normal ECG results upon presentation.[26] In these cases, cardiac biomarker laboratory testing is helpful in identifying whether other forms of MI have occurred.

Figure 2. STEMI Diagnostic Criteria[19,22,23]

American College of Cardiology/ American Heart Association ST-Segment Elevation Myocardial Infarction (STEMI) Diagnosis Guidelines

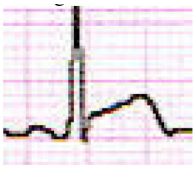
In a patient presenting with active chest pain, a 12-lead electrocardiogram showing:

1. ST-segment elevation ≥ 1 mm (0.1 mV) in 2 or more adjacent limb leads (from aVL to III, including -aVR),
2. ST-segment elevation ≥ 1 mm (0.1 mV) in precordial leads V4 through V6,
3. ST-segment elevation ≥ 2 mm (0.2 mV) in precordial leads V1 through V3, or
4. New left bundle-branch block¥

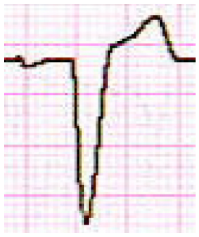
* Positive tests for cardiac enzymes troponin and creatinine kinase isoenzyme MB are helpful, but not essential. Therapy should not be delayed while awaiting results.

* Reciprocal depressions (ST depressions in the leads corresponding to the opposite side of the heart) make the diagnosis of STEMI more specific.

ST-Segment Elevation



Left Bundle-Branch Block



¥ ***See the Special Circumstances section*** *for details on diagnosing STEMI in the setting of an old left bundle-branch block.*

(ECG images from Brady W, Harrigan RA, Chan T. Section III: acute coronary syndromes. In: Marx A, ed-in-chief. Hickberger RS, Walls RM, senior eds. Rosen's Emergency Medicine Concepts and Clinical Practice. Part 3. 6th ed. St Louis, MO; CV Mosby; 2006:1165-1169.)

Differential Diagnosis

For patients presenting with acute chest pain, consider the following diagnoses:

- Aortic Dissection (AoD)
- Pneumothorax
- Pulmonary embolism
- Arrhythmia
- Myocarditis
- Pericarditis with or without cardiac tamponade
- Esophageal rupture or spasm
- Hypertensive urgency or emergency
- Gastroesophageal reflux disease
- Intercostal muscle strain
- Costochondritis

The predictive value of an ST-segment elevation on ECG is highly dependent on the incidence of the disease in the population into which the patient fits. For example, ST-segment elevations in a young person are less likely to be associated with MI because there is a lower incidence of MIs in younger populations. This fact, in and of itself, reduces the positive predictive value of the ECG as a diagnostic tool in this situation. For all patients, but particularly in the young, other causes of ST-segment elevation should be carefully investigated in the clinical context. (**See Table 4, page 8.**)

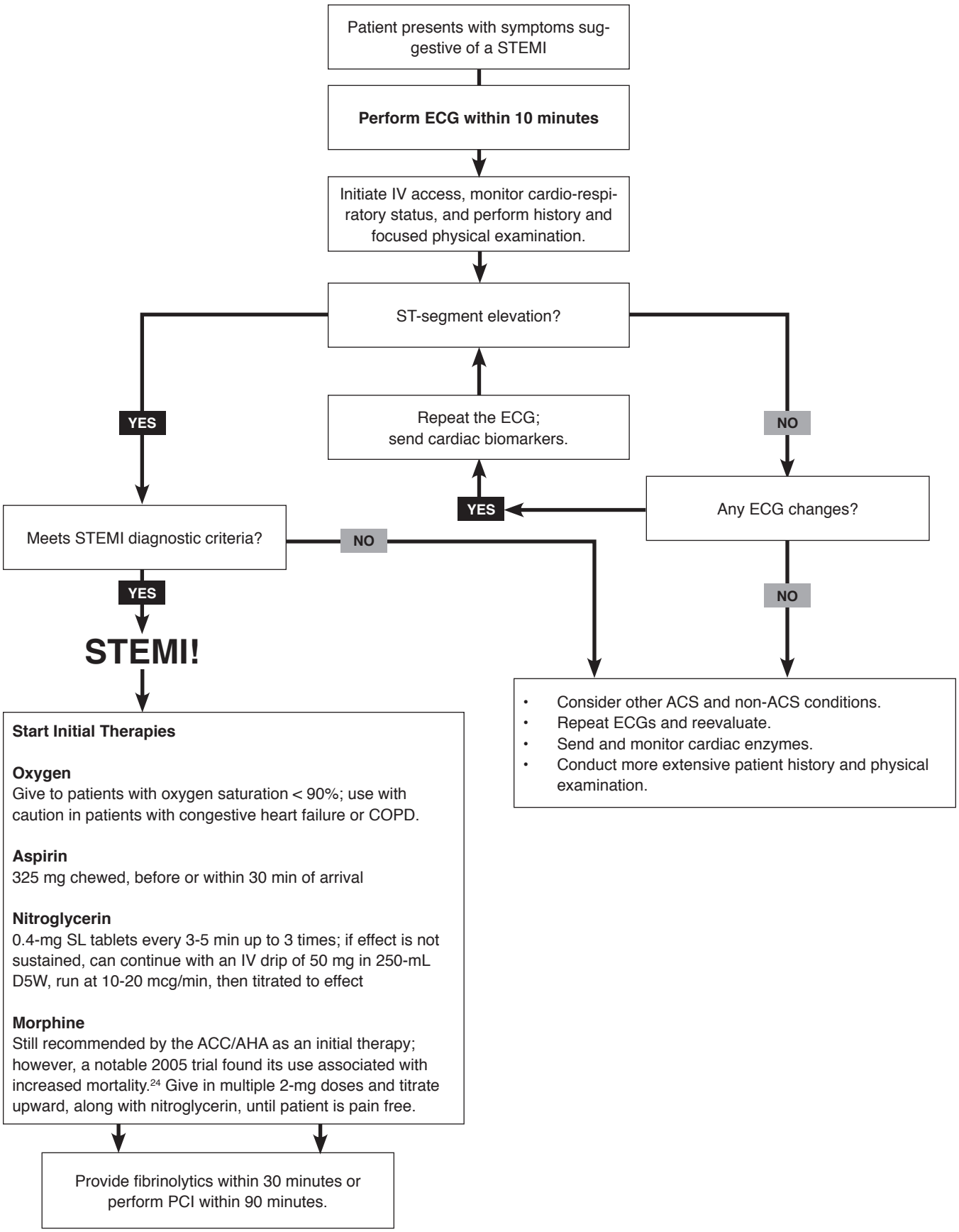
Initial Therapies

Much of what is considered standard of care for STEMI is based on the ACC/AHA guidelines, which are developed from a combination of the available evidence and consensus opinion amongst the guideline-writing group. In addition, the evidence for many common and emerging practices are controversial or under studied. For this reason, it is worth exploring these "initial therapies" in some detail.

Oxygen

Supplemental oxygen is given because of the theoretical benefit of maximizing oxygen delivery

Figure 3. Pathway For Diagnosis Of ST-Segment Elevation Myocardial Infarction



ACC/AHA, American College of Cardiology/American Heart Association; ACS, acute coronary syndromes; ECG, electrocardiogram; IV, intravenous; O_2, oxygen; PCI, percutaneous coronary intervention; SL, sublingual; STEMI, ST-segment elevation myocardial infarction.

in a patient with an ischemic condition. This was first recommended for myocardial infarction over 100 years ago.[117] However, there have been several studies dating back to the 1950s demonstrating concerning harmful effects.[118-120] Specifically, they have shown that when supplemental oxygen is given to non-hypoxic patients, it produces increased systemic vascular resistance and decreases cardiac output. In hypoxic patients, the data have varied between no effect to improvement.[121]

Our current practice is based on the first randomized controlled clinical trial done on the effects of oxygen therapy for MI patients.[122] It showed a reduction in MI-associated enzyme elevation, but these results did not achieve statistical significance (p=0.08). Given the small numbers involved in this study (n=151), it may have been underpowered to detect an actual clinical and/or statistical effect (type II error), but the results are not sufficient enough to support the routine administration of oxygen to all MI patients. In line with this evidence, the ACC/AHA's STEMI guidelines[62] only recommend supplemental oxygen for hypoxic patients. It is worth noting that all but one[123] of these studies were done before the advent of the pharmacologic agents, fibrinolytics, or PCI. In conclusion, the evidence is thin, and this highlights the need to re-consider the risks and benefits of oxygen therapy in both hypoxic and non-hypoxic patients, in the context of modern medical management of STEMI.[124]

Aspirin

Chewing an aspirin soon after the onset of symptoms has been shown to reduce mortality by 23%, as measured at 1 month after MI.[30] Aspirin is rapidly and maximally absorbed when chewed, and it takes effect in 60 minutes.[31] However, the benefits diminish greatly when aspirin is taken 4 hours after the onset of symptoms.[30] Over the years, dose recommendations have varied from 162 to 325 mg. Many studies have shown that the added bleeding risk associated with more than 162 mg of aspirin is minimal compared with the likely benefit, but a 2008 retrospective comparative study challenged this in the case of STEMI patients treated with fibrinolysis.[32] The authors concluded that the benefit of larger doses was outweighed by the proportionally increased bleeding risk in this subpopulation. If a patient is vomiting, aspirin can be given rectally with similar effect. A recent small study suggests that a 600-mg rectal suppository provides a sufficient level of salicylic acid within 90 minutes that meets or exceeds the level provided by standard doses of chewed oral aspirin.[33] If a patient has an aspirin allergy or significant active bleeding, a 300- or 600-mg bolus of clopidogrel can be given.[34] (**See the Special Circumstances section for more details.**)

Nitroglycerin

The vasodilatory effects of nitroglycerin increase blood flow to coronary arteries and help to alleviate spasmodic and ischemic pain.[35] In the pre-reperfusion era, early use was shown to limit infarct size and preserve ventricular function.[36] Nitroglycerin continues to be recommended for patients with a STEMI and active chest pain. However, the poten-

Table 2. Fibrinolytic Reperfusion Contraindications

A. Absolute Contraindications

- Known structural central nervous system lesion (eg, arteriovenous malformation, primary or metastatic tumor)
- Any prior intracerebral hemorrhage
- Ischemic stroke within the last 3 months (excluding acute ischemic stroke within the last 3 hours)
- Significant closed head or facial injury within the last 3 months
- Suspicion of aortic dissection
- Active bleeding (excluding menses) or bleeding disorders

B. Relative Contraindications

- History of chronic, severe, and poorly controlled hypertension or severe hypertension (systolic blood pressure > 180 mm Hg or diastolic blood pressure > 100 mm Hg) on admission
- History of ischemic stroke within the prior 3 months
- Dementia or other known intracranial pathology not noted above
- Traumatic or prolonged (> 10 minutes) cardiopulmonary resuscitation or noncompressible vascular punctures within the last 3 weeks
- Major surgery within the last 3 weeks
- Internal bleeding within the last 3 to 4 weeks
- Pregnancy
- Active peptic ulcer disease
- Current use of anticoagulants (the higher the international normalized ratio, the greater the risk of bleeding)
- Prior exposure (> 5 days) or prior allergic reaction to streptokinase or anistreplase (if taking these agents)

(Adapted from 2007 ACC/AHA STEMI Treatment Guidelines.)

tial benefits have to be balanced with the risks of hypotension and reflex tachycardia.

Morphine

Morphine blocks pain receptors and provides some anxiolysis, which is believed to reduce sympathetic tone and decrease myocardial metabolic demand. Its use has been a mainstay in the initial management of acute MI for decades. However, CRUSADE Initiative data, published as a 2005 case control study involving more than 17,000 patients, raised concerns that the use of morphine in patients with MI was associated with higher mortality. This excess mortality is believed to be attributed to morphine masking the symptoms of continued ischemia.[37] Despite the study's findings, morphine is still recommended as an initial therapy for STEMI by the ACC/AHA and the ESC, albeit with caution that the evidence for its use is less robust.[8]

Beta-Blockers

Beta-blockers reduce myocardial metabolic demand by decreasing heart rate and, to a lesser degree, myocardial contractility. Evidence supporting the use of beta-blockers in patients with acute MI arose from research demonstrating reduced rates of reinfarction and recurrent ischemia in those who received reperfusion therapy (fibrinolysis or PCI).[38,39] More recent evidence has shown that giving beta-blockers to all STEMI patients may lead to increased incidence of cardiogenic shock, which may outweigh the benefits.[40] In addition, a retrospective analysis of some older trial data failed to reproduce the previously reported benefits.[41]

The ACC/AHA currently recommends that an oral beta-blocker be given within 24 hours and that an IV beta-blocker is reasonable for patients who are hypertensive in the absence of (1) signs of heart failure; (2) evidence of a low cardiac output state; (3) post beta-blocker cardiogenic shock risk factors (age > 70 years, systolic blood pressure < 120 mm Hg, sinus tachycardia > 110 bpm or heart rate < 60 bpm, increased time since onset of symptoms of STEMI); or (4) other relative contraindications to beta blockade (PR interval > 0.24 s, second- or third-degree heart block, active asthma, or reactive airway disease). These recommendations are based on the results of COMMIT/CCS-2, a large randomized controlled trial that involved more than 45,000 patients.[8, 40] Oral beta-blockers do not need to be started in the ED, and the more selective use of IV beta-blockers is a change from prior recommendations and common practice, which categorize their use as an initial therapy for patients with acute MI.

Once a diagnosis of STEMI is made, these initial therapies should not delay the primary goal: to initiate definitive treatment with either fibrinolytic therapy within 30 minutes or PCI within 90 minutes. If the ECG does not meet the STEMI diagnostic criteria and the patient has ongoing ischemic symptoms, the test should be repeated at reasonable intervals along with continuous cardiac monitoring. These patients may develop a STEMI later in the symptom course.[9]

Definitive Treatment

Once a STEMI is diagnosed, the next immediate decision is whether to rapidly reperfuse the infarcting

Table 3. Signs To Look For During Physical Examination Of A Patient With Chest Pain

Sign	Concern
New murmur?	Papillary muscle rupture or acute valvular insufficiency
Jugular venous pulsation elevation?	Right-sided heart failure
Slowed capillary refill? Weak pulse?	Cardiogenic shock
Crackles or wheezes? Decreased breath sounds?	Congestive heart failure
Hemiparesis? Pulse differential between upper vs lower extremities or left vs right extremities?	Aortic dissection

Table 4. Alternative Causes of ST-Segment Elevations

Alternative Diagnosis	Clinical Context
Pericarditis/myocarditis	Fevers, recent radiation therapy
Benign early repolarization	Young, male
Left ventricular hypertrophy	Hypertension
Paced rhythm[27]	Pacemaker implanted
Significant hyperkalemia[28]	Renal failure
Coronary vasospasm	Cocaine or other stimulant use
Ventricular aneurysm	Prior infarction (usually associated with Q waves)
Spontaneous coronary artery dissection	Marfan or Ehlers-Danlos syndrome
Acute, severe emotional stressor	Takasubo cardiomyopathy

myocardium with fibrinolytic medications or with PCI via balloon angioplasty.

Fibrinolysis

Fibrinolytics are now widely available and easily accessible in most hospitals. The greatest benefit is derived when they are given within 1 to 3 hours after the onset of symptoms. Successful reperfusion rates range from 60% to 80%, but the chance of reperfusion success diminishes with time, even within this window.

The primary complications of fibrinolytics relate to excessive bleeding. Depending on where the bleeding occurs, it can also cause life-threatening problems such as large gastrointestinal tract bleeds, hemorrhagic stroke, and surgical wound dehiscence. As a result, a formal list of contraindications associated with an increased risk of hemorrhage has been compiled.[4] (**See Table 2, page 7.**) A patient with a yes response to any of the absolute contraindications in **Table 2A** is not a candidate for fibrinolysis. A yes response to any of the questions in **Table 2B** does not prohibit a patient from receiving fibrinolytic therapy, but it should raise significant caution in the mind of the deciding emergency clinician and weigh in favor of an alternative reperfusion plan.

The ACC/AHA guidelines recommend the initiation of fibrinolytic therapy within 30 minutes of a STEMI patient's contact with the medical system.[8] Reperfusion outcomes with this therapy, at 30 days post-intervention, are comparable to those with PCI when a patient has symptoms that are of short duration or when there is a low risk of bleeding or when achieving a door-to-balloon time of less than 90 minutes is not possible.[42] (**See Table 6, page 11.**) Most institutions have limited fibrinolytic options on their drug formulary. Emergency clinicians should know what options are available in advance and should be familiar with their specific characteristics and side effect profiles. (**See Table 5, page 10.**)

As noted earlier, once a fibrinolytic is administered, the complication of greatest concern is bleeding. The highest risk of bleeding occurs within the first 24 hours. Intracranial hemorrhage (ICH) is the most devastating complication. It occurs in less than 1% of patients[43] but carries a 55% to 65% mortality rate.[44] As a result, a computed tomographic (CT) scan of the head should be ordered for any post-fibrinolytic neurologic findings to rule out ICH. Also, all anticoagulants, antithrombotics, and antiplatelet agents should be held until ICH is ruled out.

Percutaneous Coronary Intervention

When available, prompt primary PCI in a cardiac catheterization laboratory is the preferred reperfusion option. If a facility has PCI capability, the STEMI should be reported as soon as the diagnosis is made, with a request to activate the catheterization laboratory emergently. (**See the Controversies and Cutting Edge section for more on this topic.**) When a facility lacks PCI capability, it may be feasible to coordinate a transfer (ambulance or helicopter transport) to another facility. In the process of identifying an accepting clinician for the transfer, a request should be made to activate the catheterization laboratory before the patient arrives. The goal is to have the patient achieve a door-to-balloon time of less than 90 minutes. The ability to achieve this goal should be incorporated into the decision of whether to use a fibrinolytic or a PCI.[50]

Fibrinolytics Versus PCI

The choice between fibrinolysis and PCI depends on the patient, the place, and the timing. Research on the relative effectiveness of fibrinolysis vs PCI has shown that the two modalities have comparable outcomes when PCI is not available within 1 to 2 hours and when contraindications to fibrinolysis are taken into consideration. Multiple clinical trials have shown that PCI, when available, has a higher rate of reperfusion and better short- and long-term outcomes than fibrinolysis.[50-53] A more recent study has shown that despite the ACC/AHA-endorsed time-to goal of 90 minutes, PCI may maintain superior outcomes for up to 150 minutes[49] For each patient, the decision should also take into account the duration of symptoms, the availability of the catheterization laboratory, the patient's mortality risk, any concerns that the STEMI might be of non-ACS origin, and the contraindications to fibrinolysis. (**See Table 6, page 11.**)

PCI And Fibrinolysis In Combination

One might think that following up the use of fibrinolytics with PCI would be a thoughtful choice for all STEMI patients. However, multiple randomized prospective trials have been unable to show a benefit of this approach.[54-56] Nevertheless, in *select* patients it is reasonable to consider PCI after fibrinolysis, in the form of facilitated PCI, rescue PCI, or follow-up PCI. The distinction between these therapies is subtle, but important.

Facilitated PCI

Generally speaking, PCI is the preferred method of reperfusion (especially for those who are in cardiogenic shock or are hemodynamically compromised) if it can be performed within 90 minutes of contact with the medical system. However, this "time-to" goal is not always achievable, particularly in facilities without PCI capability. As a result of this dilemma, researchers have sought to determine if administering fibrinolytics to initiate fibrinolysis during transport can *facilitate* reperfusion via PCI prior to arrival in the catheterization laboratory. However, a well-designed prospective multicenter study showed that when full-dose fibrinolytics were

given to all STEMI patients before PCI, the combination resulted in worse outcomes including increases in mortality, incidence of shock, reinfarction, need for urgent revascularization, and congestive heart failure.[57] The search is still on to see if facilitated PCI with less than full-dose fibrinolytics and some combination of antithrombotics will tip the balance toward favorable outcomes.

Given the limited evidence, the ACC/AHA 2007 updated guidelines do not recommend the use of full-dose fibrinolytics for facilitated PCI.[8] On the basis of data from the 2006 ASSENT trial (a randomized, controlled, prospective study involving 1667 patients),[58] the guidelines do advise that facilitated PCI with less than full-dose fibrinolytics can be considered in patients with a high mortality risk when PCI is unavailable within 90 minutes and in those who have a low bleeding risk (young age, controlled hypertension, and normal body weight).[8] A 2009 randomized controlled trial involving 1553 patients suggests that a patient whose door-to-balloon time is greater than 90 minutes but less than or equal to 150 minutes can be safely pretreated with glycoprotein IIb/IIIa complex (GPIIB/IIIa) platelet inhibitor and/or IV fibrinolytic therapy to achieve outcomes similar to those with primary PCI.[59]

Rescue PCI

Because reperfusion is not always achieved in patients who receive fibrinolysis, it is important to follow their response clinically and be prepared with an alternative plan in case of reperfusion failure.[60] Rescue, or salvage, PCI should be considered as a second attempt to achieve reperfusion in patients with (1) less than 50% resolution of ST-segment elevation in the most prominently elevated lead within 90 minutes, (2) persistent hemodynamically unstable arrhythmias, (3) persistent ischemic symptoms, or 4) developing or worsening cardiogenic shock after fibrinolytics. This can be done up to 24 hours after fibrinolysis, but it is not recommended for patients older than 75 years.[8]

Follow-up PCI

Follow-up PCI is done after primary fibrinolysis, when angiography identifies persistently narrowed coronary arteries that would benefit from angioplasty. The decision to perform follow-up PCI is rarely made within the ED. However, it is worth distinguishing this from primary PCI (door-to-balloon time < 90 minutes), facilitated PCI (a half dose of fibrinolysis with a GPIIB/IIIa agent), and rescue PCI (initiation of PCI after failed reperfusion from primary fibrinolysis).[61]

Adjuncts To Therapy

Important adjuncts to the treatment of STEMI include agents that prevent regeneration of coronary thrombi after patency has been established. The

Table 5. Characteristics Of Common Fibrinolytics For ST-Segment Elevation Myocardial Infarction[45-48]

Property	Alteplase (tPA) (Activase®)	Reteplase (Retavase®)	Tenecteplase (TNKase™)
IV Dosage	15-mg bolus, then 0.75 mg/kg over next 30 min (max of 50 mg), followed by 0.5 mg/kg over 60 min (max of 35 mg), for total dose of 100 mg	10-U bolus over 2 min, then another 10-U bolus also over 2 min (30 min later)	Weight-adjusted single bolus over 5 s < 60 kg: 30 mg 60-69 kg:35 mg 70-79 kg:40 mg 80-89 kg:45 mg ≥ 90 kg: 50 mg
Circulating Half-life	6 min	13-16 min	Initial half-life = 20-24 min Terminal half-life = 90-130 min
Route of Clearance	Liver	Liver and kidney	Liver
Antibody Formation	No	No	Yes, but rare (< 1%)
Risk of Intracerebral Hemorrhage	0.6%	0.8%	0.5%-0.7%
Reperfusion Rate by 90 min	79%	80%	80%
Lives saved per 100 persons treated	3.5	3.0	3.5

Abbreviations: IV, intravenous; tPA, tissue plasminogen activator.

2-pronged approach involves preventing thrombin generation and inhibiting platelet function.

Anticoagulants

The ACC/AHA guidelines recommend giving an anticoagulant to all STEMI patients for a minimum of 48 hours.[62] Unfractionated heparin (UFH), the traditional anticoagulant for acute MI, is given as a bolus of 60 U/kg (maximum of 4000 U) with a follow-up infusion of 12 U/kg per hour (maximum of 1000 U/hr) titrated to a targeted partial thromboplastin time (PTT) of 50 to 70 seconds. Enoxaparin (low-molecular-weight heparin [LMWH]) and fondaparinux are acceptable alternatives, with specific dosing regimens based on age and renal function. LMWH has the advantages of achieving a more consistent anticoagulation effect (so monitoring is usually unnecessary), a lower rate of heparin-induced thrombocytopenia (HIT) vs UFH, and convenience of administration. But LMWH is not without risks. Data from ExTRACT-TIMI 25, an international double-blind comparison of enoxaparin vs UFH in 20,506 patients enrolled in 48 countries, indicated that enoxaparin carries a slightly increased risk of bleeding.[8] It is also more difficult to reverse than heparin because it is not an infusion and has a longer half-life.

OASIS-6, an international randomized double-blind study comparing fondaparinux with control therapy (either placebo or UFH) in 12,092 patients enrolled in 41 countries, found that the bleeding risk with fondaparinux was lower than that for all of the other anticoagulants.[65] It is often the first-line anticoagulant in patients with HIT from prior heparin exposure, and administration is simplified with a fixed dose for all patients. The anticoagulant response is more predictable with fondaparinux than with heparin, allowing for less anticoagulation-level monitoring. However, this monitoring is done via anti-Xa levels, which are not performed in many hospital laboratories.[66] In addition, fondaparinux is not approved by the US Food and Drug Administration for this indication, and there is some literature showing an increased incidence of catheter tip thrombus when it is used in patients undergoing PCI.[67] For the dosages, advantages, and disadvantages of each of these agents, **see Table 7**.

Bivalirudin

Bivalirudin (Hirulog®, Angiomax®, Refludan®, hirudin-derived synthetic peptide) is a direct thrombin inhibitor that is available as an alternative to heparin therapy. It reversibly binds to the catalytic and substrate recognition sites on thrombin, which blocks circulating and fibrin-bound thrombin. Much like heparin, its full anticoagulation effect starts within minutes of administration, and once an infusion is stopped, it quickly diminishes with a half-life of 25 minutes.[68] Many studies done during the past 15 years have demonstrated greater reductions in ischemic outcomes with bivalirudin than with heparin, with a reduced risk of bleeding and other complications.[69-71]

The most recent ACC/AHA guidelines were published before the release of these data and offer bivalirudin as an option for use after initial heparin administration, but with class C level of evidence (consensus opinion or case study reports).[8] Results of the HORIZONS trial, a randomized multicenter comparative study of bivalirudin vs heparin with a GPIIB/IIIa agent, published in 2008, supported bivalirudin's lower rate of hemorrhagic complications, but noted an increased rate of in-stent thrombosis.[72] All of the patients were seen by an initial care team who diagnosed the patient's STEMI, started heparin, and requested urgent catheterization. Before catheterization was started, half of the patients had their heparin drip stopped and replaced with a bivalirudin drip/infusion. This study looked at bivalirudin use in the catheterization laboratory in a population who had received heparin prior to arrival. It was not designed to evaluate bivalirudin as an initial

Table 6. Choosing A Reperfusion Option For ST-Segment Elevation Myocardial Infarction

Fibrinolysis Favored	PCI Favored
• Catheterization laboratory not available	• Presentation > 3 hours after symptom onset
• Inability to obtain central vascular access	• Catheterization laboratory available in-house
• Catheterization laboratory available, but without surgical backup	• Patient with high mortality risk
• Inability to meet door-to-balloon time < 90 minutes	• Evidence of cardiogenic shock or significant hemodynamic compromise
• Door-to-balloon – Door-to-needle time > 1 hour	• Existence of significant relative contraindications to fibrinolysis
	• Uncertain STEMI diagnosis (inability to rule out other causes of ST-segment elevation or a left bundle-branch block with no prior electrocardiogram for comparison)

Abbreviations: PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction.

(Adapted from data in Antman EM, Hand M, Armstrong PW, et al. 2007 Focused Update of the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation. 2008;117(2):302-304.)

Table 7. Anticoagulants For ST-Segment Elevation Myocardial Infarction[8,66]

Drug	Dosage	Advantages	Disadvantages	Bleeding Risk
Heparin (UFH)	60-U/kg bolus (max, 4000 U), followed by 12-U/kg per hr infusion (max, 1000 U/hr)	Immediate anticoagulation Affects multiple sites in the coagulation cascade Long history of clinical use Its effect is easy to monitor via PTT Easy to stop anticoagulation by discontinuing the infusion ($t_{1/2}$ = 10 min)	Prevents free thrombin from activating, but does not inhibit clot-bound thrombin Nonspecific binding, so it has a variable anticoagulation effect requiring continued monitoring (PTT 50-70 s) Risk of HIT	Dependent on PTT level
Enoxaparin (LMWH)	Patients < 75 y with serum Cr < 2.5 mg/dL (men) or < 2.0 mg/dL (women): - 30-mg IV bolus, followed by - 1.0-mg/kg SC injection q12h Patients ≥ 75 y:- 0.75-mg/kg SC injection q12h Patients with serum CrCl < 30 mL/min: - 1.0-mg/kg SC injection every day	More effective thrombin inhibitor than with UFH More consistent anticoagulation effect, so it does not need to be monitored Lower risk of HIT than with UFH Long history of clinical use	Prevents free thrombin from activating, but does not inhibit clot-bound thrombin Less reversible than UFH Difficult to monitor Renally cleared Long half-life Risk of HIT	Highest
Fondaparinux	Patients with serum Cr < 3.0 mg/dL: 2.5-mg IV bolus for initial dose, then 2.5-mg SC injection every day, started 24 hr after	SC administration Once daily dosing Most consistent anticoagulation effect, so it does not need to be monitored Fixed dose for all patients No risk of HIT Does not cross the placenta Lower bleeding risk than with UFH or LMWH	Difficult to monitor (few laboratories can run anti-Xa levels) Long half-life Not approved by the US Food and Drug Administration Concerns about increased catheter tip thrombi in PCI patients	Lower
Bivalirudin	0.75-mg/kg IV bolus, followed by 1.75 mg/kg per hr Patients with CrCl < 30 mL/min: 0.75-mg/kg IV bolus, followed by 1.0 mg/kg per hr	Reduced risk of bleeding No risk of HIT Immediate anticoagulation Easy to stop anticoagulation by discontinuing the infusion ($t_{½}$ = 25 min)	Limited experience with its use No studies observing bivalirudin use without another anticoagulant either coadministered or used just beforehand Increased risk of in-stent thrombosis	Lowest

Abbreviations: Cr, creatinine; CrCl, creatinine clearance; HIT, heparin-induced thrombocytopenia; IV, intravenous; LMWH, low-molecular-weight heparin; PCI, percutaneous coronary intervention; PTT, partial thromboplastin time; SC, subcutaneous; $t_{1/2}$, half-life; UFH, unfractionated heparin.

anticoagulant, and prior heparin use in the experimental arm may be a confounding factor. As a result, this study's findings should not change emergency medicine practice. However, it is reasonable to discuss a transition to bivalirudin with the receiving cardiology team.

Antiplatelet Therapy

In addition to aspirin, which has been standard therapy for STEMI for 2 decades,[30,31,73] other antiplatelet agents have been used to further inhibit the formation of coronary thrombi.

GPIIB/IIIa Inhibitors: Abciximab (ReoPro®), Eptifibatide (Integrilin®), Tirofiban (Aggrastat®)

GPIIB/IIIa inhibitors are monoclonal antibodies or small polypeptides that bind to or compete with the platelet's GPIIB/IIIa receptor. This action inhibits cross-links with fibrinogen and further platelet aggregation. For STEMI patients who will be undergoing PCI, it is common practice to give a GPIIB/IIIa inhibitor (abciximab, eptifibatide, tirofiban) before or upon arrival in the catheterization laboratory to reduce the potential for clot formation.[8] However, the actual effect of GPIIB/IIIa inhibitors is not yet clear. Three major studies that examined their use in acute MI have shown improved coronary blood flow in the short term.[76-78] However, these and additional studies[79,80] have not shown long-term benefits and have demonstrated an increased risk of bleeding in patients older than 75 years. The risk vs benefit of using these agents in any particular patient should be discussed with the accepting cardiology team.

Thienopyridines: Clopidogrel (Plavix®)

Thienopyridines bind to the platelet adenosine diphosphate (ADP) $P2Y_{12}$ receptor to irreversibly inhibit activation and aggregation for the life of the platelet. An oral clopidogrel loading dose of 300 mg produces significant inhibition of ADP-induced platelet aggregation within 2 hours, with the maximal effect achieved in 6 to 15 hours, and is recommended in the ACC/AHA guidelines.[81] However, this practice does not provide a sufficient precatheterization antiplatelet effect for patients receiving primary PCI. Although it is not yet supported by clinical studies of STEMI, the pharmacodynamic profile of clopidogrel suggests that the antiplatelet effect begins earlier with larger loading doses (600 mg) than with the 300-mg dose and that this is a reasonable consideration for patients receiving primary PCI.[81-83] In situations where patients have a true aspirin allergy, clopidogrel can be used as a substitute. (**See the Special Circumstances section for more details.**)

However, many physicians hesitate to administer clopidogrel to STEMI patients who are undergoing primary PCI because clopidogrel can cause increased bleeding if coronary artery bypass grafting is needed. Two randomized studies, the COMMIT/CCS-2 and the CLARITY-TIMI 28 trial (involving 45,852 and 3491 patients, respectively), examined the effects of clopidogrel use in STEMI patients and demonstrated that the drug has added value in those who are younger than 75 years and receive fibrinolysis with subsequent PCI or are unable to receive any form of reperfusion therapy.[84,85] As a result, the current ACC/AHA STEMI guidelines support the use of clopidogrel as a reasonable therapy in STEMI patients in these 2 subpopulations, but they do not comment on those undergoing primary PCI.[8] The 2007 ACC/AHA PCI guidelines more broadly support the use of clopidogrel before or during PCI in all STEMI patients despite the lack of studies showing a benefit in patients undergoing primary PCI.[86] With respect to bleeding risks, the need for an "emergent" CABG is a very rare phenomenon, and the increased bleeding risk can be averted by stopping clopidogrel 5 to 7 days before the surgical procedure.[87] As a result, it is not unreasonable to give a loading dose of 600 mg of clopidogrel before a STEMI patient is transported to a catheterization laboratory, as long as the evidence-based limitations of this therapy are understood.

Glucose Control

Clinical trials conducted in the early 1960s showed a significant reduction in mortality with the use of glucose-insulin-potassium (GIK) infusion in STEMI patients. This therapy was introduced in the 1960s to maximize potassium flux within ischemic myocardium as a means of reducing the incidence of arrhythmia, resolving ECG changes, and improving hemodynamics.[88-90] A large 2005 randomized controlled trial involving 20,201 patients across 3 centers evaluated the impact of GIK therapy in MI but did not reproduce these results. The study indicated that GIK infusions had no effect on mortality, cardiogenic shock, or cardiac arrest when given to all STEMI patients as a standard.[91] For this reason, routinely giving GIK infusions to STEMI patients is not advised. However, for patients with diabetes, early and tight glucose control with either an insulin sliding scale or an insulin drip is recommended by the ACC/AHA.[92]

Magnesium Repletion

Despite early interest, the routine administration of magnesium to patients with a STEMI does not appear to be indicated. Early trials noted improved outcomes when magnesium was routinely repleted in STEMI patients.[93] However, a later randomized, double-blind, controlled trial involving more than 6000 patients was unable to reproduce this effect in the broader study population or in any of the subgroups.[93] Nevertheless, magnesium was not found to be harmful and can be considered in patients with documented magnesium deficits who are on diuretic medications or are experiencing arrhythmias.[94]

Disposition

For STEMI patients undergoing PCI, a system should be in place to ensure catheterization laboratory activation as quickly as possible after diagnosis. When the laboratory is at another facility, activation should be coordinated as the patient is prepared for transfer. (**See the Controversies And Cutting Edge: Strategies To Improve Door-to-Balloon Time section.**) All STEMI patients who are not taken elsewhere for primary PCI should be admitted to a setting with a cardiac intensive care unit (ICU) as the destination of choice.

Special Circumstances

Old Left Bundle-Branch Block: Sgarbossa Criteria

A new left bundle-branch block (LBBB) in the setting of chest pain is a diagnostic criterion for STEMI. (**See Figure 2, page 5.**) It is indicative of a proximal left anterior descending artery, with the potential to damage a large section of the myocardium. The resistance of the left bundle branch becomes slow or does not occur at all, so the signal traveling down the right bundle branch ends up depolarizing the left bundle after it depolarizes the right ventricle. This delay and change in the electrical axis creates the characteristic ECG pattern. When there is a preexisting LBBB in a patient with chest pain, it can mask the ECG changes of a STEMI and delay diagnosis and treatment.

Decades of work have gone into determining how to diagnose a STEMI through an LBBB. One diagnostic tool that has gained widespread use because of its high specificity is the Sgarbossa Criteria. Identified and later validated in 1996, the Sgarbossa Criteria[95] contain 3 questions that can be used to identify a STEMI through an old LBBB. (**See Figure 4.**) To help in assessing the likelihood that a given patient with chest pain and a baseline LBBB is having a STEMI, a scoring system was developed that takes into account the probability of a STEMI with each criterion.

1. ST-segment elevation ≥ 1 mm in a lead with an upward QRS complex (5 points)
2. ST-segment depression ≥ 1 mm in V1, V2, or V3 (3 points)
3. ST-segment elevation ≥ 5 mm in a lead with a downward QRS complex (2 points)

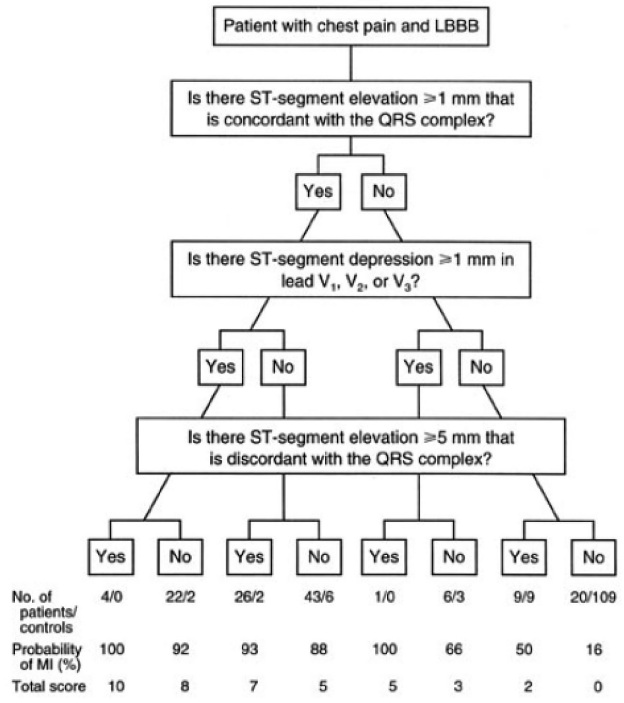
Unlike the general STEMI criteria, the Sgarbossa Criteria do not need to be found in contiguous leads.

Criterion 1 is more indicative of a STEMI than is criterion 3, and the more criteria that are met, the more likely that a STEMI has occurred. According to the scoring system, a yes to question one is equal to 5 points, a yes to question two is equal to 3 points, and a yes to the third question is equal to 2 points. It is important to note that these criteria are not very sensitive, but they are highly specific. A score of 5 to 10 indicates an 88% to 100% probability of acute MI. With 0 points, there is still a 16% chance of a STEMI.

Aspirin Allergy Or Sensitivity

A 162- to 325-mg dose of aspirin taken early in the course of MI has been shown to produce a 23% reduction in mortality, measured at 1 month after the MI.[30] Patients with an aspirin allergy are at risk of losing this benefit. As a result, it is important to identify the allergic reactions of STEMI patients and determine whether the benefits of an aspirin outweigh the consequences of the reaction. For those in whom gastrointestinal tract bleeding is a concern, the cautious use of aspirin may be the better option. A 2005 randomized study involving 320 patients found the combination of a proton pump inhibitor and aspirin was a safer alternative than clopidogrel in patients who are at risk for gastrointestinal bleeding.[96] However, the CAPRIE trial, a randomized study involving 19,185 patients, demonstrated that substituting clopidogrel for aspirin was a sufficient antiplatelet inhibitor when compared with aspirin.[97,98] Thus, in

Figure 4. Flowchart For The Prediction of Acute Myocardial Infarction In The Presence Of Left Bundle-Branch Block[95]



Abbreviations: LBBB, left bundle-branch block; MI, myocardial infarction. (Reprinted with permission. Copyright © 1996 Massachusetts Medical Society. All rights reserved.)

those patients with a definitive contraindication to aspirin (like angioedema or anaphylaxis), clopidogrel can be given as an alternative. In patients with other aspirin sensitivities, the reaction should be weighed against the cost of withholding therapy, and clopidogrel should be considered as a potent alternative. The current ACC/AHA guidelines do not comment on dosages, but keep in mind that in the acute care setting, higher loading doses of clopidogrel will be needed to approximate the platelet inhibition time-of-onset of aspirin for acute MI. As a result, a larger loading dose (600 mg or two 600-mg boluses 2 hours apart) may be most appropriate when clopidogrel is used as an aspirin substitute.[34]

MI With Aortic Dissection

The traditional teaching is that all acute MI patients should have a chest radiograph to screen for a wide mediastinum as an indication of possible AoD. Identifying AoD that presents at STEMI is important because fibrinolysis in these patients is associated with a mortality rate of 69% to 100%, often from cardiac tamponade or aortic rupture.[99,100] In general, 33% of patients whose AoDs are not diagnosed will die within the first 24 hours, 50% will die within 48 hours, and 75% within 2 weeks. Despite the high mortality, the case prevalence of AoD in the United States per year numbers in the thousands.

Ascending AoDs comprise about 50% of all dissections and are associated with a 7% to 13% incidence of retrograde dissection into a coronary ostium.[101,102] About 4% to 12% of this subpopulation of AoD patients will develop clinical and ECG findings compatible with acute MI.[103] However, STEMIs that are uncomplicated by AoD are orders of magnitude more common. In the career of any given EM clinician, far more patients with chest pain will be harmed by the delay in reperfusion than will be helped by early screening for AoD. As a result, routinely delaying reperfusion in STEMI patients in order to obtain a chest radiograph may not be appropriate general practice.

Decades of research have shown that a history of sudden onset of chest or back pain with or without syncope is the most sensitive tool in scaling the suspicion of AoD. Historical studies have shown that the sudden onset of chest pain alone has a sensitivity of 85%.[104] A study published in 2002 that used data from the International Registry of Acute Aortic Dissection and included 464 patients with confirmed AoD found that 95% reported pain in their chest, back, or abdomen; 90% reported it as severe or the worst pain they had ever experienced, and 64% described it as sharp. In addition, 72% of the patients had a history of hypertension.[105] Other data show that 75% of dissections occur in individuals 40 to 70 years of age, with the majority occurring in those 50 to 75 years old. There is a male to female predominance of 2:1 and increased incidence with cocaine use. Forty percent of dissections in women younger than 40 years occur during pregnancy.[106] A pulse deficit, blood pressure differential (between right and left or upper and lower extremities), or focal neurologic defects may be concerning signs on physical examination. These characteristics are helpful when determining when to consider AoD as a complicating factor in STEMI patients.

In addition, chest radiography is unlikely to be the ideal method of screening. Although chest radiographs are easy to obtain, not all mediastinal widening observed on the radiograph is caused by dissection, and not all dissections will show a wide mediastinum on an x-ray. Other associated findings are often absent, and few are specific for dissection. More sensitive screening tests include a chest CT enhanced with IV contrast, magnetic resonance imaging, transesophageal echocardiography, transthoracic echocardiography, and angiography (the former gold standard), which has a sensitivity of 80% to 95%.[105] For experienced EM operators, a bedside EM cardiac ultrasound can be used as an extension of the physical examination. Transthoracic and transabdominal echos are not sensitive screening studies for AoD, but when an intraluminal flap is found, it can significantly raise the level of suspicion.

The investigation of dissection in the ED should be balanced with an awareness of the rarity of its occurrence, sensitivity to the historical and demographic factors that make it more likely, and consideration of how the delay to reperfusion can affect outcomes for STEMI patients.

Controversies And Cutting Edge

EMS Bypassing Smaller Hospitals For Those With PCI Capability

Primary PCI is preferred over fibrinolytic therapy in most STEMI patients, provided they make to it the catheterization laboratory of a PCI-capable facility within 90 minutes. Historically, individual EMS providers have chosen to bypass non-PCI facilities in favor of hospitals with PCI capability, but there have been concerns that this may lead to extended prehospital travel times that diminish the benefits of primary PCI over fibrinolysis. A 2006 study of US census data revealed that about 80% of American adults lived within 60 minutes of a PCI-capable hospital. Even more notable, for those whose closest hospital did not have PCI capability, 75% would have had less than an additional 30 minutes added to their transport time if taken to a PCI-capable hospital. There were notable geographic variations, but in most parts of the country, direct EMS transport can provide access to PCI.[107] Nevertheless, many centers are still struggling to meet door-to-balloon times for patients with far shorter EMS transports.

So until internal efficiency improves, allowing longer out-of-hospital times may lead to worse outcomes. In addition, a recent study compared facilitated PCI (with clopidogrel before catheterization laboratory intervention) occurring within 150 minutes to primary PCI and suggested similar outcomes.[58] This finding makes it more reasonable for EMS providers to stop at non-PCI centers for early evaluation and facilitating therapy before transporting a confirmed-STEMI patient to a PCI-capable center.

Facilitated PCI: Variable Definitions

The concept of facilitated PCI is difficult to understand because the term is used inconsistently in the literature. Most commonly, it refers to a number of antiplatelet agents and/or fibrinolytic combinations given before PCI. Most major studies have evaluated GPIIB/IIIa agents abciximab and eptifibatide independently and in combination with the fibrinolytics reteplase (Retavase®) and tenecteplase (TNKase™), respectively. However, in one study the term facilitated PCI was used to describe the role of clopidogrel in situations better described as follow-up PCI, where PCI was done 2 to 8 days after primary fibrinolysis.[61] A more recent 2009 study used the term to refer to pretreatment with clopidogrel when door-to-balloon times for primary PCI were greater than the targeted 90 minutes but less than or equal to 150 minutes.[59] Awareness of the different definitions and the ability to characterize the definition used for any given study are important in appropriately interpreting the literature.

Improving The Sensitivity Of Occlusive Thrombi Diagnoses

The STEMI ECG diagnostic criteria were derived from data with the aim of developing a fast and highly specific test. However, studies have shown that despite a specificity of 97%, the criteria endorsed by the ACC/AHA pick up only 40% of ACS patients with completely occlusive thrombi.[14,108,109]

Common Pitfalls And Medicolegal Issues For STEMI

Missed MI is the leading reason for dollars awarded in closed malpractice settlements against EM practitioners. In addition, patients with a missed MI have a significant burden of morbidity and high mortality rates, which make this a major public health concern. The following pitfalls often lead to a missed STEMI.

- **Prolonged Time To Initial ECG**
  All patients presenting with chest pain should receive an ECG within 10 minutes of arrival. A STEMI cannot be diagnosed if a timely ECG is not performed.

- **Missed Atypical Symptoms**
  Failure to suspect STEMI in patients with atypical symptoms and chest pain equivalents (eg, shortness of breath, dizziness, nausea with or without epigastric discomfort) can lead to delayed diagnosis. Particular caution should be taken with women, the elderly, patients with diabetes, African Americans, and Hispanics, as these groups are known to present with atypical symptoms more often than others.

- **Improper ECG Interpretation**
  Memorizing the STEMI criteria is a first-line diagnostic tool for all EM practitioners.

- **Failure To Conduct Serial ECGs On Patients With Persistent Chest Pain**
  Because ECGs are snapshots in time, a single tracing does not preclude the possibility that a STEMI occurred prior to presentation and has since resolved, nor does it catch those patients whose symptoms will evolve into a STEMI pattern over time. Although serial ECGs are recommended, along with continuous monitoring, as a way to gain a longitudinal view of a patient's condition (particularly patients with ongoing chest pain), it is a less-than-perfect strategy.

- **Delayed Care**
  Once a STEMI is diagnosed, rapid reperfusion is the primary treatment goal. The door-to goal can help set the pace while staff is mobilized to implement the initial therapies and start either fibrinolysis or transport to a catheterization laboratory for PCI. Outcomes are directly related to the amount of time that elapses between presentation and reperfusion.

- **Imbalanced Consideration Of AoD**
  Retrograde dissection of AoD into coronary artery ostia can cause a STEMI, but this is rare. The benefits of screening for AoD as the cause of MI should be balanced with the consequences of prolonged ischemic time from delayed reperfusion. Universally screening for AoD is not recommended, given that more patients will be hurt than helped by delayed reperfusion. The sudden onset of chest or back pain is 85% sensitive for identifying those at high risk of AoD as the cause of acute MI.

Even more concerning, the sensitivity of the 12-lead ECG is lower than 40% for complete vessel occlusion affecting the right ventricle or posterior myocardium or for a STEMI in the presence of an old LBBB.[110] Even with right-sided and posterior leads, the sensitivity of a 12-lead ECG is only moderately improved. As a result of misclassification or the time lapse until the ECG reflects the diagnostic pattern, lost myocardial tissue leads to worse outcomes.[111] Despite the limitations of the 12-lead ECG's sensitivity, its high specificity makes it an excellent tool for identifying patients who should receive immediate reperfusion therapy in the form of PCI or fibrinolysis.

Body surface mapping (BSM), or 80-lead ECG tracing, is a technique that uses multiple anterior and posterior chest leads to obtain a more complete picture of cardiac electrical activity. Multiple studies have demonstrated its effectiveness as a more sensitive and equally specific tool for distinguishing acute MI from ACS. A 2002 multicenter randomized clinical trial in 4 ED sites that evaluated patients with chest pain suggestive of ACS found the sensitivity of BSM for STEMI (90%-100%) to be far greater than the sensitivity of clinical suspicion for STEMI along with a 12-lead ECG (76%), an eventual troponin level elevation (57.1%), or an elevated CK-MB ratio (73%), while providing comparable specificity (95%-97%).[112] Efforts to develop this and other technologies in order to increase the detection rate and translation into clinical practice are continuing.

Strategies To Improve Door-To-Balloon Time

The importance of achieving prompt reperfusion for STEMI patients cannot be overemphasized. Achieving door-to-needle times is within the control of flow dynamics in an ED. However, achieving optimal door-to-balloon time requires coordination with individuals and services outside the department, any one of which can delay a patient from receiving prompt reperfusion.[113] The Centers for Medicare and Medicaid Services is aware of how minutes matter with STEMI. The agency tracks hospitals' achievement of door-to goals and considers a hospital's performance when evaluating it for reaccreditation. Several studies have examined communication and coordination links in the STEMI reperfusion chain to see which have made the biggest differences in reducing the time to reperfusion.[114,115] A study published in 2006 noted the most effective, but least used, strategies and observed that hospitals that used the greatest number of interventions had the shortest door-to-balloon times.[116] (**See Table 8.**)

Table 8. Measures To Improve Door-To-Balloon Times[116]

Strategy	Time Saved (min)
Emergency medicine clinician activates the catheterization laboratory.	8.2
Single call to a central page operator activates the laboratory.	13.8
Emergency department staff activates the catheterization laboratory while the patient is en route to the hospital.	15.4
Staff members are expected to be in the catheterization laboratory within 20 minutes after being paged (vs 30 minutes).	19.3
An attending cardiologist is on-site at all times.	14.6
The hospital gives real-time feedback on the door-to-balloon times to the emergency department and catheterization laboratory staffs.	8.6

Summary

STEMI is a "can't miss" diagnosis in EM. A methodological approach to patients with chest pain who are at high risk of infarction is the best tool in identifying this diagnosis.

Case Conclusion

In response to the nurse who asked what you'd like to do for your patient with chest pain and 1.0- to 1.5-mm ST-segment elevations in leads II, III, and aVF, you reply, "This patient is having a STEMI, so we need to focus on immediate reperfusion." EMS already gave a full aspirin, and the 3 doses of nitroglycerin the patient received en route had minimal effect on his pain. The physical examination is negative for crackles or rales, jugular venous pulsation elevation, or a heart murmur. The patient's pulses are bilaterally symmetric in his upper and lower extremities, and he has no evidence of extremity edema or neurologic deficit. The patient is scared but awake, alert, and oriented to person, place, and time. Your hospital does not have a catheterization laboratory on-site, and the nearest PCI-capable facility is 60 minutes away. Your nurse runs through a "fibrinolytic checklist." The patient has no absolute or relative contra-indications. You write an order for a heparin bolus, followed by a continuous infusion as well as tPA, and communicate this to the nurse, who has called a colleague into the room to help start the medications.

You then call the PCI-capable facility and speak with the EM clinician there about the patient. She explains that she can activate the catheterization laboratory while the patient is en route, but she calculates that "given the 60-minute lead time, the patient will not likely make a door-to-balloon time within 90 minutes." You note that the patient has no contraindications for lysis and that the heparin and tPA have just arrived in the room. You discuss the situation with the patient and his wife, who is now at his bedside. They express understanding of the risks and the benefits of rapid reperfusion via fibrinolysis vs tPA and consent to fibrinolysis, which is immediately

pushed. You watch as the ST-segment elevation on the monitor resolves. The patient's pain resolves in synch. The nurse prints out a 12-lead ECG to confirm. You call the PCI-capable facility to coordinate transfer for continued care in their cardiac ICU and possible follow-up PCI.

Note

Full color versions of the figures in this article are available at no charge to subscribers at www.ebmedicine.net/topics.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available.

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CME Questions

1. ACS:
   a. Is a term for all MIs
   b. Describes MI caused by clots that travel to the heart and block coronary arteries
   c. Characterizes a specific pathophysiological cause for MI involving atherosclerotic plaque rupture with the formation of a superimposed clot within a coronary artery
   d. Is a term that is no longer used when discussing STEMI

2. A STEMI diagnosis can be made with:
   a. An ECG and cardiac enzymes
   b. A history and physical examination with cardiac enzymes
   c. Cardiac enzymes alone
   d. An ECG alone

3. STEMI diagnostic criteria require that a patient have chest pain or a chest pain equivalent and a qualifying ECG pattern. Which of the following is not a qualifying pattern?
   a. ≥ 1 mm (0.1 mV) in 2 or more adjacent limb leads (from aVL to III, including –aVR)
   b. T-wave inversions
   c. ≥ 2 mm (0.2 mV) in precordial leads V1 through V3
   d. ≥ 1 mm (0.1 mV) in precordial leads V4 through V6

4. When treating patients with chest pain and an ECG showing a STEMI, which of the following sets of questions is least important to ask?
   a. Questions about the nature of their chest pain
   b. Questions about risk factors that increase the chance of an acute MI
   c. Questions about when and how their chest pain started
   d. Questions about potential contraindications to fibrinolytic therapy

5. **Other causes of ECG ST-segment elevation in patients complaining of chest pain include all of the following EXCEPT:**
   a. Pericarditis/Myocarditis
   b. Benign early repolarization
   c. Left ventricular hypertrophy
   d. Paced rhythm
   e. All of the above can cause ST-segment elevations

6. **In STEMI patients with documented or reported aspirin allergies:**
   a. The risks outweigh the benefits, so aspirin should be avoided
   b. The mortality benefits outweigh the risks, so aspirin should always be given
   c. Clopidogrel can be considered as an alternative
   d. Acetaminophen can be given as an alternative

7. **In patients with a preexisting LBBB and chest pain:**
   a. It is impossible to diagnose a STEMI with confidence.
   b. If a STEMI is present, it will be masked; therefore, all patients should be taken to the catheterization laboratory for coronary evaluation.
   c. The Sgarbossa Criteria have high sensitivity in identifying a STEMI.
   d. The Sgarbossa Criteria have high specificity in identifying a STEMI.

8. **The term facilitated PCI has been used to refer to:**
   a. Antiplatelet agents given before PCI
   b. Fibrinolytics given in combination with antiplatelet agents
   c. Fibrinolytics given before PCI
   d. All of the above

Physician CME Information

Date of Original Release: June 1, 2009. Date of most recent review: May 1, 2009. Termination date: June 1, 2012.

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Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals & Objectives: Upon completion of this article, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

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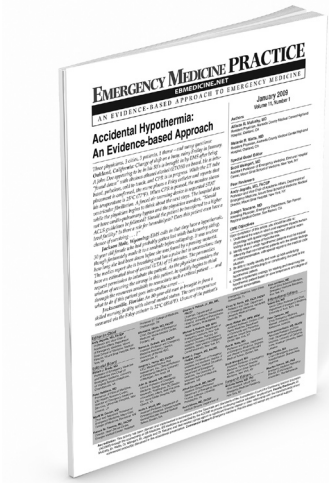

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May 2009 Errata

In the May 2009 issue of *Emergency Medicine Practice,* "Complications In Pregnancy Part II: Hypertensive Disorders Of Pregnancy And Vaginal Bleeding," question 2 was erroneously worded. To be more clear, the question should read: "Which of the following indicates severe preeclampsia?" As reworded, per Table 2 on page 3, answer "d" is correct; the other answers indicate mild preeclampsia. We apologize for any confusion.

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The Diagnosis And Treatment Of STEMI In The Emergency Department

Kosowsky, J, Yiadom, M. June 2009; Volume 11, Number 6

This issue of Emergency Medicine Practice focuses on managing STEMI in the ED setting using evidence-based practices. For a more detailed discussion of this topic, including figures and tables, clinical pathways, and other considerations not noted here, please see the complete issue at www.ebmedicine.net/topics.

Key Points	Comments
In all cases of cardiac ischemia, the treatment objectives are to increase the delivery of blood to myocytes beyond the obstructive lesion and to limit the myocytes' demand for oxygen-carrying and metabolite-removing blood.[7]	What differentiates STEMI therapy from treatment of other cardiac ischemic conditions is the primary therapeutic focus on immediate reperfusion with PCI in a cardiac catheterization laboratory or with fibrinolytic agents given intravenously.[7]
Unlike most medical conditions, STEMI is diagnosed with an ECG before a patient's evaluation is complete. The patient's history should be taken while the ECG is being performed and initial therapies are being administered.[25]	Remember that *time is myocardium.*
Diagnosing a STEMI requires a 12-lead ECG showing:[19,22,23] 1) ST-segment elevation: ≥ 1 mm (0.1 mV) in 2 or more adjacent limb leads (from aVL to III, including –aVR), or ≥ 1 mm (0.1 mV) in precordial leads V4 through V6, or ≥ 2 mm (0.2 mV) in precordial leads V1 through V3, or 2) A new left bundle-branch block	Positive tests for cardiac enzymes troponin and creatinine kinase isoenzyme MB are helpful but are not essential. Therapy should not be delayed while awaiting results. Reciprocal depressions (ST depressions in the leads corresponding to the opposite side of the heart) make the diagnosis of STEMI more specific.[19,22,23]
Upon arrival, initial therapies for a STEMI patient include aspirin, supplemental oxygen if oxygen saturation is < 90%, morphine, and/or nitroglycerin. In those patients with a confirmed STEMI, heparin should be added if there are no contra-indications.[8,30-37]	Caution should be used with morphine because of emerging evidence that its use increases mortality, as well as with nitroglycerin because of the risk of hypotension and reflex tachycardia.[8,35-37]
Initiation of reperfusion therapy is the primary focus when treating STEMI patients. This can be done via fibrinolysis (with a targeted door-to-needle time of 30 minutes) or with PCI (with a door-to-needle balloon time of 90 minutes).[8,49,50]	Reperfusion outcomes with fibrinolytic therapy, at 30 days post-intervention, are comparable to those with PCI.[42] The most appropriate intervention for any given patient is dependent on any contraindications to fibrinolysis, the ability to meet the door-to goals, the duration of symptoms, the presence of cardiogenic shock, and the patient's demographic risk of mortality.
The Sgarbossa Criteria takes into account the probability of a STEMI in patients with an old left bundle-branch block with each of the criterion:[95] 1) ST-segment -elevation ≥ 1 mm in a lead with an upward QRS complex (5 points) 2) ST-segment depression ≥ 1 mm in V1, V2, or V3 (3 points) 3) ST-segment -elevation ≥ 5 mm in a lead with a downward QRS complex (2 points)	Criterion 1 is more indicative of a STEMI than is criterion 3, and the more criteria that are met, the more likely that a STEMI has occurred. The Sgarbossa Criteria is highly specific but has low sensitivity; with 0 points, there is still a 16% chance of a STEMI.[95]

** See reverse side for reference citations.*

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These references are excerpted from the original manuscript. For additional references and information on this topic, see the full text article at ebmedicine.net.

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8.	[a]	[b]	[c]	[d]	[e]
9.	[a]	[b]	[c]	[d]	[e]
10.	[a]	[b]	[c]	[d]	[e]
11.	[a]	[b]	[c]	[d]	[e]
12.	[a]	[b]	[c]	[d]	[e]
13.	[a]	[b]	[c]	[d]	[e]
14.	[a]	[b]	[c]	[d]	[e]
15.	[a]	[b]	[c]	[d]	[e]
16.	[a]	[b]	[c]	[d]	[e]

Please take a few moments to complete this Evaluation Form. Your opinions will ensure continuing program relevance and quality.

Response codes: **5=strongly agree; 4=agree; 3=neutral; 2=disagree; 1=strongly disagree**

1. ____ The overall activity content was pertinent to my needs and expectations.
2. ____ The information was presented in an impartial and unbiased manner.
3. ____ I learned information that will enhance my professional effectiveness.
4. ____ Adequate faculty disclosure was given.
5. ____ The test questions were clear and appropriate.
6. ____ The information presented in this CME quiz was objective, balanced, and of scientific rigor.
7. ____ The authors were NOT biased in their discussion of any commercial product or service.
8. ____ The content in this activity is useful in my everyday practice.
9. ____ The first CME objective (listed on the cover of the article) was met for this activity.
10. ____ The second CME objective (listed on the cover of the article) was met for this activity.
11. What clinical information did you learn that was of value to you? _____
12. How did the clinical information you learned impact positively or change the way you care for your patients? _____
13. For future activities, what personal professional gap would you like us to fill? _____
14. What do you like MOST about *Emergency Medicine Practice*? _____
15. What do you like LEAST about *Emergency Medicine Practice*? _____
16. Please provide any additional comments. _____