Acute ST-Segment Elevation Myocardial Infarction: Critical Care Perspective

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Over 1.2 million patients suffer from new or recurrent ischemic events annually [1]. This includes an estimated 565,000 cases of first and 300,000 cases of recurrent myocardial infarction (MI) [1]. Although mortality from acute MI has declined in recent years, it still remains high at 25% to 30% [1]. Despite its high mortality, prognosis can be improved with timely and effective use of evidence-based treatment in the acute setting [2]. This review outlines the critical care management strategies for ST-segment MI (STEMI).

Etiology of STEMI

The most common cause of STEMI is acute plaque rupture and the resultant thrombosis leading to acute closure of coronary arteries. Less commonly, STEMI is caused by abnormalities of coronary vessels, wall, hypercoagulation, and substance abuse as listed in Box 1 [3].
Box 1. Nonatherosclerotic etiologies of acute myocardial infarction

*Arteritis*
Takayasu’s disease
Polyarteritis nodosa
Kawasaki syndrome
Systemic lupus erythematosus
Rheumatoid arthritis
Ankylosing spondylitis

*Trauma to coronary arteries*

*Metabolic diseases with involvement of coronary arteries*
Hurler’s syndrome
Homocystinuria
Fabry’s disease
Amyloidosis

*Other mechanisms of luminal narrowing*
Spasm
Aortic dissection involving coronary arteries

*Coronary artery emboli*
Infective endocarditis
Nonthrombotic endocarditis
Prosthetic valve emboli
Cardiac myxoma
Paradoxical emboli
Papillary fibroelastoma of aortic valve

*Congenital anomalies*
Anomalous origin of the left coronary from the pulmonary artery
Left coronary artery from anterior sinus of valsalva

*Miscellaneous*
Carbon monoxide poisoning
Polycythemia vera
Thrombocytosis
Cocaine abuse

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Clinical presentation and evaluation

Symptoms

The classic symptom of a STEMI patient is chest pain. Chest pain unique to a STEMI patient is severe and may manifest as intense pressure in the shoulders or directly under the ribs. Pain may radiate to the jaw, neck, back, shoulders, and arms. Occasionally, there may be no chest pain at all, and patients may report pain localized to any one of the areas described above [2].

Atypical symptoms are often characteristics of the elderly, women, diabetic patients, patients with prior cardiac surgery, and those in the immediate postoperative period of noncardiac surgery. These atypical symptoms include nausea, shortness of breath, diaphoresis and epigastric discomfort, dizziness, syncope, weakness, fatigue, or complaints of indigestion [2].

Physical examination

Physical examination is more important for excluding other causes of chest pain and for risk-stratifying patients with STEMI, but is not helpful by itself for making the diagnosis of STEMI. A thorough baseline and periodic examination allows for identification of patients who present with or who develop congestive heart failure, mechanical complications, and pericarditis. A fourth heart sound is present in most patients, whereas systolic blood pressure, heart rate, rales, and third heart sound provide important prognostic information.

Electrocardiogram

An electrocardiogram should be performed within 10 minutes of arrival to emergency room in patients with chest pain or other ischemic symptoms [2]. Elevation of ST segments greater than 0.1 mV in two consecutive leads is typically indicative of a STEMI, and elevation of greater than 0.2 mV has been shown to be more specific in accurately diagnosing a STEMI. Right-sided leads are desirable in all patients with inferior STEMI to rule out right ventricular infarction (RVI). While new left bundle branch block in presence of ischemic symptoms is considered consistent with the diagnosis of STEMI, the presence of previous left bundle branch block may confound the diagnosis of STEMI. In these patients, a STEMI can be diagnosed by the following criteria: (1) ST elevation greater than or equal to 0.1 mV in leads with a positive QRS; (2) ST depression greater than or equal to 0.1 mV in V1 to V3; and (3) ST elevation greater than or equal to 0.5 mV in leads with a negative QRS [4]. As STEMI evolves, new Q waves develop, ST segment elevation resolves, and new T-wave inversions are evident. Besides helping in diagnosis, ST segment elevations are important for localization of infarct and infarct-related artery. Additionally, they impart important prognostic information, ie, the risk of mortality is proportional to the number of leads showing ST segment elevation.
elevations and resolution of ST segments with reperfusion therapies suggests establishment of normal myocardial flow and is associated with better prognosis.

**Imaging**

Transthoracic echocardiography allows bedside confirmation or exclusion of the diagnosis of STEMI, although EKG and availability of cardiac markers have limited its use. Nevertheless, it remains the most valuable tool for evaluation of left and right ventricular function as well as for the diagnosis of mechanical complications. Other imaging modalities such as transesophageal echocardiography, a contrast chest CT scan, or magnetic resonance imaging are predominantly useful for excluding some of the other causes of chest pain, i.e., aortic dissection, pulmonary embolism, and so forth.

**Cardiac biomarkers**

The most commonly used markers in clinical practice to diagnose and assess infarct size include creatine kinase (CK)-MB fraction and cardiac troponins. CK-MB is elevated 3 to 12 hours after onset of ischemia and has a mean peak time of 24 hours. Cardiac troponin I (cTnI) and cardiac troponin T (cTnT) are considered elevated above the 99th percentile of a reference control group. Both troponins are detectable 4 to 12 hours after the onset of ischemia, and peak at 12 to 48 hours. CK-MB may remain elevated for up to 3 days after infarction, while troponins may be elevated for more than a week. CK-MB has proven quite specific for diagnosing a myocardial infarction and only rarely do myocardial infarcts occur without elevated CK-MB levels.

Although an elevated CK-MB has long been considered the “gold standard” for myocardial necrosis, recent studies show that troponin may, in fact, be even more sensitive and specific for detecting necrosis of coronary vessels at the microscopic level [5]. The values of both baseline CK-MB and troponin levels are associated incrementally with risk of mortality in patients with STEMI [6]. However, because of its higher sensitivity and specificity, their measurement has largely replaced CK-MB evaluation for suspected MI and should be measured in all patients with suspected STEMI.

**Differential diagnosis**

Box 2 shows a list of differential diagnoses that should be considered in patients presenting with ischemic symptoms [2]. Rapid physical examination, laboratory tests, and imaging studies serve to eliminate these diagnoses. An erroneous diagnosis of STEMI among these patients may increase their risk not only related to missed diagnosis, but also because fibrinolytic agents in some of these patients have potential for harm.
Box 2. Differential diagnosis of ST-elevation myocardial infarction

*Life-threatening*
- Aortic dissection
- Pulmonary embolus
- Perforating ulcer
- Tension pneumothorax
- Boerhaave syndrome (esophageal rupture with mediastinitis)

*Other cardiovascular and nonischemic*
- Pericarditis
- Atypical angina
- Early repolarization
- Wolff-Parkinson-White syndrome
- Deeply inverted T waves suggestive of a central nervous system lesion or apical hypertrophic cardiomyopathy
- LV hypertrophy with strain
- Brugada syndrome
- Myocarditis
- Hyperkalemia
- Bundle-branch blocks
- Vasospastic angina
- Hypertrophic cardiomyopathy

*Other noncardiac*
- Gastroesophageal reflux (GERD) and spasm
- Chest-wall pain
- Pleurisy
- Peptic ulcer disease
- Panic attack
- Biliary or pancreatic pain
- Cervical disc or neuropathic pain
- Somatization and psychogenic pain disorder

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**Treatment**

Box 3 outlines the initial diagnostic and therapeutic measures. A treatment algorithm is outlined in Figs. 1 and 2 [7]. Important initial goals are
Box 3. Diagnostic and treatment measures in patients with STEMI

Initial diagnostic measures
1. Use continuous EKG, automated blood pressure, heart-rate monitoring
2. Take targeted history (for acute myocardial infarction inclusions, thrombolysis exclusions), check vital signs, perform focused examination
3. Start intravenous lines and draw blood for serum cardiac markers, hematology, chemistry, lipid profile
4. Obtain 12-lead EKG
5. Obtain chest x-ray (preferably upright)

General treatment measures
1. Aspirin, 160–325 mg (chew and swallow)
2. Nitroglycerin, sublingual: test for Prinzmetal’s angina, reversible spasm; anti-ischemic, antihypertensive effects
3. Oxygen: sparse data; probably indicated, first 2–3 hours in all; continue if low arterial oxygen saturation (<90%)
4. Adequate analgesia: small doses of morphine (2–4 mg) as needed

Specific treatment measures
1. Reperfusion therapy: goal—door-to-needle time <30 min; door-to dilatation time <60 min
2. Conjunctive antithrombotics: aspirin, heparin (especially with fibrin-specific lytic agents)
3. Adjunctive therapies: Beta-adrenoceptor blockade if eligible, intravenous nitroglycerin (for anti-ischemic or antihypertensive effects), angiotensin-converting enzyme inhibitor (especially with large or anterior ST-elevation, heart failure without hypotension [SBP >100 mm Hg], previous myocardial infarction)

proceed with the chosen mode of reperfusion (Fig. 3). The National Heart Attack Alert Program Coordinating Committee has established a door-to-needle time (for fibrinolysis) to be less than 30 minutes and door-to-balloon time (for PCI) to be less than 90 minutes in which diagnosis is to be completed and reperfusion achieved [8].

Choosing a reperfusion strategy

Patients presenting within 12 hours should undergo reperfusion therapy [2]. An invasive strategy is preferred for high-risk patients (elderly, large MI, cardiogenic shock, or those with comorbid conditions) if the door-to-balloon time can be achieved within 90 minutes, or there is contraindication for fibrinolysis or diagnosis uncertain (see Fig. 3). On the other hand, fibrinolytic therapy remains the principal mode of reperfusion globally because of lack of facilities and accessibility to invasive centers that preclude timely primary PCI [2].
Fibrinolytic therapy represents one of the major advances in the management of STEMI. Fibrinolytic agents dissolve infarct artery thrombus and restore myocardial perfusion, thereby reducing infarct size, preserving left ventricular systolic function, and improving survival. Patients with more than 1 mm ST elevation in two or more contiguous leads or new left bundle branch block within 12 hours of symptom onset should be administered one of the currently available fibrinolytic agents (Table 1) unless contraindicated. The success of fibrinolytic therapy is largely dependent on timely administration, as early as in the prehospital setting. The most effective fibrinolytic regimens achieve epicardial infarct artery patency rates in 75% of patients within 90 minutes, but requires blood transfusion in 5% and is associated with hemorrhagic stroke in approximately 1% of patients [2,9]. Prehospital fibrinolysis has been shown to have excellent outcomes with no increased
risk compared with in-hospital treatment and in fact outcomes that are similar to primary PCI. The guidelines recommend fibrinolytic therapy within the first hour after symptom onset, since mortality significantly increases every hour thereafter [9]. The benefits of fibrinolytic therapy on STEMI have been well established with overall 18% risk reduction in 30-day mortality relative to control [9]. Furthermore, this reduction in mortality is risk dependent with higher risk subgroups showing the greatest benefit [9].

For no other treatment of STEMI is consideration of risks versus benefits more important than for the use of a fibrinolytic agent. A major concern with the administration of fibrinolytics is the risk of intracranial hemorrhage [2,9]. This is because it is fatal in up to one half to two thirds of patients and associated with permanent disability in a vast majority of patients who survive this event [10,11]. Models for assessment of risk of intracranial hemorrhage have been developed and allowed accurate estimation of risks before administration of fibrinolytic treatment so that risks versus benefits could be appropriately weighed [10,11]. Factors identified with increased risks have included increasing age, African American race, lower body weight, prior transient-ischemic attack or stroke, presenting systolic blood pressure, excessive anticoagulation, and fibrin-specific agents compared with non–fibrin-specific agents. Mental status and neurological signs and symptoms
must be monitored closely after administration of fibrinolytic agents. A change in mental status within 24 hours of treatment should be considered to be due to intracranial hemorrhage until proven otherwise, and immediate neurology/neurosurgery consults are recommended so that appropriate management is undertaken to prevent further neurological damage.

**Primary PCI**

Primary PCI with patency rates greater than 90% and few contraindications is an attractive reperfusion strategy. This mode of reperfusion has been shown to decrease mortality, nonfatal reinfarction, and hemorrhagic stroke when compared with fibrinolytic therapy [12]. Thus, primary PCI is a preferred reperfusion strategy when performed in a timely manner (90-minute “door-to-balloon time” after arrival to the emergency department [ED]) by individuals skilled in this procedure (performed more than 75 PCI procedures/y) and supported experienced personnel in high-volume centers (more than 200 PCI/y). Major limitations of primary PCI include the lack of availability and the delay in time to treatment. It is the reperfusion strategy of choice in patients with cardiogenic shock. The efficacy of PCI decreases as time to perfusion increases. In fact, in patients with STEMI, particularly those at high risk, presenting to ED, longer door-to-balloon times are associated

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**Table 1**

Comparison of approved thrombolytic agents

<table>
<thead>
<tr>
<th></th>
<th>Streptokinase</th>
<th>Alteplase(^a)</th>
<th>Reteplase</th>
<th>tenecteplase-tPA(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dose</strong></td>
<td>1.5 MU in 30–60 min</td>
<td>100 mg in 90 min</td>
<td>10 U × 2 each over 2 min</td>
<td>30–50 mg based on weight</td>
</tr>
<tr>
<td><strong>Bolus administration</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Antigenic</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Allergic reactions</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>(hypotension most common)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Systemic fibrinogen depletion</strong></td>
<td>Marked</td>
<td>Mild</td>
<td>Moderate</td>
<td>Minimal</td>
</tr>
<tr>
<td>90-min patency rates, approximate %</td>
<td>≈ 50</td>
<td>≈ 75</td>
<td>≈ 75</td>
<td>≈ 75</td>
</tr>
<tr>
<td><strong>Thrombolysis in Myocardial Infarction grade 3 flow, %</strong></td>
<td>32</td>
<td>54</td>
<td>60</td>
<td>63</td>
</tr>
<tr>
<td><strong>Cost per dose (US)</strong></td>
<td>$613</td>
<td>$2974</td>
<td>$2750</td>
<td>$2833</td>
</tr>
</tbody>
</table>

\(^a\) Bolus 15 mg, infusion 0.75 mg/kg for 30 minutes (maximum 50 mg), then 0.5 mg/kg not to exceed 35 mg over the next 60 minutes to an overall maximum of 100 mg.

\(^b\) Thirty milligrams for weight less than 60 kg; 35 mg for 60–69 kg; 40 mg for 70–79 kg; 45 mg for 80–89 kg; 50 mg for 90 kg or more.

Box 4. Contraindications and cautions for fibrinolysis in ST-elevation myocardial infarction

**Absolute contraindications**
- Prior intracranial hemorrhage
- Known structural cerebral vascular lesion (e.g., arteriovenous malformation)
- Known malignant intracranial neoplasm (primary or metastatic)
- Ischemic stroke within 3 months EXCEPT acute ischemic stroke within 3 hours
- Suspected aortic dissection
- Active bleeding or bleeding diathesis (excluding menses)
- Significant closed-head or facial trauma within 3 months

**Relative contraindications**
- History of chronic, severe, poorly controlled hypertension
- Severe uncontrolled hypertension on presentation (SBP greater than 180 mm Hg or DBP greater than 110 mm Hg)
- History of prior ischemic stroke greater than 3 months, dementia, or known intracranial pathology not covered in contraindications
- Traumatic or prolonged (>10 minutes) cardiopulmonary resuscitation or major surgery (less than 3 weeks)
- Recent (within 2 to 4 weeks) internal bleeding
- Noncompressible vascular punctures
- For streptokinase/anistreplase: prior exposure (more than 5 days ago) or prior allergic reaction to these agents
- Pregnancy
- Active peptic ulcer
- Current use of anticoagulants: the higher the prothrombin time, the higher the risk of bleeding


with increased late mortality (more than 3 hours after presentation). Efforts to reduce the door-to-balloon time (prehospital EKG, transmission of the EKG to the ED, administration of antithrombotic agents by the paramedics, notifying the catheterization laboratory staff of an incoming STEMI patient, and preparing the catheterization laboratory by the time the patient arrives) are expected to improve survival significantly in those undergoing primary
PCI. If a longer delay in door-to-balloon time is anticipated, use of full-dose fibrinolytic agents may be more appropriate. Facilitated PCI (use of half- or full-dose lytics, glycoprotein IIbIIIa receptor antagonists or combination of the two followed by immediate PCI) have not proven to be effective strategies and in fact may be associated with increased risks of complications. Potential limitations of primary PCI include arterial access site complications; adverse reactions related to contrast, volume loading, and antithrombotic agents; and reocclusion (5%) and restenosis (20%) [12].

Coronary artery bypass surgery in STEMI

Coronary artery bypass surgery (CABG) as primary reperfusion strategy is rarely needed in the current era of fibrinolytic therapy and PCI and may be considered appropriate in patients with STEMI and suitable anatomy who are not candidates for fibrinolysis or primary PCI and are within 12 hours of symptom onset. Emergency CABG is also indicated for patients with failed PCI and recurrent ischemia or hemodynamic instability; at the time of surgical repair for ventricular septal rupture, mitral valve insufficiency, or cardiac rupture; cardiogenic shock in patients with STEMI within 36 hours of symptom onset (18 hours of shock) having multivessel or left main disease; and in those with severe life threatening ventricular arrhythmias and multivessel or left main disease [2]. Finally, guidelines for elective CABG in patients with STEMI do not differ from those for other patients and include spontaneous or stress-induced ischemia in patients with left main or multivessel disease, particularly those with significant left ventricular (LV) dysfunction [2].

Adjunctive management

Supplemental oxygen is indicated for those patients with O2 saturations less than 90%; those with ongoing ischemia, hemodynamic instability, or pulmonary congestion; and during first 2 to 3 hours in all patients with STEMI. Vasodilators such as morphine and nitroglycerin can decrease oxygen requirement, decrease anginal pain, and prevent further myocardial necrosis. Nitroglycerin can be administered sublingually or as a spray. If pain is still not alleviated, or for patients with uncontrolled hypertension, left ventricular dysfunction, or pulmonary congestion, intravenous nitroglycerin should be administered and continued for 24 to 48 hours. Nitroglycerin is contraindicated in those with hypotension, bradycardia, or those who have received sildenafil in the preceding 24 hours. It should be used with caution in patients with right ventricular infarction. While symptomatic benefit is seen in most patients, no studies have conclusively shown a significant mortality benefit from nitroglycerin.

Antiplatelet therapy

Patients should chew 162 to 325 mg of aspirin unless otherwise contraindicated and continued indefinitely. Use of aspirin alone has been shown to
be associated with 23% relative risk reduction, similar to that seen with streptokinase alone and combination of aspirin and streptokinase results in an even greater 42% relative risk reduction among STEMI patients. Clopidogrel or ticlopidine is a reasonable alternative for patients allergic to aspirin [13]. Aspirin should be administered as soon as patients complain of symptoms presumed to be ischemic in origin [2].

Pretreatment with clopidogrel 600 mg or ticlopidine 500 mg (in addition to aspirin) is indicated as soon as a decision regarding primary PCI is made and this treatment continued for minimum of 1 to 6 months depending on the type of stent used during primary PCI [2]. Recent data indicate a benefit of clopidogrel even among patients treated with fibrinolysis. In patients receiving fibrinolytic therapy, aspirin and clopidogrel together may improve reperfusion and coronary flow. In the Clopidogrel and Metoprolol in Myocardial Infarction Trial (COMMIT), patients received 75 mg clopidogrel in addition to 165 mg aspirin, versus clopidogrel alone. Patients receiving dual therapy with fibrinolytic regimen had significantly reduced risk of in-hospital outcomes, including mortality [14]. Similarly, the CLARITY-TIMI 28 investigators demonstrated that in STEMI patients younger than 75 years who received aspirin and standard fibrinolytic therapy, addition of clopidogrel (300 mg load, 75 mg/d) versus placebo resulted in a significantly lower combined end point of occluded infarct artery on angiography or death or recurrent infarction before angiography in the clopidogrel group by 36% and 30-day end point of cardiovascular death, recurrent infarction, or myocardial ischemia requiring urgent revascularization by 20%. There was no increase in major bleeding in the clopidogrel group [15]. Thus, clopidogrel pretreatment is reasonable in most patients with STEMI in the emergency department along with aspirin, unless contraindicated. Moreover, for patients undergoing PCI, clopidogrel reduces mortality before and after revascularization, without any increase in major or minor bleeding risk [15].

Antithrombotic agents

Unfractionated heparin is indicated for all STEMI patients, except those receiving streptokinase. The recommended heparin regimen with fibrinolysis is a bolus of 60 U/kg (maximum 4000 U) and maintenance of 12 U/kg/h (maximum 1000 U/kg/h [800 U/kg/h in elderly]). The goal is to maintain an activated partial thromboplastin time 1.5 to 2.0 times that of control times (or between 50 and 70 seconds). An alternative to unfractionated heparin is low molecular weight heparin (LMWH, 30 mg IV bolus and 1 mg/kg every 12 hours). Recent investigations have supported the use of LMWH over unfractionated heparin for the reduction of recurrent ischemic events in patients receiving fibrinolysis and those undergoing primary PCI [16,17]. However, LMWH should only be used in patients younger than 75 without renal dysfunction receiving fibrinolytic therapy. The role of LMWH in patients undergoing primary PCI is less clear. Fondaparinux, a novel factor Xa inhibitor,
has been shown to significantly reduce mortality and reinfarction in patients with STEMI, particularly those not undergoing primary PCI and may be considered as an antithrombotic agent for those receiving fibrinolytic therapy [18].

**Glycoprotein IIb/IIIa inhibitors**

The American College of Cardiology/American Heart Association (ACC/AHA) guideline recommends that it is reasonable to start abciximab (a glycoprotein GP IIbIIIa receptor antagonist) as soon as possible in the emergency department once a decision for primary PCI is made (Class IIa recommendation, [2]). This treatment has been shown to be associated with increased infarct artery patency before primary PCI and reduction in recurrent ischemic events needing urgent target vessel revascularization in these patients [2]. Similarly, the guidelines recommend that the use of abciximab with half-dose reteplase or tenecteplase may be considered for preventing reinfarction in selected patients with STEMI (anterior infarction, age younger than 75 and low risk of bleeding, Class IIa recommendation). The role of eptifibatide and tirofiban is less well defined in patients with STEMI.

**Beta-blockers, calcium antagonists, angiotensin converting enzyme (ACE) inhibitors, angiotensin receptor blockers, lipid lowering agents, warfarin, and modulation of glucose-insulin axis**

All STEMI patients without contraindications should receive beta-blocker therapy upon arrival. Contraindications to beta-blocker therapy include heart rate less than 50 beats per minute (bpm), peripheral hypoperfusion, decompensated congestive heart failure, shock, advanced AV block, asthma, or reactive airway disease [2]. The use of these agents has been shown to decrease the risks of mortality, recurrent ischemic events, reinfarction, ventricular fibrillation, sudden cardiac death, cardiac rupture, and intracranial hemorrhage. Oral over intravenous beta-blockers should be preferred unless patients have significant hypertension and tachyarrhythmias at presentation. Calcium channel blockers should be avoided in STEMI patients. However, verapamil or diltiazem may be prescribed to patients with STEMI and recurrent ischemic events or atrial tachyarrhythmias who are intolerant to beta-blocking agents and who do not have hypertension, advanced AV block, heart failure, shock, bradycardia, or left ventricular ejection fraction less than 40%.

An angiotensin converting enzyme (ACE) inhibitor should be started in the first 24 hours of admission in all patients with STEMI who have an left ventricular ejection fraction less than 40%, pulmonary congestion, anterior STEMI who do not have a systolic blood pressure less than 100 mm Hg or 30 mm Hg below baseline, or who have no contraindications to these agents (Class IA recommendation, [2]). In patients intolerant to ACE inhibitors, an angiotensin receptor blocker should be administered in this cohort.
ACE inhibitors have been shown to decrease mortality, heart failure, and recurrent ischemic events in this high-risk cohort. ACE inhibitors (or angiotensin receptor blockers when ACE inhibitors are contraindicated) should also be used in all patients with STEMI with diabetes or hypertension. Intravenous ACE inhibitors have been shown to increase adverse events and should not be used in STEMI patients [2].

A lipid profile should be obtained within 24 hours of admission [2], since low density lipoproteins cholesterol levels begin decreasing immediately after the event. Aggressive lipid-lowering therapy in the acute phase has been shown to be associated with modest benefit. Nonetheless, aggressive lipid-lowering therapy has been unequivocally proven to be efficacious for secondary prevention of patients with coronary artery disease for reduction in mortality, recurrent ischemia or infarction, need for repeat revascularization, or stroke and should be prescribed at discharge unless contraindicated [19].

Long-term anticoagulation is indicated in patients with large anterior infarction, left ventricular aneurysm, or atrial fibrillation for prevention of intracardiac thrombus and its embolic complications. An insulin infusion should be given in the first 24 to 48 hours to normalize blood glucose in patients with STEMI, particularly those with complicated course. Finally, electrolyte abnormalities of potassium and magnesium should be closely monitored and treated appropriately to prevent arrhythmic events [2].

Other invasive management

Intraaortic balloon pump (IABP) use is indicated in all patients with cardiogenic shock, acute mitral regurgitation, ventricular septal rupture, refractory postinfarction angina, or recurrent intractable ventricular arrhythmias [2]. The need for temporary pacing has decreased significantly with the advent of reperfusion strategies but should be considered in patients with symptomatic bradyarrhythmias, bilateral alternating bundle branch block, new trifascicular block, or Mobitz type II block [2]. The use of pulmonary artery catheter may be considered in patients with severe progressive heart failure, progressive hypotension, shock, ventricular septal rupture, mitral regurgitation, or cardiac tamponade [2]. Similarly, invasive arterial monitoring is recommended for patients with systolic blood pressure less than 80 mm Hg, cardiogenic shock, and use of intravenous vasopressors or nitroprusside [2].

Complications of STEMI

Mitral regurgitation

Acute mitral regurgitation is a life-threatening complication that can occur with or without papillary muscle rupture. It is more common with inferior STEMI, usually because of occlusions of the right coronary or left circumflex arteries. Medical management carries a very high mortality (70%). Surgical mortality, although high, is still lower (40%) than medical
treatment alone [20]. Diagnosis can be established rapidly by transthoracic and if required transesophageal echocardiography. All patients should be considered for emergent surgery while stabilization is achieved by IABP, inotropes, and vasodilators. Delay in operation increases the risk of myocardial and other organ injury and subsequent death [2]. Five-year survival is excellent and reported to be between 60% and 70% in patients who survive surgery [2]. Mitral regurgitation in absence of papillary muscle rupture indicates extensive infarct and severe left ventricular dysfunction. Medical treatment may sometimes lead to reduction in mitral regurgitation severity in this cohort. However, when surgery is required for ongoing ischemia or critical coronary anatomy, mitral valve surgery should be undertaken in patients with mitral regurgitation > grade 2 on transesophageal echocardiography [2].

**Ventricular septal rupture**

The frequency of acute ventricular septal rupture (VSR) has decreased in the reperfusion era and occurs in fewer than 1% of patients with STEMI. Emergency surgical repair is necessary not only in patients with pulmonary edema or cardiogenic shock, but also in hemodynamically stable patients, as sudden hemodynamic collapse occurs even in these patients. Initial stabilization with IABP, invasive monitoring, inotropes, and vasodilators and prompt surgical referral is recommended for almost every patient with an acute VSR. Surgical mortality remains high and has been reported to be 20% to 50% and is much higher in patients with cardiogenic shock [21]; however, surgical mortality is significantly less than medical management alone. Too few patients with postinfarction VSR have been treated by transcatheter closure with a septal occluding device to make any definitive recommendations.

**Left ventricular free wall rupture**

Cardiac rupture occurs in up to 2% of all patients admitted with STEMI and is typically manifested by chest pain and EKG changes, with rapid progression to hemodynamic collapse and electromechanical dissociation. Cardiac rupture is observed most frequently in patients with their first myocardial infarction, those with anterior infarction, the elderly, women, hypertension during the acute phase of STEMI, lack of previous angina and myocardial infarction, lack of collateral blood flow, Q waves on the EKG, use of corticosteroids or nonsteroidal anti-inflammatory drugs, and use of fibrinolytic therapy more than 14 hours after onset [2]. Reperfusion therapy decreases risk of cardiac rupture [22]. Pseudoaneurysm is a serious complication after rupture of the free ventricular wall. Clot forms in the pericardial space, and an aneurysmal wall containing clot and pericardium prevents exsanguination. Prompt surgical correction is indicated for pseudoaneurysm to prevent rupture. Pericardiocentesis, preferably in the operating room, for relief of tamponade and emergency surgical repair may be life saving with repair of rupture undertaken soon. Surgical mortality in studies
with small number of patients with this complication has been reported to be as high as 60% [2].

**Left ventricular aneurysm**

Left ventricular aneurysm after STEMI usually occurs in patients with anterior wall infarction with total left anterior descending artery occlusion. Clinical consequences include angina pectoris, heart failure, thromboembolism, and ventricular arrhythmias. Like all other complications of STEMI, reperfusion therapy is associated with a significantly reduced incidence of LV aneurysm formation. Oral anticoagulation is recommended in patients with mural thrombus and for 3 months after acute anterior STEMI. Surgery for ventricular aneurysm early after STEMI is recommended for control of heart failure or intractable ventricular arrhythmias unresponsive to conventional therapy. Patients with severe left ventricular dysfunction have an increase in mortality as high as 19% in those with left ventricular ejection fraction less than 20%. Operative survivors have clear improvement in New York Heart Association class and a 60% 5-year survival rate [2].

**Right ventricular infarction**

Right ventricular infarction (RVI) commonly occurs in patients with an inferior myocardial infarction (and very rarely with anterior myocardial infarction). Although RVI is evident in approximately 25% of an inferior STEMI patients, hemodynamic compromise is evident in fewer than 10% of these patients. Consequently, EKGs with right-sided precordial leads should be monitored in all patients with an inferior STEMI [2]. A triad of hypotension, jugular venous distention, and clear lungs is very specific but has poor sensitivity for RVI. In the ED, RVI can be diagnosed by ST elevation in lead V4R, and suspected in hypotension induced by nitroglycerin. A right atrial pressure higher than 10 mm Hg and a right atrial/pulmonary capillary wedge pressure ratio of 0.8 or higher are strongly suggestive of RVI. Besides hypotension and shock, other concomitant findings include advanced atrioventricular block and atrial tachyarrhythmias. Treatment of RVI includes volume loading, inotropic support with dobutamine, and maintenance of atrioventricular synchrony. Immediate reperfusion with primary PCI (or fibrinolytic therapy when timely primary PCI not available) have shown to improve right ventricular function and decrease 30-day mortality [2].

**Left ventricular failure and cardiogenic shock**

Heart failure is present in 15% to 25% of patients with acute myocardial infarction with an in-hospital mortality rate of 15% to 40%. The severity of left ventricular dysfunction is proportional to the extent of myocardial injury. Mortality has been reported to vary from 6% in patients with clear lung fields and no third heart sound to up to 60% in patients with cardiogenic shock in
reperfusion era. Low output, or cardiogenic shock can occur in patients with severe left or right ventricular dysfunction, acute papillary muscle, ventricular septal or left ventricular free wall rupture, or tachy- or bradyarrhythmias [2]. Those at high risk for cardiogenic shock are elderly, female, hypertensive, diabetic, and with prior myocardial infarction. Fibrinolysis is not an effective reperfusion strategy in this cohort, but emergency revascularization (percutaneous or surgical) is associated with significant reduction in mortality [23]. Medical stabilization with IABP, invasive monitoring, inotropes, and vasodilators should be achieved with a goal for emergent revascularization.

Arrhythmias in patients with STEMI

Detailed description and management of all arrhythmias complicating STEMI is beyond the scope of this review and some of these are discussed in detail in other sections of this monograph. The two important arrhythmic complications reviewed here are ventricular and atrial tachyarrhythmias.

Atrial fibrillation/flutter

Atrial fibrillation (and flutter) in STEMI is an independent predictor of 30-day mortality. While it may be related to atrial infarction, pericarditis, or excessive sympathetic stimulation from pain, distress, or anxiety, another important cause is left ventricular failure with elevated left atrial pressure [24]. Atrial fibrillation leads to increased oxygen demand, decreased left ventricular filling, loss of atrial contribution to left ventricular filling, and diminished forward cardiac output. Thus, all efforts should be directed at reducing ventricular rate (beta-blockers, verapamil, diltiazem, digitalis, anti-congestive measures) and preferably toward restoration of sinus rhythm (cardioversion, procainamide, amiodarone, and rapid atrial overdrive pacing). Prevention of thromboembolic events with long-term warfarin should be an important goal if sinus rhythm is not restored [2].

Ventricular fibrillation and tachycardia

Ventricular tachycardia (VT) is defined as more than 100 bpm, with sustained VT for longer than 30 seconds and nonsustained VT for less than 30 seconds. VT occurs more frequently within the first 48 hours of symptom onset and, in the past, was generally believed to be unrelated to prognosis. Newer studies indicate that nonsustained VT and sustained monomorphic VT even within the first few hours of symptom onset indicate poorer inhospital and long-term outcomes. VT that occurs more than 48 hours after STEMI may denote an arrhythmic substrate deserving of further evaluation by an electrophysiology study [2].

Sustained VT should be managed by immediate cardioversion if the patient is hemodynamically unstable. If angina, pulmonary edema, or hypertension are not present, patients may be treated with intravenous
amiodarone, lidocaine, or procainamide. Replacement of potassium and magnesium, treatment with beta-blockers, and reperfusion with relief of ischemia may help decrease the incidence of VT.

Primary ventricular fibrillation (VF) must be distinguished from secondary ventricular fibrillation that occurs in patients with congestive heart failure or cardiogenic shock [25]. Late VF occurs more than 48 hours after onset of STEMI. Secondary and late VF is associated with significantly higher mortality than primary VF. VF should be treated immediately with unsynchronized monophasic electric shock. Other measures, such as correction of electrolytes, reperfusion, and beta-blockers, may help reduce the incidence of VF. Prophylactic use of lidocaine has no role in prevention of ventricular arrhythmias and may increase incidence of asystolic arrest and should be avoided in all patients with STEMI.

Finally, an implantable cardioverter defibrillator (ICD) is indicated for patients with VF or hemodynamically significant sustained VT more than 2 days after STEMI, provided the arrhythmia is not judged to be due to transient or reversible ischemia or reinfarction. Additionally, patients without spontaneous VF or sustained VT more than 48 hours after STEMI whose STEMI occurred at least 1 month previously, who have a left ventricular ejection fraction between 31% and 40%, demonstrate additional evidence of electrical instability (eg, nonsustained VT), and have inducible VF or sustained VT on EP testing may also benefit from ICD for prevention of sudden cardiac death. In patients with left ventricular ejection fraction less than 30% at 1 month post-STEMI, ICD is also indicated for secondary prevention of sudden cardiac death even in the absence of any ventricular arrhythmias [2].

**Recurrent ischemic events**

Infarct extension may occur as extension of infarction in the same territory as subendocardial or transmural myocardial necrosis or involving adjacent territories. Postinfarct angina occurs in 23% to 60% of patients and is higher among patients receiving fibrinolysis compared with primary PCI [12]. Postinfarct angina is associated with increased incidence of sudden death, reinfarction, and other acute cardiac events. Definitive treatment is achieved with percutaneous or surgical revascularization of ischemic coronary arteries.

**Pericarditis**

Pericarditis occurs in about 10% of patients, usually within first 24 to 96 hours. This event is heralded by progressive, severe chest pain that increases with inspiration, swallowing, and body movements and is postural, being alleviated when the patient sits up. The incidence has decreased significantly in the era of reperfusion therapies. Treatment consists of high-dose aspirin (650 mg every 4 to 6 hours). Nonsteroidal anti-inflammatory agents and steroids should be avoided as they impair myocardial healing and
promote infarct expansion. Colchicine may be beneficial in patients with recurrent pericarditis. Finally, Dressler’s or post–myocardial infarction syndrome occurs in 1% to 3% of patients about 1 to 8 weeks after STEMI. Patients present with chest pain suggestive of pericarditis, fever, arthralgia, malaise, elevated leukocyte count, and elevated erythrocyte sedimentation rate [2]. Treatment is similar for acute pericarditis, and occasionally long-term corticosteroids with slow taper is needed.

Prognosis

Many risk prediction models have been developed for estimating the risk of patients presenting with STEMI. The Thrombolysis in Myocardial Infarction (TIMI) risk score for patients with STEMI is shown in Fig. 4 and has been validated in several trials [26]. The TIMI risk score is useful in discriminating patient risk across a wide spectrum with a score of 0 associated with less than 1% to that which is more than 30-fold higher when the total score is more than 8 (35.9%). It should be recognized that risk stratification is a continuous process and requires incorporation of information over time after initial assessments that includes indicators of failed reperfusion (eg, recurrence of chest pain, persistence of EKG findings indicating infarction), left ventricular systolic function, mechanical complications, 

Fig. 4. Prediction of 30-day mortality using Thrombolysis in Myocardial Infarction (TIMI) risk score for ST-elevation myocardial infarction. (Adapted from Morrow DA, Antman EM, Charlesworth A, et al. TIMI risk score for ST-elevation myocardial infarction: a convenient, bedside, clinical score for risk assessment at presentation: An Intravenous nPA for Treatment of Infarcting Myocardium Early II trial substudy. Circulation 2000;102:2031–7; with permission.)
arrhythmic events after 48 hours, new-onset heart failure or shock, and lack of secondary prevention therapies or intolerance to these treatments, all of which increase subsequent risks. Risk stratification allows for early discharge of low-risk patients and aggressive invasive management and closure surveillance of the high-risk group.

Other in-hospital and discharge care of STEMI patients

Evidence-based approaches of the need for invasive procedures (cardiac catheterization and revascularization) and noninvasive tests are outlined in Fig. 2. This strategy is helpful in deciding the type of exercise test and the cohort who should undergo invasive procedures. Ejection fraction should be estimated by echocardiography in patients managed medically.

Finally, all secondary prevention strategies should be instituted before discharge and continued after discharge. Education regarding patient’s disease and methods to prevent recurrent ischemic events should be an important part of discharge planning. All patients should be considered for long-term therapy with aspirin, beta-blockers, lipid-lowering agents, and ACE inhibitors. Clopidogrel is indicated in patients with aspirin allergy and in those who had coronary stent(s) implanted before discharge. Warfarin anticoagulation is indicated for patients with large anterior STEMI, left ventricular thrombus, atrial fibrillation, and those unable to take long-term aspirin or clopidogrel. All patients should be considered for a cardiac rehabilitation program and should follow diet and exercise prescriptions. Smoking cessation and control of hypertension, dyslipidemia, diabetes, and weight to target values should be vigorously pursued [2].

References


