Standard Patient Assessment—Monitoring Devices and Medicine—Cardiovascular

Competency Integrates scene and patient assessment findings with knowledge of epidemiology and pathophysiology to form a field impression. This includes developing a list of differential diagnoses through clinical reasoning to modify the assessment and formulate a treatment plan.

Integrates assessment findings with principles of epidemiology and pathophysiology to formulate a field impression and implement a comprehensive treatment/disposition plan for a patient with a medical complaint.

TOPIC 27

ACUTE CORONARY SYNDROME AND THE MULTILEAD ECG

INTRODUCTION

Every year, nearly 500,000 Americans die from acute myocardial infarction (AMI). In fact, in the acute setting of an AMI, mortality rates go up 1 percent for every 10 minutes of an occluded coronary artery. As such, treatment of these patients is truly a race against the clock. Treatment of AMI has progressed in leaps and bounds in the past 20 years, and the level of technology used to resolve this pathology is at an all-time high.

All these methodologies rely on teamwork at all levels of the health care world. To maximize outcomes, prehospital providers must pair with emergency department (ED) personnel, and hospital staff must work closely with more advanced departments, to provide the patient a smooth and rapid transition to definitive care. Few other areas of prehospital medicine rely more heavily on these partnerships.

Within this team dynamic, paramedics are used to rapidly identify and transport the AMI patient. An AMI is diagnosed using history, electrocardiograms (ECGs), and biomarkers; even though none of these elements is immediate or perfectly precise, ECG, when used correctly, can provide a reliable method to rapidly rule in at least a certain percentage of these patients. This capability has been proven to be accessible and reliable in the world of prehospital medicine.

Although the ST elevation myocardial infarction (STEMI) is present in a comparatively small minority of the overall number of patients having an AMI, it is still readily identifiable and, as such, is an important marker that can be used to initiate treatment. Moreover, this marker is used not just in the hospital, but in the prehospital environment as well. Paramedics every day combine a larger clinical picture of the patient with this key ECG finding and initiate a specific treatment standard to aggressively treat the AMI.

In some cases, paramedics will initiate thrombolytic medications, but even if definitive treatment is not administered prehospitally, the identification of an AMI and subsequent notification has been shown consistently to significantly reduce the time it takes to initiate definitive care in the hospital. Many acute coronary syndrome (ACS) systems rely on early identification of STEMI to initiate multiple levels of response to provide the highest level of therapy—and, in most cases, identification begins in the prehospital world. Multilead monitoring is a vital component of ACS care; every paramedic should use it to its fullest capability.

TRANSITION *highlights*

- ***Importance of acute myocardial infarction (AMI) recognition.***
- ***Role of multilead monitoring in AMI recognition.***
- ***Review of key monitoring steps.***
- ***Findings that can indicate the AMI.***
- ***Findings that mimic the AMI.***
- ***The future of multilead monitoring.***

This topic reviews the role of multilead monitoring in the identification and treatment of AMI. It is not intended to be a comprehensive review of cardiac monitoring. Rather, this topic reviews the general diagnostic uses of ECG in ACS and examines key steps to make its use most beneficial. In some cases, this topic discusses specific application procedures, but it does not provide a complete step-by-step process. If you are uncomfortable with basic ECG monitoring, please refer to a paramedic textbook for more information (also see Topic 22, "Patient Monitoring Devices," for further information).

Paramedics must always assess and treat the patient, not just the cardiac monitor.

ECG AND AMI DIAGNOSIS

In ACS, ECG is only one part of a larger diagnostic picture. Paramedics must always assess and treat the patient, not just the cardiac monitor. However, ECG can be a vital tool when used in the correct context.

An AMI is caused by obstructed blood flow to myocardial tissue. As this tissue becomes ischemic and injured and begins to die, predictable signs become evident. As Topic 26 discussed, these signs are often perceptible from the outside. Chest pain, for example, is a frequent result of ischemia in the heart. Other signs can include the detectable release of chemical biomarkers that indicate cardiac injury.

Electrically speaking, ischemia, injury, and infarction also cause predictable changes in the cardiac conduction system. The pathophysiology of poor myocardial cell perfusion causes very specific changes to the depolarization and repolarization process used to initiate and transmit cardiac conduction. As blood flow (and oxygen delivery) to the myocardial cell is diminished, the cell becomes depleted of the adenosine triphosphate (ATP) that powers its sodium–potassium pump. When the pump is disrupted, the movement of sodium and potassium is delayed or stopped, resulting in a slowing or a failure of the cell to repolarize. A multilead cardiac monitor can identify the sum of these repolarization changes by looking at the ST segment of the QRS complex. ST segment depression—and, more important, ST segment elevation—signify changes in repolarization and can be used to identify ischemia and injury issues within the myocardium that are frequently caused by ACS.

Slow repolarization and infarction of cardiac cells can also cause changes in the vector of repolarization and depolarization through the heart. Depolarization of the heart occurs along a predictable pathway. Organization of pacemaker cells and the conduction pathway cause predictable deflections of the QRS complex as the heart muscle is depolarized and repolarized.

Most STEMI protocols are activated by the identification of ST elevation in two or more congruent leads.

As you may recall, the direction of deflection of the various waves that make up the QRS complex represent the vector (direction) of either depolarization (as in the QRS complex itself) or repolarization (as in the T wave). When conduction in the heart is disrupted by ischemia, these vectors can change. Slowly repolarizing tissue causes the direction of conduction to be altered. For example, T waves represent the repolarization of ventricular tissue. When this tissue repolarizes slowly as a result of ischemia, T wave vectors can be found moving in opposite directions compared with the QRS complex (this condition is commonly called *flipped T waves*). Q waves can also be deepened by electrically neutral infarcted (dead) cells.

Occasionally, ischemic and infarcted cells also can cause a bundle branch block. Here, normal cardiac depolarization must bypass the area of poor conduction and typically does so by moving off the conduction pathway. Not only does this shift the axis of depolarization, but the cell-to-cell transmission also slows conduction, causing a widened QRS complex on the ECG.

Electrical Diagnostic Criteria

The pathophysiology of ACS can be represented on a multilead ECG in three ways:

- **Ischemia.** Ischemia can be seen by looking for new ST depression (an ST segment at least 1 mm depressed from the isoelectric baseline in at least two congruent leads) and flipped T waves (T waves with opposite vectors compared with the QRS complex in at least two congruent leads).
- **Injury.** Injury is identified by ST segment elevation (>1 mm in two congruent leads) (some references will note >2 mm in septal leads).
- **Infarction.** Infarction is identified by the presence of pathologic Q waves (>0.04 sec wide or 1/3 of R, with ST elevation).

Practical Application of ECG Diagnostic Criteria

Although system protocols vary, most organized STEMI protocols are activated by the identification of ST elevation in two or more congruent leads. It is also generally accepted that the presence of a new onset left bundle branch block (LBBB) is a presumptive positive finding (although differentiating new versus old in the prehospital environment may be challenging). It cannot be emphasized enough, however, that no patient is diagnosed purely on ECG criteria. Many additional clinical factors must be considered. ECG does play an essential role, however. The paramedic will use electrical findings in context with other signs and symptoms to help define a larger clinical picture.

The paramedic must further discern transient and permanent electrical findings. Pathologic Q waves identify infarcted cells but are not typically useful in the prehospital world because they are a permanent finding associated with AMI. That is, once they present, they are always there. As such, without an older ECG for comparison, it is impossible to determine whether Q waves are related to an acute event or to an older long-standing problem. Bundle branch blocks can be a permanent finding, but they can also be transient in nature.

Transient findings occur acutely, but can resolve as the dysfunction is eliminated. Transient findings are generally more important in the diagnosis of an acute event. Because transient findings are correctable, they generally symbolize new findings and are more reliable indicators of an acute problem. ST elevation is the most important finding, as it most commonly represents newly injured myocardial cells. Most ACS treatment systems use this finding (in context) to initiate specific AMI treatment. Remember also that transient changes develop (and change) over time. Initial findings may be very different from later findings. Multilead ECG is therefore an important serial finding.

There is context even within electrical findings. The importance of multilead monitoring is that it gives credibility to specific findings. Just as reporters use multiple sources to confirm a story, paramedics use multiple leads to confirm their suspicions. Multiple leads look individually at specific anatomic regions of the left ventricle (and the entire heart) and provide multiple electrical views of cardiac conduction.

Changes found in one lead are not diagnostic. For example, a singular ST elevation finding in lead II is meaningless. However, multilead ECG can confirm this finding by identifying it in other leads that look at similar regions of the heart (congruent leads). Although singular findings in just lead II are meaningless, elevations found in leads II, III, and AVF would be considered indicative of AMI. Paramedics should be familiar with the specific ECG leads and the regions of

TABLE 27-1 ECG Leads and Their View of the Heart

Region of the Heart	Leads
Inferior wall (of the left ventricle)	II, III, AVF
Septal wall (of the left ventricle)	V_1, V_2
Anterior wall (of the left ventricle)	V_3, V_4
Lateral wall (of the left ventricle)	I, AVL, V_5, V_6
Posterior wall (of the left ventricle)	V_8, V_9
Right ventricle	V_4R, V_6R

the heart to which they correspond (see Table 27-1).

Furthermore, specific findings can be reinforced by reciprocal changes. Reciprocal changes are changes that occur in a wall of the heart opposite the site of a myocardial infarction (Table 27-2). These specific changes are generally limited to the circumstances related to AMI and greatly enhance the accuracy of a diagnosis.

It is exceptionally important to remember that not every AMI presents with the electrical changes discussed previously. The development of these changes greatly depends on the depth and significance of the AMI. In many cases, these changes will develop and worsen over time. Often, a patient will present with other clinical findings and will not demonstrate electrical changes, but is indeed having a heart attack. At no time should a lack of electrical changes be used to rule out an AMI. Electrical findings, on the other hand, are used to rule *in* AMI. These changes—in the context of a larger clinical picture that includes chief complaint, history, and, at times, cardiac biomarkers—offer a presumptive positive for myocardial infarction.

TABLE 27-2 Reciprocal Changes

Primary Change	Reciprocal Change
II, III, AVF (inferior)	I, AVL (lateral)
I, AVL (lateral)	II, III, AVF (inferior)
V_1, V_2 (septal), V_3, V_4 (anterior)	V_7, V_8, V_9 (posterior)
V_7, V_8, V_9 (posterior)	V_1, V_2 (septal), V_3, V_4 (anterior)

ACCURACY IN DIAGNOSIS

To use the multilead ECG effectively in the diagnosis of ACS, care must be taken to use the device and interpret the results effectively. Improper use can render electrical findings meaningless. Accuracy is ensured in two ways. First, you must ensure accuracy of the setup and lead placement. These physical steps ensure the validity of the product you will next interpret. Second, you must ensure the accuracy of the interpretation to be sure your electrical diagnosis is correct.

ECG Setup and Lead Placement

The use of an electrocardiograph requires appropriate knowledge and proper utilization. As with any machine, it must be used correctly in order to obtain accurate results. ECG machines must be properly maintained, handled, stored, and calibrated according to manufacturer's recommendations in order to be reliable. ECG cables must be handled and stored with care and replaced when malfunctioning.

ECG leads rely on exact external chest placement to reliably look at specific anatomic regions of the heart. Simply put, they must be placed properly to see what they are supposed to see. A common error in ECG-related diagnosis is improper lead placement.

Proper multilead ECG placement begins with the three leads of Einthoven's triangle. These leads were designed as "limb leads" and as such, should be placed on the limbs. Movement of the hands and feet can often interfere with proper electrical tracings; if necessary, these leads can be moved closer to the body, but, by definition, they should not be placed superior to the inguinal folds of the groin or medial to the shoulder joint (▶ Figure 27-1).

Chest leads, also known as the precordial leads, also have exact placement. Table 27-3 and ▶ Figure 27-2 detail specific placement of these leads.

Accuracy of an ECG is also enhanced by obtaining a clear tracing—that is, by eliminating interference and artifacts. A paramedic can take several steps to enhance the clarity of ECG production.

- **Prepare the patient.** Paramedics should always consider preparing the skin prior to application of an ECG lead. Sweat and wetness should be wiped away. Excessive hair should be clipped or shaved. Dead skin should be gently exfoliated by using commercially available prep tape or with the simple use of gentle scrubbing with a towel. Patient preparation also includes talking to the patient about remaining still during the ECG acquisition.
- **Use appropriate leads.** Quality ECG leads are often the most important element in obtaining a quality ECG tracing. Use high-quality leads and handle them properly. Most leads use a water-based conductive gel; when left unsealed, these gels can dry out and cause poor lead contact. Keep leads in sealed containers prior to their use.

Accuracy of Interpretation

In addition to the physical elements of accuracy, accuracy of interpretation is also important. Although the scope of this topic limits a full discussion of ECG interpretation, you should consider interpretation of findings as important as any other element of diagnosis. You should take seriously this responsibility and train accordingly. ECG interpretation can be difficult even under optimal circumstances, and the only way to improve is practice. Paramedics should keep the following concepts in mind:

A common error in ECG-related diagnosis is improper lead placement.

- **Treat the patient.** Always keep in mind that fewer than 40 percent of diagnosed AMIs occur with ST segment elevation. That means that the majority do not. Look at all the clinical findings and history that point to ACS and be inclusive, rather than exclusive. A 12-lead ECG without ST segment elevation does not rule out an AMI. Remember that, at times, diagnosis of an AMI may be a relatively low priority. Always treat immediate life threats, such as bradycardias and tachycardias, first.
- **You are not just diagnosing the ACS.** The underlying rhythm interpretation is important as well. Rhythm abnormalities, such as ventricular

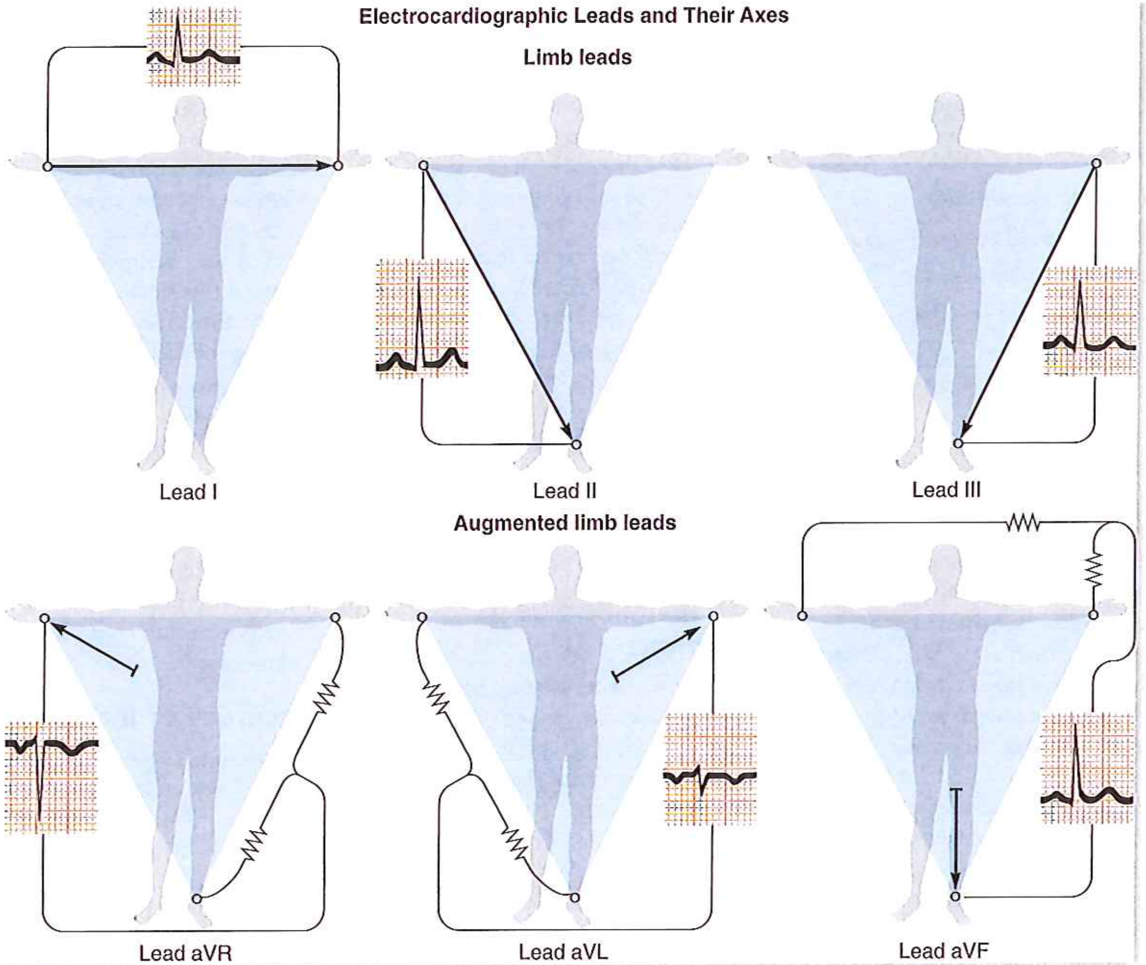

Figure 27-1 Placement of limb leads.

rhythms and bundle branch blocks, can interfere with your ability to make ST segment judgments and identify ACS. Always start with basic ECG interpretation and then move to ST analysis.

TABLE 27-3 Precordial Lead Placement

Lead	Placement
V_1	4th intercostal (IC) space right of the sternum
V_2	4th IC space left of the sternum
V_3	Midway between V_2 and V_4
V_4	5th IC space midclavicular line
V_5	5th IC space anterior axillary line
V_6	5th IC space mid-axillary line
V_8	5th IC space mid-scapular
V_9	5th IC space between V_8 and spine
V_4R	Same as V_4 but on right chest
V_6R	Same as V_6 but on right chest

- **Look at multiple leads.** No one lead can be diagnostic in and of itself. Diagnosis of ACS requires multilead interpretation.
- **Practice and utilize quality improvement.** ECG interpretation is a skill that is acquired through practice and self-examination. Take advantage of training opportunities and always review the mistakes you made. Take time to discuss questionable findings. Discuss your thoughts with your medical director.
- **Use diagnostic software.** Although there are flaws, most modern diagnostic packages are exceptionally sensitive to recognizing STEMI. Of course, you should place that diagnosis in the context of the larger clinical picture, but think of it as a second set of eyes.

STEMI IMITATORS A variety of conditions can mimic the electrical findings of STEMI. Although there are far more conditions that can confound diagnosis, the following situations are the most commonly confused imitators:

- **Left bundle branch block (LBBB).** LBBB can cause ST elevation changes as the vector of depolarization is altered and repolarization of cells takes place more slowly outside the conduction pathway. This can cause ST elevation because of the block and not necessarily because of acute injury to cells. Unfortunately, an LBBB can actually be caused by an AMI, so it is difficult to discern whether what you are seeing is acute or chronic. As previously stated, most systems accept LBBB as a presumptive positive finding for AMI.
- **Left ventricular hypertrophy (LVH).** In this chronic condition, in which the left ventricle becomes enlarged and more massive, conduction changes (particularly axis and repolarization changes) can mimic STEMI. A key differential will be exceptionally positive or negative R and S waves. A typical diagnostic criterion is to add the depth of the S wave in V_1 or V_2 (whichever is deepest) to the

height of the R wave in V_5 or V_6 (whichever is tallest). If the total is ≥35 mm, then LVH is present.) LVH also does not present with reciprocal change, so the presence of such changes can be indicative of ACS.

- **Pericarditis.** An infection causing inflammation and the accumulation of fluid in the pericardial membrane can put pressure on the myocardium and cause resultant electrical changes in the ST segment. Pericarditis is typically differentiated by the fact that its changes are not specific to a region but are generally more global. Rather than seeing ST elevation in the inferior leads, you would see elevation among all leads. History that points to infection (fever, chronic onset, pain increased by supine position) can also guide this differential diagnosis.
- **Hyperkalemia.** Hyperkalemia, or increased potassium levels, can cause ST elevation and T wave changes that mimic STEMI. Typically, the hyperkalemic patient has a history that points toward electrolyte imbalance. Hyperkalemia is common among renal failure and dialysis patients. Hyperkalemia can typically be differentiated by looking for its signature elevated and peaked T waves, but there also may be decreasing amplitude P waves and widening QRS complexes as the condition worsens.

It is important to point out that each of these imitators has at least one element that can be identified through a thorough patient history. This fact underscores the importance of assessing the entire patient, not just the ECG finding.

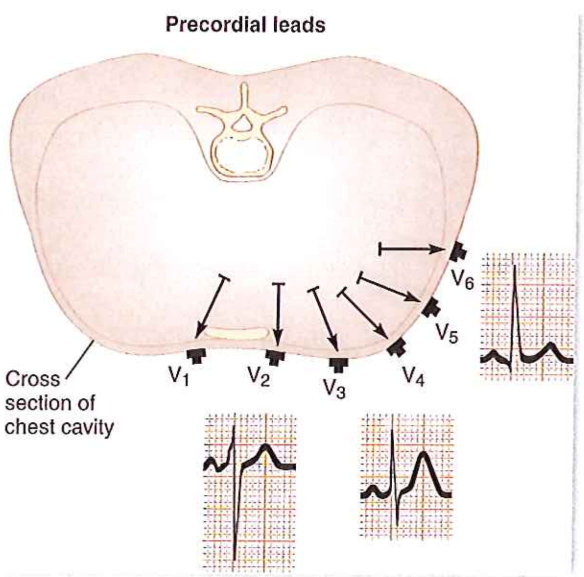

Figure 27-2 Precordial lead placement.

CREATING A COORDINATED RESPONSE ACROSS THE HEALTH CARE SYSTEM

In many cases, ECG is an important criterion used to activate a larger series of events. Although a lack of ST elevation does not rule out an MI, accurate interpretation of ST elevation can rule one in. As such, identifying such findings is an important start to many larger protocols. In fact, many treatment protocols identify STEMI as a separate category of care because of the relative sensitivity of the ECG finding. In other words, because ST elevation is such a reliable finding, we can be more aggressive in treating these patients. In other situations, without ECG confirmation, we may still treat ACS, but we may need to be slightly more conservative until more definitive diagnostics, such as biomarkers, are available.

Although local protocols vary, ECG findings commonly are used to guide destination choices. Many systems have developed protocols for the immediate transfer of patients to specific hospitals that are capable of percutaneous coronary intervention (PCI); typically, the most important indicator for the bypass of other facilities is ST elevation (and, in some cases, LBBB). Some systems, in the interest of decreasing door-to-open-artery time, have even allowed for bypass of the ED and transport directly to the catheterization center. Although this practice would be otherwise dangerous and create increased liability, it can be made possible by the specific finding of STEMI.

Note that ECG is not the only factor considered in any cardiac triage system; the larger clinical picture of the patient is always examined as well. ECG findings must be paired with symptomology and patient history and placed within the context of the larger system protocols. Many systems further require the use of interpretive software and some require transmission of findings. Although some paramedics consider these requirements to be a doubting of their own capabilities, these additional requirements should be viewed as enhancing the diagnostic capability and avoiding overtriage. Of course there is no way to avoid a certain number of mistakes. Most trauma systems happily accept overtriage rates as high as 10 percent to 15 percent (and, in some cases, much higher).

Even if your system does not allow for bypassing a smaller hospital or direct transport to the catheterization center, STEMI findings can still decrease door-to-open-artery time. Although you may transport to a hospital without catheterization capabilities, notifying the hospital of earlier presumptive findings can simply make all levels of care move faster. In some cases, that may mean that fibrinolytics are considered earlier; in other cases, it may mean more active steps. In any case, earlier treatment means less mortality.

THE FUTURE OF ACS CARE

Because mortality is so linked with time in ACS care, the future is surely linked to earlier and earlier identification and treatment. Most likely, the capabilities to recognize an STEMI will increase.

Paramedics should adapt their practice to include earlier acquisition of 12-lead ECG. The American Heart Association now recognizes the first 10 minutes as a target window for ECG acquisition. Paramedics should consider suspected ACS as a time-sensitive disorder. Furthermore, the criteria for 12-lead ECG should also be expanded. More patients, especially those with vague complaints, should receive a multilead ECG. Weakness, syncope, and shortness of breath should all be considered indications for a multilead ECG. Again, recognizing STEMI creates different treatment options.

In the future, technology will enhance our capabilities. Even in the past few years, interpretive software has become more sensitive and more specific. The future will likely hold advances that can assist our interpretation and rely less on human frailties and biases. Transition capabilities have also dramatically improved. The paramedic's ability to share not only ECG data, but also the full spectrum of telemedicine findings, will enhance communication and will allow for a further extension of the health care system.

Some examples exist of paramedics initiating thrombolytic therapy in the field. In most cases, these administrations are both guided by transmission capabilities and reviewed under a rigid system of medical direction. The debate about the value of PCI and thrombolytics continues, but this area may certainly provide a boon once more information is made available.

TRANSITIONING

REVIEW ITEMS

1. New ST depression, when found in two congruent leads, would be an ECG finding that indicates ______.
   a. ischemia
   b. infarction
   c. injury
   d. normal conduction

2. New ST elevation, when found in two congruent leads, would be an ECG finding that indicates ______.
   a. ischemia
   b. infarction
   c. injury
   d. normal conduction

3. Which of the following would be the transient ECG finding most commonly used to identify injury to myocardial cells?
   a. ST depression in two congruent leads
   b. Q-waves
   c. cardiac biomarkers
   d. ST elevation in two congruent leads

4. Which of the following would be considered a presumptive positive finding that indicates AMI?
   a. left ventricular hypertrophy
   b. T-wave inversion
   c. left bundle branch block
   d. ST depression in two congruent leads

5. Which of the following would be a condition that mimicked the ECG findings associated with STEMI?
   a. asthma
   b. endocarditis
   c. hyperkalemia
   d. pulmonary embolism

APPLIED PATHOPHYSIOLOGY

1. Describe briefly why ST segment elevation occurs in some AMIs.
2. Explain the difference between transient and permanent ECG findings.
3. Why are transient ECG findings more important than permanent findings in diagnosing AMI?
4. Explain how you might differentiate pericarditis from STEMI.
5. Explain why an ECG cannot rule out an AMI.

CLINICAL DECISION MAKING

A 61-year-old woman complains of acute onset nausea, vomiting, and weakness. She states that she feels like she is going to pass out. On arrival, you find her seated on the toilet, pale, diaphoretic, and breathing rapidly.

1. Describe your initial actions and assessments.
2. Based on the initial description, do you consider ACS as a possible cause of her problems? Why or why not?

The patient's airway is patent, but she tells you she cannot catch her breath. Her respiratory rate is 30 with clear lung sounds. The patient has a weak radial pulse at 52. Her skin is wet. She is awake and alert, but notes she feels very dizzy. The patient denies chest pain and notes that the nausea and vomiting "came on out of nowhere." Initial vital signs are pulse 58, respirations 30, blood pressure 86/62 mmHg.

3. Given this primary assessment, what immediate actions do you need to take?
4. What additional diagnostic tests do you need to run?
5. Should you initiate a 12-lead ECG?

You decide to do a 12-lead ECG, which shows ST elevation in leads II, III, and AVF and T wave inversion in leads I and AVL.

6. Given these findings, what should you conclude?
7. What additional therapies does this patient need?