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Learning objectives for this study guide

Given information from class discussion, class handouts and reading materials, and this study guide, the CET candidate will demonstrate the ability to:

- Describe proper lead placement when acquiring various EKG tracings.
- List the EKG waveforms.
- Identify specific waveforms on the EKG.
- Measure the duration of waveforms on the EKG.
- Identify the direction of wave deflection.
- Determine T wave symmetry.
- Determine P wave symmetry.
- Measure the heart rate from the EKG tracing.
- Differentiate artifact from normal EKG tracing waveforms.
- Describe how to eliminate artifact from an EKG.
- Interpret arrhythmias originating in the sinus, atria, junction, and ventricles.
- Recognize pacer spikes on the EKG.
- Identify ischemic changes on the EKG.
- Describe the proper response for life-threatening arrhythmias.
- Describe how to maintain the EKG machine.
- Obtain the patient’s social, medical, surgical, and medication history.
- Educate patients about the EKG, Holter monitoring, stress testing, and telemetry.
- Properly apply EKG electrodes to acquire a 3-, 5- and 12-lead EKG, and for Holter monitoring.
- Discuss modifications to EKG lead placement for pediatric patients, right-sided EKG, and patients with limb amputations.
- Discuss the signs and symptoms of cardiopulmonary compromise.
- Discuss the Health Insurance Portability and Accountability Act (HIPAA) and protected health information (PHI).
- Monitor the patient’s condition during stress testing.
- Respond to complications during stress testing.
- List expected reference range vital-sign parameters for different age groups.
About the certification

Certified EKG Technician (CET) is a certification the National Healthcareer Association (NHA) issues to a person who obtains additional training in administering and interpreting EKG tests and passes a national certification exam. CETs work in a variety of clinical settings, including hospitals and physicians’ offices. The CET prepares and educates patients prior to collecting valuable diagnostic data used to determine heart function. Using machines to monitor the electrical conduction of the heart, the CET acquires EKGs, prepares patients for stress testing, and applies Holter monitors. The CET certification can lead to additional employment opportunities in the health care field and provide a foundation for future training.

The purpose of the CET certification is to establish a standard of care among EKG technicians. In order to sit for the CET examination, the applicant must have a high school diploma or GED and complete a 60-hour training program. The CET candidate may substitute one year of EKG technician experience in lieu of attending a formal training program. With this option, the CET candidate must provide documentation of having successfully interpreted at least ten EKGs. Candidates can register for the examination online at http://www.nhanow.com/ekg-technician.aspx.

The CET exam is a 110-question, multiple-choice exam (100 scored items) that is administered via the web or in paper/pencil format at a registered NHA test site, or via the web at a PSI testing center. All NHA tests are proctored.

The candidate is allotted a total of 110 minutes to complete the exam, and all test questions are weighted equally. A scaled score of 390 out of 500 is required to pass the exam. For web/PSI candidates, the preliminary score is provided immediately after completing the exam. PSI and paper/pencil candidates will be able to get their reports online in two business days. Hard copies of all score reports will be mailed within seven to 10 business days.

The following is a list of helpful test-taking strategies:

**Manage time effectively** – All test items are weighted equally. Don’t spend too much time on any given question. Periodically evaluate your progress on the exam.

**Answer the question that is asked** – Read the question and rephrase it to ensure understanding. Although this sounds intuitive, it is not uncommon to answer a question incorrectly because the test question was not fully understood.

**Avoid selecting pitfall answer choices** – Before reading the answer choices, form a mental prediction of the correct answer, and then select the answer choice that best matches that prediction. This avoids the possibility of being led astray by “rationalizing” incorrect answer choices.
About this study guide

This study guide presents the principles of EKG monitoring and associated patient care for which the CET exam tests. Each chapter presents learning objectives, enabling the candidate to focus attention on specific areas needing improvement. Practice questions are provided at the end of Chapters 1 and 2 to reinforce key concepts. Key terms and definitions are located throughout the text and at the end of chapters 1 and 2. Another section contains additional practice questions in case-study format.

NHA Certified EKG Technician (CET)
Detailed Test Plan based on the 2011 Job Analysis Study
100 scored items, 10 pretest items

<table>
<thead>
<tr>
<th>1. EKG Monitoring</th>
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<tbody>
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<td>A. Calculate a patient’s heart rate from the EKG tracing (e.g., 6-second method, R to R, sequencing).</td>
<td>60</td>
</tr>
<tr>
<td>B. Identify artifacts from the tracing (e.g., wandering baseline, somatic, electrical).</td>
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<td>C. Resolve artifacts from the tracing (e.g., wandering baseline, somatic, electrical).</td>
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<tr>
<td>D. Record an EKG lead on a patient.</td>
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<td>2. 5-lead</td>
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<td>3. 12-lead</td>
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<td>E. Verify the leads recorded on an EKG.</td>
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<td>F. Upload a completed EKG to a patient’s electronic medical record.</td>
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<td>G. Mount a completed EKG for a patient’s chart.</td>
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<td>H. Measure a patient’s heart rhythm from the EKG tracing.</td>
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<tr>
<td>I. Inspect the waveforms of a cardiac cycle for symmetry, direction, and amplitude (e.g., P waves, QRS complexes, ST segments, T waves).</td>
<td></td>
</tr>
<tr>
<td>J. Measure a patient’s heart conduction from the EKG tracing (e.g., PR-interval (PRI), QRS duration, QT-interval).</td>
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**NHA Certified EKG Technician (CET) Detailed Test Plan based on the 2011 Job Analysis Study**

100 scored items, 10 pretest items

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K. Identify the major classifications of arrhythmias from the EKG tracing (e.g., sinus, atrial, ventricular, junctional).

L. Identify the major variances to waveforms related to ischemia, injury, or infarction.

M. Respond to potentially life-threatening arrhythmias.

N. Verify EKG machine paper speed (e.g., 25 mm/second, 50mm/second).

O. Verify EKG machine sensitivity (e.g., h, 1, 2).

P. Maintain EKG equipment and the work environment.

Q. Recognize pacemaker spikes on an EKG trace.

**2. Patient Care**

A. Prepare the patient

1. EKG monitoring (e.g., patient history, cardiac medications, patient positioning).

2. Holter monitoring

3. Stress testing

4. Telemetry monitoring

B. Apply electrodes on patients

1. EKG

2. Holter monitoring

3. Stress testing

4. Telemetry

5. Pediatric patients

6. Patients with special considerations (e.g., right sided heart, posterior chest, amputations)
### NHA Certified EKG Technician (CET)
**Detailed Test Plan based on the 2011 Job Analysis Study**
100 scored items, 10 pretest items

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### Introduction to the Heart: Anatomy and Physiology

The human heart is a four-chambered organ responsible for supplying oxygenated blood to the entire body. The four chambers consist of the right and left atria and the right and left ventricles. A wall called the septum separates the right and left sides of the heart. The heart wall is composed of three distinct layers: the endocardium, myocardium and pericardium. The innermost layer, or endocardium, lines the chambers of the heart and forms the valves. The endocardium is designed to promote laminar blood flow through the heart. The middle layer, or myocardium, is composed of involuntary striated muscle tissue and is responsible for physically propelling blood forward. Cardiac muscle fibers contract, or decrease in length, reducing the size of the heart chambers and forcing blood out in a pumping action. The outermost layer, or pericardium, consists of connective tissue that forms a sac around the heart. The pericardial sac completely surrounds the heart and provides protection and lubrication between the heart and other organs in the chest.

Valves control the direction of blood flow through the heart. Several leaflets or flaps make up a valve. Though they are extremely strong, heart valves are also very floppy and require support to ensure tight closure of the flaps. Specialized filaments called chordae tendineae provide support to the floppy valve leaflets and prevent regurgitation of blood into other chambers of the heart. The chordae tendineae are anchored to structures called papillary muscles found along the inside wall of the ventricles. A total of four valves are found in the heart. The tricuspid valve separates the right atrium from the right ventricle. The bicuspid or mitral valve separates the left atrium from the left ventricle. The pulmonary semilunar valve lies between the right ventricle and pulmonary arteries.
The aortic valve lies between the left ventricle and the aorta. Synchronized valve closure prevents blood from flowing backward inside the heart.

The right atrium receives deoxygenated blood from the systemic circulation by way of the inferior and superior venae cavae. The blood from the coronary circulation also returns to the right atrium through the coronary sinus.

The right atrium pumps blood through the right atrioventricular (tricuspid) valve into the right ventricle. The right ventricle pumps blood through the pulmonary semilunar valve to the pulmonary arteries, which direct blood to the lungs for oxygenation.

The blood is oxygenated in the capillary beds of the lungs and returned to the left atrium via the pulmonary veins. The left atrium pumps blood through the left atrioventricular (mitral) valve into the left ventricle. The left ventricle pumps blood through the aortic semilunar valve into the aorta.

**Vessels** – The coronary circulation is a passive, low-pressure system. Two vessels arise from the root of the aorta; these are the right and left coronary arteries. The coronary circuit is perfused during ventricular diastole. This is different from the rest of the circulatory system, which is normally perfused during ventricular systole. The right and left coronary arteries originate at the root of the aorta; during ventricular systole, the semilunar flaps of the aortic valve occlude the orifices. During ventricular systole, pressure inside the ventricles is high, causing high pressure on the epicardium, compressing the coronary vessels. Furthermore, as the ventricular myocardium is contracting, the surface length is shorter than during diastole. This causes the coronary vessels that are located on the epicardium to become tortuous. Attempting to perfuse these vessels during ventricular systole would mean having to overcome high pressure, high vascular resistance, and tortuous vessels. This situation would not be efficient.

**Right coronary artery** – The right coronary artery (RCA) is one of two main arteries that carry oxygenated blood to the myocardium. The RCA is responsible for supplying oxygenated blood to the right ventricle and the inferior wall of the left ventricle. In addition, it perfuses the sinoatrial node in 50% of the population and the atrioventricular node in 90% of the population. This anatomical distribution is important to remember and has electrocardiographic implications. In some patients, the posterior descending artery also arises from the distal region of the RCA. Those patients are said to exhibit right-side dominance.

**Sinoatrial node artery** – The sinoatrial artery supplies the sinoatrial node. Occlusion of this artery can manifest as extreme sinus bradycardia on the EKG tracing.

**Atrioventricular node artery** – The atrioventricular (AV) node is perfused by the atrioventricular node artery, which arises from the RCA in more than 90% of the population. Occlusion of the AV node artery often results in high-degree heart block on the EKG.
**Left main coronary artery** – The left main coronary artery (LMCA) is the second of two main arteries that carry oxygenated blood to the myocardium. The LMCA is short and bifurcates into the left circumflex artery (LCx) and the left anterior descending artery (LAD).

**Left Circumflex artery** – The LCx supplies oxygenated blood to the posterolateral aspect of the left ventricle.

**Left anterior descending artery** – The left anterior descending artery (LAD) supplies the anterior wall of the left ventricle. LAD occlusion can lead to ventricular arrhythmias and death. Health care professionals colloquially refer to LAD occlusion as the “widowmaker.”

**Collateral circulation** – The large coronary arteries are not interconnected. However, small arteries may lengthen and connect if perfusion is decreased, forming collateral vessels. Because the collateral vessels can compensate for reduced oxygen supply, patients with coronary heart disease may not experience symptoms until the disease has progressed to advanced stages.

**Conduction system**

**Normal pathways** – The synchronous, rhythmic contraction of the heart muscle is controlled by an intrinsic electrical conduction system. In the normal heart, electrical impulses are initiated in the sinoatrial node (SA node), conducted through both atria, and directed to the atrioventricular node (AV node). The AV node delays transmission of the signal to the ventricles, allowing them to completely fill with blood. Depolarization continues toward the apex of the heart through the bundle of His and the left and right bundle branches, and terminate in the Purkinje fibers. As the electrical impulses reach the myocardium, the muscle cells depolarize and contract.

In addition to the organized conduction system, the heart muscle can initiate its own impulse. This property is called automaticity. Occasionally, a small area in atrial or ventricular tissue becomes irritated and initiates an electrical impulse from outside the normal pathways. These are called ectopic beats and can be seen on the EKG as premature atrial, junctional, or ventricular complexes.
**Sinoatrial node** – The SA node is found in the right atrium and functions as the primary pacemaker of the heart. In adults, it fires approximately 60 to 100 times per minute. Depolarization of the right atrium occurs first, followed closely by the left. The pathway connecting the right and left atrium is called Bachman’s bundle. The P wave seen on the EKG is a result of atrial depolarization.

**Internodal pathways** – The electrical impulse is conducted from the SA node to the AV node via the internodal pathways located in the walls of the atria. Three pathways – the anterior, medial, and posterior pathways – connect the SA node to the AV node.

**Atrioventricular node** – The atrioventricular (AV) node is the only part of the conduction system that connects the atria to the ventricles. Absent any “accessory pathways,” there are no other connections between the atria and ventricles. Just below the AV node lies the junction. The junction can function as a backup pacemaker if the SA node fails, and fires at approximately 40 to 60/min. The AV node “holds” the electrical signal received from the SA node for a short period of time to allow the ventricles to completely fill with blood. On the EKG, the time needed for an electrical impulse to travel from the SA node through the AV node to the ventricles is seen as the PR interval. If the AV node is not conducting impulses normally, the PR interval may increase. Complete heart block occurs when the AV node is unable to conduct any electrical impulses from the SA node to the ventricles.

**Bundle of His** – The AV node conducts the impulse to the bundle of His, or interventricular bundle, located in the interventricular septum. The bundle of His transmits impulses to the right and left bundle branches.

**Right bundle branch** – The right bundle branch (RBB) carries the electrical impulse from the AV node to the Purkinje fibers of the right ventricle, causing depolarization. The RBB is located in the interventricular septum and is supplied by the LAD.

**Left bundle branch** – The left bundle branch (LBB), located in the interventricular septum, carries the electrical impulse from the AV node to the Purkinje fibers of the left ventricle, causing depolarization. The LBB is short and further divides into the left anterior fascicle and the left posterior fascicle. The left anterior fascicle runs along the anterior surface of the heart, while the left posterior fascicle runs the length of the septum and conducts impulses to the Purkinje fibers on the posterior surface of the left ventricle. Both bundle branches receive oxygenated blood from the LAD, although the left posterior fascicle receives additional blood supply from the RCA, causing it to be more resistant to ischemia.

**Purkinje fibers** – The Purkinje fibers are a network of conduction pathways that traverse the surface of the ventricles and depolarize them, initiating myocardial contraction. In the absence of electrical stimulation from the SA and AV nodes, the Purkinje fibers will fire at an intrinsic rate of 20 to 40/min.
EKG Theory

**Concept of EKG acquisition** – The EKG is a sophisticated tool that measures very low differences in electrical energy traveling across the surface of the human body. Muscle tissue releases electrical energy when it depolarizes and causes a change in electrical potential across the surface of the skin. Using special electrodes, the EKG machine records changes in electrical potential on graph paper. The EKG is a graphic representation of changes in energy over time. Many diseases of the heart result in specific changes to the EKG.

**Standard grid** – Standard EKG paper contains small boxes that measure 1 millimeter (mm) tall by 1 mm wide. Five small boxes make up a larger box on the EKG paper. Thicker gridlines indicate 5 mm boxes. Each millimeter increment on the Y axis (vertical) represents 0.1 millivolt (mV). Each millimeter increment on the X axis (horizontal) represents 40 milliseconds, or 0.04 seconds.

**Standard paper speed** – Standard paper speed is 25 mm/second. Paper speed can be changed to facilitate interpretation of the EKG tracing in certain cases. By increasing the paper speed to 50 mm/second, the EKG appears to “slow,” and waves that were previously all “bunched” together become more clearly visible. Paper speed should never be changed without a physician’s order. Improper paper speed can result in improper arrhythmia interpretation.

**Standard amplitude** – The standard EKG is acquired using an amplitude of 10 mm per 1 mV. Calibration boxes are small rectangles printed at the beginning of each lead indicating the paper speed and amplitude of the EKG. The standard calibration box should measure 10 mm tall by 5 mm wide. These measurements indicate a standard paper speed and amplitude of 25 mm/second and 10 mm/mV, respectively.

**Einthoven’s triangle** – Willem Einthoven was a physiologist who discovered tiny electrical charges on the surface of the human skin. Using buckets of saltwater and a primitive form of an oscilloscope, Einthoven recorded the first tracing of electrical activity of the heart. He measured the tiny electrical charges traveling to the hands and feet and used the data to form an imaginary equilateral triangle over the torso with the heart at its center, as shown in this diagram.
Correct limb lead placement is of critical importance as it serves to measure the heart’s electrical axis and as the reference point for the unipolar leads.

**Wilson’s central terminal** – Wilson’s central terminal (WCT) is a reference point created by the three limb leads. It serves as a reference point for six of the 12 leads, and serves as the “zero” end for each of the nine unipolar leads on the EKG. Proper limb lead placement is critical to ensure proper calculation of WCT. Improper limb lead placement creates an incorrect WCT reference point.

**Unipolar and bipolar leads** – Unipolar leads are defined as leads that have only one “pole.” Unipolar leads use a reference point to create “the other end” of the lead system. Wilson’s central terminal serves as the reference point for all unipolar leads. Unipolar leads are considered to be the positive end of the lead system.

Bipolar leads are defined as leads that have two poles: one positive, one negative.
Learning Objectives
At the completion of this chapter, the CET candidate will be able to:

- Describe proper lead placement when acquiring various EKG tracings.
- List the EKG waveforms.
- Identify specific waveforms on the EKG.
- Measure the duration of waveforms on the EKG.
- Identify the direction of wave deflection.
- Determine T wave symmetry.
- Determine P wave symmetry.
- Measure the heart rate from the EKG tracing.
- Differentiate artifact from expected EKG tracing waveforms.
- Describe how to eliminate artifact from an EKG.
- Interpret arrhythmias originating in the sinus, atria, junction, and ventricles.
- Recognize pacer spikes on the EKG.
- Identify ischemic changes on the EKG.
- Describe the proper response for life-threatening arrhythmias.
- Describe how to maintain the EKG machine.

Overview

This chapter provides the information necessary to systematically approach the EKG and interpret arrhythmias encountered in the clinical setting. In addition, the chapter includes pictures and real EKG tracings to promote rhythm recognition. Important terms are located at the end of the chapter in a special section, enabling students to locate definitions quickly. The chapter concludes with a 10-question self-assessment drill.

Calculate a patient’s heart rate from the EKG tracing

Heart rate can be measured from the EKG using a variety of different approaches. The following are the most commonly employed methods.
**The 1500 method** – Calculate the heart rate using the 1500 method by counting the number of small boxes between the P-P interval (for atrial rate) or R-R interval (for ventricular rate), then dividing 1,500 by that number. Fifteen hundred represents the number of small boxes, or the number of mm of paper consumed in one minute of time at the standard 25 mm/second paper speed. For example, if there are 15 small boxes between two R waves (R-R interval), the heart rate equals 1500/15, or 100/min. This is a great method for very precise measurements and is best applied to fast rhythms.

**Sequence method** – The sequence method (also known as the 300 method) is derived from the 1500 method. There are 300 large, 5 mm boxes in every minute of EKG tracing at the normal 25 mm/second print speed. Remember the pattern 300-150-100-75-60-50. Calculate these numbers by dividing 300 by the number of large boxes between QRS complexes. Find an R wave and start counting away from it moving towards the right of the tracing in 5 mm segments (one large box). With every move, apply the number in the pattern you memorized. This is a wonderful rule to apply most of the time, with one exception: irregular rhythms.

**6-second rule** – The 6-second rule is simple and works well in any situation. It is the gold standard for estimating the rate of an irregular rhythm. At the top of the tracing, there are small hash marks indicating 3-second intervals. Count the number of QRS complexes in two of the sections (6-second period) and multiply by 10. For example, you count six QRS complexes in 6 seconds. 6 X 10 = 60/min.
Identify artifacts from the tracing

Artifact can come from a variety of both patient and nonpatient factors. The most common reasons for artifact on the EKG caused by the patient include seizure, trembling, fast breathing, dry or wet skin, and shivering. Nonpatient causes include use of electrodes with dry gel, damaged patient cables, electromagnetic frequency, and interference from cell phones and other medical and nonmedical devices.

Resolve artifacts from the tracing

**Wandering baseline** – A wandering baseline often appears on the EKG when the electrodes are improperly placed on the patient’s torso. The wandering baseline almost always represents the patient’s respirations. An easy way to eliminate the wandering baseline is to move the limb leads to the wrists and ankles. Another way to reduce the artifact is to have the patient relax and breathe more slowly.

**Seizure** – Seizure activity will cause huge artifact problems on the EKG. Seizure activity must be controlled prior to acquiring the EKG tracing.

**Trembling** – Some patients may be anxious, cold, or have an essential tremor. The EKG technician must reassure the patient to keep him/her calm, provide warm blankets to control shivering, and attempt to move the electrodes to an area with minimal tremor.

**Dry skin** – If the patient’s skin is very dry, the electrodes and gel won’t adhere well to the skin. The gel will be unable to have the appropriate surface area contact to ensure a strong signal. The technician can reduce artifact from dry skin by gently abrading the skin and using tincture of benzoin to promote good adhesion and surface contact.

**Wet skin** – Some patients will be diaphoretic during EKG acquisition. The technician can wipe the patient off with a towel and apply tincture of benzoin to the patient’s skin before placing the electrodes. The benzoin needs to completely dry prior to applying the EKG electrodes.

**Cold patient** – If the patient is very cold, they may shiver, and in some cases, the electrodes won’t adhere to the skin. The technician should provide the patient with warm blankets. Some patients may be unable to stop shivering, and the EKG may have to be acquired with the artifact.

**Dry gel** – The gel on the EKG electrodes is specially designed to interface with the patient’s skin. The gel is able to sense extremely low levels of energy and requires the full surface area to make contact with the patient. Electrodes with dry gel should not be used.

**Cell phone interference** – Cell phone interference can cause lots of artifact on the EKG. It may appear as flutter or P waves on the tracing at a rate of 300/min. Though the cell phone artifact morphology is different than normal P wave or flutter wave
morphology, take special care to ensure the patient’s cell phone is off or moved away from the patient during the procedure.

**Medical device interference** – Medical and other electronic devices can interfere with the EKG tracing. Ensure that all unnecessary devices are moved away from the patient or turned off. Medical devices are often designed to minimize interference with other devices, so the technician should consider nonmedical devices as the source of interference first.

**Record an EKG on a patient**

3-lead

The 3-lead EKG configuration is generally used to continuously monitor the patient’s heart rhythm.

- **White lead** – Right shoulder or clavicle area
- **Black lead** – Left shoulder or clavicle area
- **Red lead** – Left lower abdominal area
- **Green lead** – Right lower abdominal area

5-lead

The 5-lead EKG configuration refers to the standard Holter monitor setup or the 5-lead rhythm monitor setup. The Holter monitor setup varies depending on the type of monitor. The 5-lead setup pictured here is the most common configuration employed.

- **White lead** – Right sternum/clavicle area
- **Black lead** – Left sternum/clavicle area
- **Red lead** – Left lower thoracic area
- **Green lead** – Right lower thoracic area
- **Brown lead** – Just below and to the right of the bottom of the sternum
12-lead

The standard 12-lead EKG requires placement of 10 electrodes; the standard 4 limb leads, plus 6 precordial leads.

**Precordial Leads – Left side**

- V1 – 4th intercostal space (ICS), R of sternum
- V2 – 4th ICS, L of sternum
- V4 – 5th ICS, midclavicular
- V3 – between V2/V4
- V6 – 5th ICS, midaxillary
- V5 – 5th ICS between V4/V6

Certain conditions, including inferior wall ST segment elevation, myocardial infarction, and patients less than 8 years old, require a right-sided 12-lead EKG. Limb leads are placed in the normal fashion, but the precordial leads are placed as illustrated below.

**Precordial Leads – Right side**

- V1 – 4th ICS, L of sternum
- V2 – 4th ICS, R of sternum
- V4 – 5th ICS, midclavicular (R) (most sensitive and specific to R ventricular infarction)
- V3 – between V2/V4
- V5 – 5th ICS between V4/V6
- V6 – 5th ICS, midaxillary

**Verify the leads recorded on an EKG**

After acquiring an EKG, the technician should verify that each of the leads is free of artifact and has properly recorded on the EKG paper. Sometimes, the stylus on the machine gets dirty and is unable to print in a certain region of the EKG paper. If certain leads did not print on the EKG paper, first verify that the leads did not accidentally fall off the patient. Also ensure that the EKG electrodes and wires are securely connected, and
ensure that the wires are securely plugged into the EKG device. If a certain area still isn’t printing, or if the recording is very faint, try changing the cables on the machine. If the problem persists, contact the manufacturer for direction.

**Upload a completed EKG to a patient’s electronic medical record**

Become familiar with your institution’s policy on uploading EKGs to the patient’s electronic medical record. Ensure that patient identifiers have been entered onto the EKG. It is critical to verify that the EKG being attached to the patient’s record is that patient’s EKG. Follow established policies and guidelines to prevent errors in medical record-keeping.

**Mount a completed EKG for a patient’s chart**

As with uploading a complete EKG to a patient’s electronic record, become familiar with your institution’s policy on mounting a completed EKG to a patient’s chart. Ensure that patient identifiers have been entered onto the EKG. Some facilities require attaching stickers with bar codes to identify the patient and any test results such as an EKG.

**Measure a patient’s heart rhythm from the EKG tracing**

A number of different methods exist to systematically approach the EKG for interpretation. The underlying rhythm can be interpreted using a simple five-step method (shown below). First, calculate the heart rate, both atrial and ventricular. Next, measure the PR interval, then measure the QRS duration. Determine if the rhythm is regular, irregular, or irregularly irregular. Lastly, use the findings to interpret the underlying rhythm.

The following is a handy template to use while learning how to interpret arrhythmias.

Rate: Atrial _________ Ventricular _________

PR interval: _________

QRS duration: _________

Rhythm: (circle one) Regular Irregular Irregularly irregular

Arrhythmia (interpretation): ________________________________
Inspect the waveforms of a cardiac cycle for symmetry, direction, and amplitude

Identify the direction of the wave deflection.

**Positive** – A positive deflection is a wave that exists above the isoelectric line. Any part of a wave that exists above the isoelectric line is said to be positive, even if it is moving downward on the EKG paper. Once the wave reaches the isoelectric line and continues to travel downwards, then the wave becomes negatively deflected.

**Negative** – A negative wave is a wave that exists below the isoelectric line. Any part of a wave that exists below the isoelectric line is said to be negative, even if it is moving upward on the EKG paper. Once the wave reaches the isoelectric line and continues to travel upward, then the wave becomes positively deflected.

**Determine T wave symmetry** – T wave symmetry is defined as a T wave that is symmetrical with respect to the Y axis. In other words, a T wave whose right and left sides form mirror images on the vertical axis are said to exhibit symmetry.

**Determine P wave symmetry** – P wave symmetry is defined as a P wave that is symmetrical with respect to the Y axis. In other words, a P wave whose right and left sides form mirror images on the vertical axis are said to exhibit symmetry.

**Determine the amplitude of a wave** – The amplitude of any wave is measured using the horizontal grid lines on the EKG. Each small square is exactly 1 mm tall. Locate the lowest and highest points of the wave. Count the number of small boxes between the two points. The answer is the number of small boxes in millimeters.

**Measure a patient’s heart conduction from the EKG tracing**

<table>
<thead>
<tr>
<th>Interval</th>
<th>Expected reference range</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR</td>
<td>0.12 to 0.2 seconds</td>
</tr>
<tr>
<td>QRS</td>
<td>0.06 to 0.12 seconds</td>
</tr>
</tbody>
</table>

**PR segment** – The PR segment represents the time it takes for electricity to travel through the AV node. The PR segment is measured from the end of the P wave to the beginning of the QRS.

**PR interval** – The PR interval represents the time it takes for the SA node to fire, atria to depolarize, and electricity to travel through the AV node. The PR interval is measured from the beginning of the P wave to the beginning of the QRS complex.
**QRS complex** – The QRS complex represents the time it takes for the ventricles to depolarize. The QRS complex is measured from the end of the PR interval to the J point.

**ST segment** – The ST segment represents the early phase of ventricular repolarization. The shape of the ST segment is very important when looking for patterns of ischemia. Refer to the Many Faces of Ischemia section later in the study guide for specifics related to ischemia and ST segment changes.

**J point** – The J point represents the exact point in time where ventricular depolarization stops and ventricular repolarization starts. The J point occurs at the end of the QRS complex, or where the ST segment begins. During myocardial ischemia the J point can elevate or depress below baseline. Refer to the ischemia section of the study guide for specific changes related to myocardial ischemia.

**QT interval** – The QT interval represents one complete ventricular cycle; in other words, it represents one complete cycle of ventricular depolarization and repolarization. The QT interval is measured from the beginning of the Q wave to the end of the T wave.

**P-P interval** – The P-P interval represents the amount of time between atrial depolarization cycles (between P waves). The P-P interval is measured from the beginning of one P wave to the beginning of the next P wave.

**R-R interval** – The R-R interval represents the amount of time between ventricular depolarization cycles (between R waves). The R-R interval is measured from the beginning of one R wave to the beginning of the next R wave.

### Identify the major classifications of arrhythmias from the EKG tracing

Rhythms that originate in the SINUS node:

- Regular sinus rhythm
- Sinus bradycardia
- Sinus tachycardia
- Sinus arrhythmia
EKG findings common to sinus rhythms:

- P wave present
- P wave is upright and rounded
- P wave amplitude less than 2.5 mm
- P wave duration less than 110 milliseconds
- QRS complex usually narrow

### Regular (normal) Sinus Rhythm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>Upright, one for every QRS complex</td>
</tr>
<tr>
<td>PR interval</td>
<td>120 to 200 milliseconds</td>
</tr>
<tr>
<td>QRS duration</td>
<td>80 to 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>60 to 100/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*

### Sinus Bradycardia

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>Upright, one for every QRS complex</td>
</tr>
<tr>
<td>PR interval</td>
<td>120 to 200 milliseconds</td>
</tr>
</tbody>
</table>

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*
**Sinus Bradycardia**

- QRS duration: 80 to 120 milliseconds
- Ventricular rate: Less than 60/min
- Rhythm regularity: Regular

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*

---

**Sinus Tachycardia**

- P wave: Upright, one for every QRS complex
- PR interval: 120 to 200 milliseconds
- QRS duration: 80 to 120 milliseconds
- Ventricular rate: Greater than 100/min
- Rhythm regularity: Regular

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*

---

**Sinus Arrhythmia**

- P wave: Upright, one for every QRS complex
- PR interval: 120 to 200 milliseconds
- QRS duration: 80 to 120 milliseconds
- Ventricular rate: Usually 60 to 100/min, can be slower or faster

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*
**Sinus Arrhythmia**

<table>
<thead>
<tr>
<th>Rhythm regularity</th>
<th>Irregular</th>
</tr>
</thead>
</table>

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*

Rhythms that originate in the ATRIA:

- Atrial fibrillation
- Atrial fibrillation with rapid ventricular response
- Atrial flutter
- Premature atrial complex
- Supraventricular tachycardia (SVT)

EKG findings common to atrial rhythms:

- P wave absent or abnormal shape
- Fibrillatory (f) waves present
- Flutter (F) waves present
- QRS complex usually narrow

**Atrial Fibrillation**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>None, fibrillatory waves (f)</td>
</tr>
<tr>
<td>PR interval</td>
<td>None</td>
</tr>
<tr>
<td>QRS duration</td>
<td>80 to 120 milliseconds</td>
</tr>
</tbody>
</table>
**Atrial Fibrillation**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventricular rate</td>
<td>60 to 100/min</td>
</tr>
<tr>
<td>Atrial rate (if different than ventricular rate)</td>
<td>300 to 600/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Irregularly irregular</td>
</tr>
</tbody>
</table>

**Atrial Fibrillation with Rapid Ventricular Response (AF-RVR)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>None, fibrillatory waves (f)</td>
</tr>
<tr>
<td>PR interval</td>
<td>None</td>
</tr>
<tr>
<td>QRS duration</td>
<td>80 to 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>Greater than 100/min</td>
</tr>
<tr>
<td>Atrial rate</td>
<td>300 to 600/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Irregularly irregular</td>
</tr>
</tbody>
</table>

**Atrial Flutter**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>None, flutter waves (F)</td>
</tr>
</tbody>
</table>
### Atrial Flutter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR interval</td>
<td>None</td>
</tr>
<tr>
<td>QRS duration</td>
<td>80 to 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>Usually 60 to 100/min, often seen at 130, 150, 160</td>
</tr>
<tr>
<td>Atrial rate</td>
<td>240 to 320/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular (irregular with variable conduction)</td>
</tr>
</tbody>
</table>

### Supraventricular Tachycardia (SVT)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>May be hard to find. If present, one per QRS complex</td>
</tr>
<tr>
<td>PR interval</td>
<td>Usually not measurable</td>
</tr>
<tr>
<td>QRS duration</td>
<td>80 to 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>150 to 240/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>
Premature Atrial Complex (PAC)

PACs are atrial depolarizations that occur early in the cardiac cycle. The characteristic findings on an EKG include:

- A P wave (may be buried in the preceding T wave)
- A QRS complex that follows
- A QRS that looks the same as the QRS complexes in the underlying rhythm

PACs are not rhythms! They are complexes that appear in an underlying rhythm. First name the underlying rhythm, and then add PAC. For example, the tracing above reveals a regular sinus rhythm with one PAC. The premature beat is the beat that occurs early in the cycle, followed by a rest period known as a compensatory pause. This pause is a built-in delay mechanism enabling the heart to resume its electrical activity on time following a premature beat.

Rhythms that originate near the A/V JUNCTION:

- Junctional rhythm
- Junctional bradycardia
- Accelerated junctional rhythm
- Junctional tachycardia
- Premature junctional complex

EKG findings common to junctional rhythms:

- P wave absent or inverted
- QRS complex on the long end of normal (can be wide)
### Junctional Rhythm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>Absent or inverted</td>
</tr>
<tr>
<td>PR interval</td>
<td>None or 120 to 200 milliseconds</td>
</tr>
<tr>
<td>QRS duration</td>
<td>80 to 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>40 to 60/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*

### Junctional Bradycardia

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>Absent or inverted</td>
</tr>
<tr>
<td>PR interval</td>
<td>None or 120 to 200 milliseconds</td>
</tr>
<tr>
<td>QRS duration</td>
<td>80 to 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>Less than 40/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>
Accelerated Junctional Rhythm

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>Absent, inverted, retrograde, or inverted and retrograde</td>
</tr>
<tr>
<td>PR Interval</td>
<td>None, or 120 to 200 milliseconds</td>
</tr>
<tr>
<td>QRS Duration</td>
<td>80 to 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular Rate</td>
<td>Greater than 60/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>

Rhythms that originate in the VENTRICLES:

- Idioventricular rhythm
- Polymorphic ventricular tachycardia
- Ventricular tachycardia (monomorphic)
- Ventricular fibrillation
- Premature ventricular complex

EKG findings common to ventricular rhythms:

- QRS complex wide
**Idioventricular Rhythm (Ventricular Escape Rhythm)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>None</td>
</tr>
<tr>
<td>PR interval</td>
<td>None</td>
</tr>
<tr>
<td>QRS duration</td>
<td>Greater than 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>20 to 40/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>

In the following strip for polymorphic ventricular tachycardia (PMVT), notice the varying amplitude of the QRS complexes.

**Polymorphic Ventricular Tachycardia**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>None</td>
</tr>
<tr>
<td>PR interval</td>
<td>None</td>
</tr>
<tr>
<td>QRS duration</td>
<td>Greater than 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>Greater than 120/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>

In the following ventricular tachycardia strip, notice the identical amplitude of all the QRS complexes.
Ventricular Tachycardia (Monomorphic)

Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.

<table>
<thead>
<tr>
<th>P wave</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR interval</td>
<td>None</td>
</tr>
<tr>
<td>QRS duration</td>
<td>Greater than 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>Greater than 120/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>

Ventricular fibrillation is an extremely chaotic rhythm with no discernable waves.

Ventricular Fibrillation

Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.

<table>
<thead>
<tr>
<th>P wave</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR interval</td>
<td>None</td>
</tr>
<tr>
<td>QRS duration</td>
<td>None</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>Greater than 300/min</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Irregular</td>
</tr>
</tbody>
</table>

Asystole is the absence of electrical activity in the heart.
EKG Monitoring

Asystole

<table>
<thead>
<tr>
<th>Feature</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>None</td>
</tr>
<tr>
<td>PR interval</td>
<td>None</td>
</tr>
<tr>
<td>QRS duration</td>
<td>None</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>None</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>None</td>
</tr>
</tbody>
</table>

Premature Ventricular Complex (PVC)

PVCs are ventricular depolarizations that occur early in the cardiac cycle. The characteristic findings on the EKG include:

- Absent P wave preceding the early QRS
- A wide QRS complex
- A QRS that looks different than the QRS complexes in the underlying rhythm
- The direction of the QRS complex and the T wave oppose one another

Like PACs, PVCs are not rhythms. They are complexes that appear in an underlying rhythm. First name the underlying rhythm, then add PVC. For example, the tracing above reveals a regular sinus rhythm with PVCs. PVCs can appear in many different patterns. They can also come in many different shapes. When a single PVC appears, name the underlying rhythm and add “with a PVC.” PVCs can appear with different shapes; in this case, the term “multifocal PVCs” is used. PVCs can also appear in groups. For example, in the tracing above, PVCs occur as every other complex. This pattern is called ventricular bigeminy.
Heart blocks are a special set of arrhythmias that indicate a difficulty in communication or no communication between the atria and ventricles. A heart block is often communicated as being first-degree, second-degree type 1, second-degree type 2, or third-degree heart block. It is important to remember that proper identification of the arrhythmia includes interpretation of the atrial and ventricular rhythm and the degree of block that exists between the two. See the note in the third-degree heart block section on page 31.

First-degree heart block represents a slow or delayed conduction through the AV node, resulting in a prolonged PR interval. Specifically, the PR segment elongates in first-degree heart block.

### First-Degree Heart Block

<table>
<thead>
<tr>
<th>P wave</th>
<th>One for every QRS complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR interval</td>
<td>Greater than 200 milliseconds</td>
</tr>
</tbody>
</table>

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*

### Second-Degree Type I (Mobitz I, Wenckebach)

<table>
<thead>
<tr>
<th>P wave</th>
<th>One for every QRS complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR interval</td>
<td>Elongates; eventually a QRS complex is lost</td>
</tr>
<tr>
<td>QRS duration</td>
<td>Usually 80 to 120 milliseconds, can be wider</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>Usually 60 to 100/min, can be slower</td>
</tr>
</tbody>
</table>

*Rhythm strip from 12-Lead ECG: The Art of Interpretation, courtesy of Tomas B. Garcia, M.D.*
Second-Degree Type I (Mobitz I, Wenckebach)

| Atrial rate (if different than ventricular rate) | Usually 60 to 100/min |
| Rhythm regularity | Irregular |

Second-Degree Type 2 (Mobitz II)

| P wave | 2 or more for every QRS complex |
| PR interval | Constant |
| QRS duration | Usually 80 to 120 milliseconds, can be wider |
| Ventricular rate | Usually 60 to 100/min, can be slower |
| Atrial rate (if different than ventricular rate) | Usually 60 to 100/min |
| Rhythm regularity | Usually regular |

Third-Degree Heart Block

Third-degree heart block is characterized by a complete lack of association between atria and ventricles. P waves can be seen marching through the rhythm, and none are responsible for triggering ventricular depolarization. The ventricular activity is completely independent of atrial activity and is often seen as a junctional or ventricular escape rhythm.

Note: Although it is standard practice to simply state “third-degree heart block,” it’s important to remember that three distinct things are happening in the tracing below:

- **Atrial activity** – Sinus tachycardia
- **Ventricular activity** – Junctional rhythm (junctional escape rhythm)
- **Communication between the two** – Third-degree or complete heart block. The signal from the atria is completely blocked from reaching the ventricles.
**Heart Blocks Made Simple**

Perform a normal arrhythmia interpretation on the tracing. If you find more P waves than QRS complexes, evaluate the following:

1. Measure the RR interval
2. Measure the PR interval

If the RR interval is CONSTANT, the block must be second-degree type 2 or third-degree. If the PR interval varies, how does it vary?

- If it elongates, the block must be second-degree type 1.
- If there is no association, the block must be third-degree.
Identify the major variances to waveforms related to ischemia, injury, or infarction

**J point** – The J point is the junction point between the QRS complex and the ST segment. It signifies the end of ventricular depolarization and the beginning of ventricular repolarization. For the purposes of this course, think of acute myocardial injury and infarction as a problem of repolarization. This will prompt you to look for anomalies on the right side of the QRS complex.

**Ischemia** – The classic pattern of myocardial ischemia is ST segment depression and/or T wave inversion. Deeply inverted T waves are a frequently encountered presentation of ischemia.

**Injury** – The classic pattern of myocardial injury is ST segment elevation myocardial infarction (STEMI).

STEMI is diagnosed using the following criteria:

1. ST segment elevation in two or more contiguous leads
   - Greater than 1 mm in the limb leads
   - Greater than 2 mm in the precordial leads
2. Reciprocal changes may also be present.

**Infarction** – Two main electrocardiographic changes can be observed days to weeks after myocardial infarction; complete resolution of and normalization of the tracing, or the development of a pathological Q wave. It is of critical importance to remember that the presence of pathological Q waves does not rule out an acute cardiac event.
Localization of ischemia on the EKG – Localization of ischemia, injury, or infarction is performed using the following criteria:

<table>
<thead>
<tr>
<th>Leads</th>
<th>Area of Involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>II, III, aVF</td>
<td>Inferior wall</td>
</tr>
<tr>
<td>V1, V2</td>
<td>Septum</td>
</tr>
<tr>
<td>V3, V4 or V1 to V4</td>
<td>Anterior wall</td>
</tr>
<tr>
<td>Leads I, aVL</td>
<td>Lateral wall – high</td>
</tr>
<tr>
<td>Leads V5, V6</td>
<td>Lateral wall – low</td>
</tr>
<tr>
<td>Leads V7 to V9</td>
<td>Posterior wall</td>
</tr>
<tr>
<td>Lead V4R</td>
<td>Right ventricle</td>
</tr>
</tbody>
</table>

Reciprocal changes – Reciprocal changes are changes that occur as a result of opposing view angles between leads. In other words, if lead A “sees” ST segment elevation, lead B “sees” ST segment depression. Reciprocal changes are highly confirmatory for acute ischemic/injury events.

Reciprocal leads – The most important reciprocal leads are:

- Leads II, III, aVF: reciprocal to leads I, aVL
- Leads V1 to V3: reciprocal to leads II, III, aVF

The Many Faces of Ischemia

(Note: Information and images in this section were previously published in the following text: American Academy of Orthopaedic Surgeons, Nancy Caroline's Emergency Care in the Streets, Seventh Edition. 2012: Jones & Bartlett Learning, Burlington, MA. www.jblearning.com. Reprinted with permission.)

The tracings on the following pages represent common electrocardiographic findings suggestive of myocardial ischemia.
The “J” Point

If the J point is depressed or elevated, as shown on the tracings that follow, it can suggest ischemia.

![J point depression and elevation](image)

ST Segment Morphology

**Convex** – A convex ST segment favors ischemia. Test for this by drawing a line from the J point to the peak of the T wave, as shown below. If the line superimposes or if the T wave is above the line, the segment is convex.

![Convex ST segments](image)

**Concave** – A concave ST segment favors benign conditions, but beware – ischemia can also manifest with this pattern, as seen in this STEMI:

![Concave ST segment](image)
All of the examples below illustrate myocardial ischemia. The horizontal and downsloping ST segments are always pathological findings. A “slow” up-slope is most often a pathological finding. A rapidly up-sloping ST segment is generally a normal electrocardiographic change, as demonstrated during exercise stress testing.

T Wave Morphology

The diagram that follows shows when the appearance of the T wave indicates ischemia. The apex of the T wave elevates and forms a peaked appearance, and the height of the T wave exceeds half the overall height of the QRS. During ischemia, the T wave becomes symmetrical with respect to the Y axis, and the base of the T wave broadens.

Respond to potentially life-threatening arrhythmias

According to the American Heart Association’s Emergency Cardiac Care Guidelines (2010), two of the most important interventions for cardiac arrest are 1) high-quality cardiopulmonary resuscitation (CPR), and 2) early defibrillation. EKG technicians should maintain CPR certification and be able to use an automatic external defibrillator (AED). Technicians should become familiar with institutional guidelines or protocols to fully understand their role during resuscitation efforts.
**Ventricular fibrillation (VF)** – Ventricular fibrillation is a disorganized, chaotic, non-perfusing, and lethal dysrhythmia. The technician plays an important role in the response to VF. First, the technician must recognize the lethal rhythm. Patients often experience symptoms such as dizziness, feeling of impending doom, chest discomfort, and shortness of breath immediately before the arrest or at the time of arrest. The technician should immediately call for help using the established guidelines for the facility. The technician should initiate CPR as quickly as possible, ensure emergency services are notified, and send another person to retrieve the AED, if available. The technician should be prepared to assist with other tasks requested by the physician or other advanced healthcare worker.

**Ventricular tachycardia (VT)** – Ventricular tachycardia is an organized ventricular rhythm that often results in precipitous drops in blood pressure and level of consciousness. Ventricular tachycardia may continue to produce a pulse but often deteriorates to a pulseless rhythm or into VF. Similar to the response for VF, the technician must first recognize the lethal rhythm. Patients often experience symptoms such as dizziness, feeling of impending doom, chest discomfort, and shortness of breath immediately before the arrest or at the time of arrest. The technician should immediately call for help using the established guidelines for the facility. The technician should initiate CPR as quickly as possible if the patient does not have a pulse or completely loses consciousness, ensure emergency services are notified, and send another person to retrieve the AED, if available. The technician should be prepared to assist with other tasks requested by the physician or other advanced health care worker.

**Asystole** – Asystole is the complete cessation of electrical activity in the heart. Common causes of asystole include large pulmonary embolism, large myocardial infarction, respiratory arrest (hypoxia) and overdose. Other causes include hypothermia, acidosis, electrolyte abnormalities, tension pneumothorax and trauma. If the technician recognizes asystole on the EKG, another lead should immediately be checked to confirm asystole. Patients may or may not complain of any symptoms prior to arrest. If a patient’s rhythm deteriorates to asystole, the technician should immediately call for help using the established guidelines for the facility. The technician should initiate CPR as quickly as possible, ensure emergency services are notified, and send another person to retrieve the AED, if available. The technician should be prepared to assist with other tasks requested by the physician or other advanced healthcare worker.

**Bradycardia** – Bradycardia is defined as a slow heart rate. The technician is responsible for recognizing when the patient’s vital signs, including heart rate, fall outside of expected parameters. The technician should notify the physician if the patient develops bradycardia using established methods of communication in the facility. The technician should continue to monitor the patient until care is transferred to another health care worker. The technician should also be prepared to assist with placing pacing pads on the patient.
**Tachycardia** – Tachycardia is defined as a fast heart rate. As with bradycardia, the technician should notify the physician if the patient develops tachycardia using established methods of communication in the facility. The technician should continue to monitor the patient until care is transferred to another health care worker and be prepared to assist with placing defibrillation pads on the patient.

**Verify EKG machine paper speed**

Every EKG tracing prints the paper speed at the top or bottom of the paper. The most common paper speed is 25 mm/second. Another common paper speed is 50 mm/second. The faster paper speed is sometimes used to space out EKG waves when the heart rate is very fast. The faster speed enables certain waves to become visible on the tracing.

**Verify EKG machine sensitivity**

Every EKG tracing starts with a calibration marker before printing any waveforms. The calibration marker looks like an upside-down U shape with 90-degree angles. Another way to describe this is to imagine a rectangle resting on its short edge. The bottom edge of the rectangle is absent. The calibration marker measures 5 mm wide by 10 mm tall. The marker represents a calibration of 10 mm per millivolt (mV), the standard EKG gain. The gain is often also printed near the top or bottom of the tracing and represented with a 1X or 2X or 3X to represent normal, twice the size, or three times the size, respectively.

** Maintain EKG equipment and the work environment**

Every manufacturer makes specific recommendations on how to perform user tests, clean the machine, change paper, maintain the machine, etc. Refer to the user manual and the institution’s policies and guidelines to properly perform these tasks. The CET should be familiar with how to perform a daily user test, clean the machine, keypad, wires and other components, properly connect the device to a power source (AC power, DC power, etc.), and how to change the paper.

It is best practice to maintain a clean work environment. This includes keeping machines clean, consumables stocked, and work areas free of clutter. A clean work environment can also reduce the potential for errors. For example, if the work area is kept clean and organized, the chance of accidentally applying the wrong patient information to the EKG is reduced.

**Recognize pacemaker spikes on an EKG trace**

Electrical “spikes” may also be seen immediately prior to the QRS complex, such as on the following rhythms:
Paced Ventricular Rhythm (Ventricular Pacer)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>May or may not be present</td>
</tr>
<tr>
<td>PR interval</td>
<td>May or may not be present</td>
</tr>
<tr>
<td>QRS duration</td>
<td>Greater than 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>60 to 100</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>

Atrial-Ventricular Paced Rhythm (AV Sequential Paced)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>Present</td>
</tr>
<tr>
<td>PR interval</td>
<td>120 to 200</td>
</tr>
<tr>
<td>QRS duration</td>
<td>Greater than 120 milliseconds</td>
</tr>
<tr>
<td>Ventricular rate</td>
<td>60 to 100</td>
</tr>
<tr>
<td>Rhythm regularity</td>
<td>Regular</td>
</tr>
</tbody>
</table>

Summary

This chapter presented the information necessary to systematically approach the EKG and interpret arrhythmias encountered in the clinical setting. In addition, the chapter included pictures and real EKG tracings to promote rhythm recognition.
Chapter drill questions

Use the tracing below to answer questions 1 to 5.

![EKG tracing]

1. What is the patient’s heart rate?
   - A. 65/min
   - B. 85/min
   - C. 120/min
   - D. 180/min

2. What is the PR interval duration?
   - A. 100 milliseconds
   - B. 300 milliseconds
   - C. 160 milliseconds
   - D. 250 milliseconds

3. What is the QRS duration?
   - A. 20 milliseconds
   - B. 90 milliseconds
   - C. 120 milliseconds
   - D. 200 milliseconds

4. Which of the following is the approximate QT interval duration?
   - A. 100 milliseconds
   - B. 280 milliseconds
   - C. 380 milliseconds
   - D. 480 milliseconds

5. Which of the following types of rhythms is displayed above?
   - A. Sinus rhythm
   - B. Sinus bradycardia
   - C. Junctional rhythm
   - D. Ventricular tachycardia
Use the tracing below to answer questions 6 to 8.

6. Which of the following types of rhythms is displayed above?
   A. Sinus rhythm
   B. Sinus bradycardia
   C. Junctional rhythm
   D. Ventricular tachycardia

7. After viewing this rhythm, what action should the EKG technician take first?
   A. Perform rescue breathing.
   B. Call for help and the automated external defibrillator.
   C. Check for a medical alert bracelet.
   D. Administer high-flow oxygen.

8. What is the patient’s heart rate?
   A. 60/min
   B. 90/min
   C. 136/min
   D. 170/min

Use the tracing below to answer question 9.

9. Which of the following types of rhythms is displayed above?
   A. Sinus rhythm with PACs
   B. Variable bradycardia
   C. Junctional rhythm
   D. Atrial fibrillation with rapid ventricular response
Use the tracing below to answer question 10.

![EKG tracing]

10. Which of the following types of rhythms is displayed above?

   A. Sinus rhythm
   B. Supraventricular tachycardia
   C. Junctional tachycardia
   D. Ventricular tachycardia
Chapter drill answers

Use the tracing below to answer questions 1 to 5.

1. What is the patient’s heart rate?
   
   **A. 65/min**
   
   B. 85/min
   
   C. 120/min
   
   D. 180/min

   The correct heart rate for the above tracing is 65/min.

2. What is the PR interval duration?

   A. 100 milliseconds
   
   B. 300 milliseconds
   
   **C. 160 milliseconds**
   
   D. 250 milliseconds

   The PR interval is measured from the beginning of the P wave to the beginning of the QRS complex. Each small box represents 40 milliseconds. The PR interval in this tracing is 4 boxes in duration, or 160 milliseconds.

3. What is the QRS duration?

   A. 20 milliseconds
   
   B. 90 milliseconds
   
   **C. 120 milliseconds**
   
   D. 200 milliseconds

   The QRS duration is measured from the beginning of the Q wave to the end of the S wave. Each small box represents 40 milliseconds. The QRS in this tracing is 3 boxes in duration, or 120 milliseconds.
4. Which of the following is the approximate QT interval duration?

A. 100 milliseconds  
B. 280 milliseconds  
C. 380 milliseconds  
D. 480 milliseconds

The QT interval is measured from the beginning of the Q wave to the end of the T wave. Each small box represents 40 milliseconds. The QT interval in this tracing is approximately 12 small boxes in duration, or approximately 480 milliseconds.

5. Which of the following types of rhythms is displayed above?

A. Sinus rhythm  
B. Sinus bradycardia  
C. Junctional rhythm  
D. Ventricular tachycardia

A sinus rhythm has one P wave per QRS complex, a rate of 60 to 100/min, and a PR interval of less than 200 milliseconds. The rate in this tracing is too fast to be sinus bradycardia, and junctional rhythms do not have upright P waves. Ventricular tachycardia is characterized by a faster rate, wide QRS complex, and the absence of P waves.

Use the tracing below to answer questions 6 to 8.

6. Which of the following types of rhythms is displayed above?

A. Sinus rhythm  
B. Sinus bradycardia  
C. Junctional rhythm  
D. Ventricular tachycardia

This is ventricular tachycardia because it has a wide QRS complex, no P waves, and a heart rate greater than 120/min. The rate is too fast to be a sinus rhythm or sinus bradycardia, and the absence of a P wave further rules out those two rhythms. The rate is too fast for a junctional rhythm, and the QRS complex is too wide.
7. After viewing this rhythm, what action should the EKG technician take first?

A. Perform rescue breathing  
**B. Call for help and the automated external defibrillator.**  
C. Check for a medical alert bracelet.  
D. Administer high-flow oxygen

The American Heart Association recommends calling for help and the AED. Among the options above, the next step is to perform rescue breathing. Then, the technician should check for a medical alert bracelet. Lastly, the technician should administer high-flow oxygen.

8. What is the patient’s heart rate?

A. 60/min  
B. 90/min  
C. **136/min**  
D. 178/min

The most accurate method for determining the heart rate of tachyarrhythmias is the 1500 method. In this case, there are 11 mm between RR complexes. $\frac{1500}{11} = 136$/min.

Use the tracing below to answer question 9.

9. Which of the following types of rhythms is displayed above?

A. Sinus rhythm with PACs  
B. Variable bradycardia  
C. Junctional rhythm  
**D. Atrial fibrillation with rapid ventricular response**

AF RVR is characterized by an irregularly irregular heart rhythm, a heart rate greater than 100/min, and the absence of P waves. The heart rate is too fast for this rhythm to be a sinus rhythm with PACs, variable bradycardia, or a junctional rhythm, and a sinus rhythm with PACs would have visible P waves.
Use the tracing below to answer question 10.

10. Which of the following types of rhythms is displayed above?

A. Sinus rhythm  
B. **Supraventricular tachycardia**  
C. Junctional tachycardia  
D. Ventricular tachycardia

SVT is characterized by absent or retrograde P waves, a heart rate greater than 150/min, and narrow QRS complexes. The heart rate is too fast for this tracing to represent a sinus rhythm or junctional tachycardia, and the QRS complexes are too narrow for it to represent ventricular tachycardia.
Chapter terms & definitions

**Angina pectoris** – The sensation of pain or discomfort in the chest. Typically divided into “stable” and “unstable” episodes. Stable angina typically occurs with exercise and is relieved with rest or medication. Attacks usually last less than 20 minutes and occur with an expected pattern or frequency. Unstable angina is characterized by pain that occurs suddenly and without warning. Pain may last in excess of 20 minutes and may not be relieved with the usual measures. It represents a change in frequency and character from the patient’s “usual” pain.

**Aorta** – The largest artery in the human body. The aorta carries oxygenated blood away from the heart.

**Aortic valve (aortic semilunar)** – The aortic semilunar valve prevents blood in the aorta from returning to the left ventricle during diastole.

**Apex** – The lower pointed end of the heart

**Arrhythmia** – An abnormal heart rhythm

**Arteriosclerosis** – A chronic disease characterized by thickening and hardening of the arteries

**Artifact** – Electrical or magnetic interference that alters the EKG tracing

**Asystole** – The absence of any electrical activity in the heart

**Atherosclerosis** – Plaque buildup on the inner lining of blood vessels

**Atrioventricular (AV) node** – The AV node consists of specialized tissue that is able to regulate the impulses between atria and ventricles.

**Atrium** – A small muscular pouch-like structure that fills the ventricles with blood

**Augmented leads** – Leads created by combing two of the three limb leads to create a positive electrode. The third creates the negative electrode

**Base** – The top of the heart

**Baseline** – An electrically neutral area on the EKG

**Bicuspid valve (mitral)** – A valve in the heart that is situated between the left atrium and the left ventricle and prevents the backflow of blood into the right left atrium during diastole. Its flaps consist of two triangular cusps.

**Bradycardia** – Slow heart rate

**Bundle branch** – The bundle branches are part of the conduction system responsible for triggering ventricular muscle contraction

**Bundle of His** – The bundle of His is part of the conduction system responsible for conducting a stimulus to the septum and bundle branches

**Cardiac arrest** – The absence of cardiac activity

**Coronary arteries** – The arteries that supply oxygenated blood to the myocardium

**Depolarization** – A loss of polarization resulting from a sudden influx of sodium ions into the cardiac muscle cells. This results in contraction.
Ectopic – Originating in an area of the heart other than the sinoatrial node

Electrocardiograph (EKG) – A graphic representation of the electrical activity of the heart

Electrode – A specialized interface between the human body and an EKG machine

Endocardium – The innermost layer of the heart

Epicardium – The outermost layer of the heart

Inferior vena cava (IVC) – The largest vein in the human body. The IVC returns de-oxygenated blood to the heart.

Intercostal – Between the ribs

Ischemia – Insufficient oxygenation of tissue

Leads – Flexible or solid insulated conductors connected to or leading out from an electrical device. These conductors are typically placed on the skin surface and designed to measure electrical impulses.

Mediastinum – One of three compartments inside the chest. The mediastinum encapsulates the heart and great vessels.

Midaxillary – An imaginary line through the axillary region that separates the front and back of the human body

Midclavicular – An imaginary line through the middle of the clavicle that extends vertically

Myocardial infarction – Ischemia and death of heart muscle tissue

Myocardium – The middle muscular layer of the heart

Pacemaker – A medical device that provides artificial stimulation to the heart muscle to trigger contraction

Pericardium – A serous sac that encases the heart, is formed from two layers, and is usually filled with a small amount of fluid

PQRST waves – The standard waveforms found on the EKG tracing. Each wave corresponds to a specific event within the heart’s electrical cycle.

Precordial leads – Six EKG leads placed on the anterior chest to record electrical activity of the heart, mainly the electrical impulses originating in the ventricles or the heart’s anterior wall

Pulmonary artery – The only artery in the body that carries de-oxygenated blood. The pulmonary arteries carry blood to the lungs.

Pulmonic valve (pulmonary semilunar) – The pulmonary semilunar prevents blood in the lungs from returning to the right ventricle during diastole

Pulmonary vein – The only vein in the body that carries oxygenated blood. The pulmonary veins carry blood from the lungs to the heart.

Purkinje fiber – Fibers that serve to conduct electrical impulses through the right and left ventricles.
**Repolarization** – The process of moving sodium from inside the cell to the outside, and potassium from outside the cell to the inside. Repolarization involves establishing an electrical gradient across a cell membrane.

**Septum** – A dividing wall or partition, such as the one found between the atria and the ventricles

**Sinoatrial (SA) node** – A small mass of tissue, located in the right atrium, which serves to originate impulses that stimulate the heartbeat. SA node deplorarization corresponds to the P wave on the electrocardiogram.

**Superior vena cava** – The second-largest vein in the human body

**Tachycardia** – Fast heart rate

**Tricuspid valve** – The tricuspid valve separates the right atrium from the right ventricle

**Vasoconstriction** – The act of constricting a blood vessel

**Vasodilation** – The act of opening a blood vessel

**Ventricle** – The ventricles are responsible for pumping blood to the lungs and entire body
Learning Objectives
At the completion of this chapter, the CET candidate will be able to:

- Obtain the patient’s social, medical, surgical, and medication history.
- Educate patients about the EKG, Holter monitoring, stress testing, and telemetry.
- Properly apply EKG electrodes to acquire a 3-, 5-, and 12-lead EKG and Holter monitor.
- Discuss modifications to EKG lead placement in pediatric patients, rightsided EKG, and patients who have limb amputations.
- Discuss the signs and symptoms of cardiopulmonary compromise.
- Discuss the Health Insurance Portability and Accountability Act (HIPAA) and protected health information (PHI).
- Monitor a patient’s condition during stress testing.
- Respond to complications during stress testing.
- List expected reference range vital-sign parameters for different age groups.

Overview
This chapter presents the necessary information an EKG technician needs to educate patients on various procedures involving the EKG. This chapter also presents techniques for acquiring a patient’s medical, surgical, social, and medication history. The chapter provides a brief overview of HIPAA regulations as they pertain to protected health information, and reviews expected reference range vital signs across the lifespan. Ten drill questions conclude this chapter.

Prepare the patient

Before acquiring an EKG on a patient, gather pertinent medical, social, surgical, and medication history from the patient. Diseases, prior surgical procedures, and medications can all impact the appearance of the EKG tracing and must be documented.

Gathering patient history – Interviewing the patient and gathering pertinent health history is an important responsibility of the CET. It can provide clues to help clinicians form an accurate diagnosis.
Pertinent patient history includes social history, medical conditions, surgical history, and a complete list of current medications. Social history can help to determine the patient’s risk for many cardiac conditions, while medical history includes information about previous acute conditions, ongoing chronic conditions, and any current signs or symptoms.

Examples of questions about social history include the following:

- Does the patient smoke? If so, how many packs per day? If the patient quit smoking, how long ago did he/she quit?
- Does the patient drink alcohol or use drugs? How much? What kind?
- Does the patient lead a stressful life? Have they experienced any major life changes, such as caring for a sick loved one, divorce, unemployment, or relocation? What does the patient do to cope with stress?
- Does the patient exercise? If so, how often does he/she exercise, and what type of exercise does he/she do?
- What does the patient eat? Ask the patient about his/her diet and determine if he/she consumes high amounts of fat, sodium, and/or caffeine.
- Ask about the patient’s work environment and whether he/she is exposed to chemicals or is required to wear a respirator.
- Ask about the patient’s support system, such as family and friends whom the patient can turn to for help.
- Determine the patient’s marital status and whether he/she has children.

Examples of questions about medical history include the following:

- Ask about pertinent previous medical conditions, including hospitalizations and illnesses.
- Determine any history of heart attack, stroke, aneurysm, murmurs, endocarditis, pulmonary embolism, or deep vein thrombosis.
- Ask about chronic conditions such as heart failure, hypertension, hyperlipidemia, hyperglycemia or diabetes, COPD, cardiac arrhythmias, and obesity.
- Ask a female patient if she is pregnant.
- Ask about any allergies, including drug, food, and environmental allergies.

- Ask about any current symptoms the patient is experiencing. Use the mnemonic OPQRST (onset, provocation, quality, radiation, severity, time) to get a description of the symptom. For example, if the patient reports chest pain, ask what the patient was doing when it began, what relieves or worsens it, ask if it is sharp, burning, or dull, how severe the pain is, and how long ago it began. Ask if the patient has experienced any of the following symptoms:

  - Chest pain
  - Shortness of breath
  - Swelling of the legs and feet
  - Palpitations or racing heart
  - Fainting
  - Fatigue or weakness
  - Pallor
  - Coughing up blood

To gather surgical history:

- Document all surgeries, when and where the surgery was performed, and any complications that may have occurred.

- Ask about any history of valve replacement, cardiac catheterization, coronary artery bypass graft surgery, aneurysm repair, childhood cardiac surgeries, pacemaker implant or heart transplant.

To gather medication history:

- Document any allergies or adverse responses to medications, and describe the details of the allergic or adverse reaction. Document all medications that the patient is currently taking, including the name of the medication, the dose, and how often and the time of day that the medication is taken.

- Ask about any over-the-counter medications, herbal supplements, and vitamins.

- Ask patients about pharmacologic birth control or erectile dysfunction drugs, as they may forget to include them in a list of medications.
**Patient education** – Prior to performing any tests, educate the patient about the procedure to build trust and alleviate any anxiety. Keep in mind the patient must understand the procedure in order to provide informed consent. To facilitate communication, maintain a nonjudgmental attitude and demonstrate good listening behaviors (make eye contact, face the patient, repeat or clarify what the patient says to show understanding).

Assess the patient’s knowledge base to determine health literacy and ability to understand new information. Those who have cognitive disabilities may require extra time with the EKG technician to ensure that they understand the procedure. Older adults may also require more time to process and understand new information. People who have sensory impairments, such as blindness, hearing loss, and dysphasia, may require additional audiovisual media, such as written material with pictures or audiotapes. If the patient speaks a language other than English, communicate through a trained interpreter. By law, all patients must have access to a trained interpreter who speaks their native language. Avoid using family members as interpreters; they may not communicate information accurately to the patient.

Describe the purpose, length, and steps of the procedure as well as any preparation for which the patient is responsible. Explain the patient’s role during the test, and describe any side effects or follow-up care that the patient may need. Answer any questions that the patient may have, clarify any misinformation, and alleviate any fears.

The following lists include relevant information and instructions for performing each type of procedure:

**EKG**

- The static EKG is a diagnostic test that allows the physician to assess the electrical activity of the heart.

- It is a non-invasive, painless procedure that takes only a few minutes to complete.

- Ask the patient if he/she has ever had a reaction to latex or rubber.

- Explain that you will apply sticky electrodes that can be easily removed to the patient’s chest, arms, and legs. Explain that you will clean the skin and trim hair, if necessary, to ensure proper contact between the skin and electrode.

- Instruct the patient to remove any electronic devices from his/her pockets, as they may interfere with the test.

- Instruct the patient to lie flat, or with the head slightly elevated, and avoid touching anything that conducts electricity, such as the handrails of the bed.
Instruct the patient to remain as still as possible during the test for approximately 10 seconds while the machine acquires the EKG.

Advise the patient to notify the technician if he/she experiences itching, swelling, or redness where the electrodes contact the skin.

There are no significant side effects to this procedure.

Holter monitoring

The Holter monitor is a device used to monitor the electrical activity of the heart over a period of 24 to 72 hr as prescribed by the physician. It may detect problems that occur transiently.

Instruct the patient to bathe prior to his/her appointment, since the patient cannot remove the electrodes or immerse the device in water after it is in place.

Instruct the patient to wear loose-fitting clothing so the monitor can be worn under a shirt or blouse. The Holter monitor can be worn with a bra.

Ask the patient if he/she has ever had a reaction to latex or rubber.

Place sticky electrodes on the patient’s chest and keep them in place for the duration of the test. The skin may need to be cleaned to ensure that the electrodes adhere securely.

Advise the patient to notify the CET if the patient experiences itching, swelling, or redness where the electrodes contact the skin.

Instruct the patient to continue his/her normal daily routine, including work, exercise, and sleep. Tell the patient to keep the Holter monitor in place continuously.

Instruct the patient to keep a journal for the duration of the test. The patient should note the date, time, and duration of any symptoms, such as lightheadedness, palpitations, chest pain, and breathing problems, and describe what he/she was doing when they started. The patient should also note the date and time he/she takes any medications, engages in physical activity, and sleeps.

Instruct the patient to call the physician’s office if the electrodes fall off or the device malfunctions.

Tell the patient to call 911 if he/she experiences any serious signs or symptoms, such as fainting, weakness, profuse sweating without physical activity, or unrelieved chest pain that radiates to the arms or jaw.
• Instruct the patient that he/she is responsible for returning the monitor intact to the physician’s office.

• Although wearing the Holter monitor may be inconvenient, there are no significant side effects to the test.

Stress testing

• A stress test is used to determine how the heart functions under the increased workload caused by physical exercise. Specifically, the stress test is designed to provoke myocardial ischemia under controlled settings. If heart disease is suspected, symptoms may manifest during exercise that are not present at rest.

• The stress test takes approximately 10 minutes to complete. Apply electrodes to the patient’s chest, and if necessary, clean the skin and/or remove hair to ensure the electrodes adhere. Place a blood pressure cuff on the upper arm to monitor blood pressure during the test.

• If the patient experiences itching, swelling, or redness where the electrodes contact the skin, he/she should notify the technician.

• Take the patient’s baseline EKG at rest. Then instruct the patient to walk on a treadmill or use a stationary bike to gradually increase physical activity until you detect symptoms, the patient becomes fatigued or ill, or a target heart rate is reached.

• Instruct the patient to wear comfortable walking shoes and loose-fitting, lightweight clothing for the test.

• Instruct the patient not to eat, drink, or smoke for 3 hr before the test.

• Tell the patient to continue his/her normal medication routine unless the physician tells him/her otherwise.

• Ask the patient if he/she has had any reactions to rubber or latex. Ask the patient if he/she has a history of exercise-induced asthma or respiratory distress, or requires the use of an inhaler.

• Tell the patient he/she can stop the test at any time if he/she experiences fatigue, lightheadedness, dizziness, shortness of breath, or chest pain.

• After exercising, the patient may need to sit or stand still for a few minutes while the machine continues to record heart activity.

• Potential complications include low blood pressure and abnormal heart rhythms. These symptoms are usually alleviated when the patient stops exercising.
Telemetry monitoring

- Telemetry is used to continuously monitor the electrical system of the heart in patients who are at high risk for cardiac complications.

- Telemetry monitoring is non-invasive and painless.

- Determine if the patient has had a reaction to rubber or latex.

- Place electrodes on the patient’s arms and legs and keep them in place continuously. If necessary, clean the skin and trim hair to ensure the electrodes adhere securely.

- Advise the patient to notify the technician if he/she experiences itching, swelling, or redness where the electrodes contact the skin.

- Either registered nurses or technicians monitor the EKG. The monitors are programmed to alarm if the EKG detects a dangerous rate or rhythm.

- If the electrodes fall off at any time, the patient should notify hospital staff.

- Instruct the patient to notify hospital staff if he/she experiences dizziness, lightheadedness, weakness, chest pain, nausea or vomiting, shortness of breath, or profuse sweating.

Apply electrodes on patients

EKG

The 3-lead EKG configuration is generally used to continuously monitor the patient’s heart rhythm. Review the 3-lead configuration covered in Chapter 1:

- **White lead** – Right shoulder or clavicle area

- **Black lead** – Left shoulder or clavicle area

- **Red lead** – Left lower abdominal area

- **Green lead** – Right lower abdominal area
Holter monitoring

As you learned in Chapter 1, the 5-lead EKG configuration refers to the standard Holter monitor setup or the 5-lead rhythm monitor setup. The Holter monitor setup varies depending on the type of monitor. The 5-lead setup, pictured here and previously in Chapter 1, is the most common configuration employed:

**White lead** – Right sternum/clavicle area

**Black lead** – Left sternum/clavicle area

**Red lead** – Left lower thoracic area

**Green lead** – Right lower thoracic area

**Brown lead** – Just below and to the right of the bottom of the sternum

Stress testing

Stress testing requires slight modification of limb lead electrode placement to minimize limb motion artifact. Place the six precordial leads – leads V1 through V6 – in the same locations required for the standard 12-lead EKG, as described in Chapter 1. But place the four limb lead electrodes on the patient’s torso, rather than on the arms and legs, as shown in the diagram at right.

**White lead** – Right clavicle/shoulder area

**Black lead** – Left clavicle/shoulder area

**Red lead** – Left lower thoracic area

**Red lead** – Left lower abdominal area

**Green lead** – Right lower abdominal area
Telemetry

Telemetry monitoring can be executed in either a 3-lead or a 5-lead setup. The diagram at right shows the most commonly employed electrode placement for each.

The picture on the left illustrates the standard 3-lead configuration. Place the white electrode on the right shoulder area; the black electrode on the left shoulder area, and the red electrode on the lower left abdominal area.

The picture on the right illustrates the standard 5-lead configuration. Lead placement follows the 3 lead configuration exactly with the addition of a green electrode, placed on the lower right abdominal area, and a brown electrode placed just to the right of the bottom of the sternum. The brown lead provides similar information to lead V1 in the standard 12-lead tracing.

Pediatric patients

Patients younger than 2 years old require a right-sided, 12-lead EKG, which you learned about in Chapter 1. For patients who are ages 2-8, you can use either left- or right-sided EKGs. After age 8, you can no longer use the right-sided EKG. You can also use the right-sided EKG for patients with certain conditions, including inferior wall ST segment elevation and myocardial infarction.

For a right-sided, 12-lead EKG, you place limb leads in the normal fashion, but place the precordial leads as illustrated in the diagram at right.

**Precordial leads – Right side**

- V1 – 4th ICS, L of sternum
- V2 – 4th ICS, R of sternum
- V4 – 5th ICS, midclavicular (R) (most sensitive and specific to R ventricular infarction)
- V3 – between V2/V4
- V5 – 5th ICS between V4/V6
- V6 – 5th ICS, midaxillary

Patients with special considerations

**Inferior wall infarction** – When there’s an inferior wall infarction, you always need to consider posterior wall involvement. This diagram shows proper placement of leads V7, V8, and V9 for a posterior EKG. You will rarely perform the posterior EKG. Using the concept of reciprocal change discussed in Chapter 1, you can glean the same information from viewing leads V1 to V4.

**Amputation** – Lead placement must be modified in patients who have extremity amputation. Leads can be moved to an area just above the knees and elbows in patients who have distal extremity amputation. If the patient’s amputation is close to the torso, EKG electrodes can be placed on the patient’s torso.

**Respond to signs and symptoms of cardiopulmonary compromise**

Signs and symptoms of cardiopulmonary compromise can include the following:
- Tachycardia or bradycardia
- Pallor
- Diaphoresis
- Low blood pressure
- Fast, labored, shallow, or slow respirations
- Anxiety or confusion
- Cyanosis
- Chest pain that radiates to the back, arms, or jaw
- Chest tightness (squeezing sensation)
- Shortness of breath
- Nausea and vomiting
- Lightheadedness
- Weakness
- Syncope

Immediately notify the physician if the patient experiences any of the above symptoms before, during, or after stress testing.

Adhere to HIPAA regulations regarding Protected Health Information (PHI)

The Health Insurance Portability and Accountability Act of 1996 (HIPAA) established guidelines for the use and distribution of protected health information (PHI). PHI includes any information about the health status, use of health care services, and payment for health services that can be linked to an individual. This includes any patient identifiers, such as name, date of birth, medical record number, Social Security number, phone number, and address. All treatments, assessments, test results, diagnoses, medications, and payments for services are considered PHI.

Under HIPAA, limit communication of PHI to the patient and essential clinicians and staff members. Limit discussion of PHI among clinicians to the minimum amount of information necessary to accomplish the goal. Furthermore, health care staff who are not directly involved in patient care are not allowed to review patient medical records unless the patient’s case is being discussed during quality assurance meetings. PHI may be used for educational purposes if all patient identifiers are removed.

Patients have the right to confidentiality. Open discussion of PHI in public areas is prohibited. Patients can request that communication regarding their medical care be conducted through a particular phone number. Do not disclose PHI to family members or friends unless authorized by the patient. In some cases, PHI must be reported to regulating agencies, including cases of abuse, crime, or certain infectious diseases.

Patients also have a right to accurate medical records and can ask that any errors be corrected. Patients can also request to see any medical records; this information must be provided within 30 days of the request.
Monitor patient condition during stress testing

During stress testing, monitor the patient for abnormal vital signs, arrhythmias, and signs of cardiopulmonary compromise. The heart rate increases with physical activity, but extremely high rates may be a concern. Observe the EKG for arrhythmias such as polymorphic or monomorphic PVCs, ventricular tachycardia, supraventricular tachycardia, and heart blocks. Look for signs of ischemia, including T wave inversion and ST segment changes.

If the patient complains of dizziness, lightheadedness, nausea, severe shortness of breath, chest pain, or fatigue, stop the test and notify the physician.

Respond to complications during stress testing

Complications of stress testing include hypotension and arrhythmias. These usually resolve with rest. If hypotension persists, have the patient lie supine with legs elevated and notify the physician. Also notify the physician of persistent arrhythmias. Rarely, patients suffer cardiac arrest or ventricular arrhythmias requiring resuscitation. Continuously monitor the patient during and after the stress test and immediately report any concerning findings to the physician.

Verify patient understanding of Holter monitor procedures

Patients undergoing continuous heart monitoring in the outpatient setting should receive information about the device and how to troubleshoot common problems. To ensure patient understanding of Holter monitor procedures, ask the patient to verbalize the correct response to commonly asked questions:

- Is it okay to remove the electrodes? *(No.)*
- Is it okay to remove the battery? *(No.)*
- Is it okay to disconnect the leads or move them to a different location? *(No.)*
- What should you do if you experience itching, swelling, or redness at the site of electrode placement? *(Call the physician’s office.)*
- Is it okay to go to work, exercise, etc. while wearing the Holter monitor? *(Yes.)*
- What do you need to do when you experience any symptoms while wearing the Holter monitor? *(Write the date, time, and duration of symptoms, and what the symptoms were.)*
- What should you do if your symptoms include chest pain, shortness of breath, unexplained profuse sweating, or passing out? *(Call 911.)*
Obtain patient vital signs

**Normal vital signs** – Assess vital signs on every patient. It is important to know the expected reference range of vital signs for all age groups. Report vital signs that are outside the expected reference range to clinical staff. The table below summarizes normal vital signs for multiple age groups.

<table>
<thead>
<tr>
<th></th>
<th>Heart rate</th>
<th>Resp. rate</th>
<th>SpO2</th>
<th>Systolic BP</th>
<th>Diastolic BP</th>
<th>Temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adult</strong></td>
<td>60 to 100/min</td>
<td>12 to 20/min</td>
<td>95 to 100%</td>
<td>90 to 120 mm Hg</td>
<td>60 to 90 mm Hg</td>
<td>35.8 to 37.3º C (96.4 to 99.1º F)</td>
</tr>
<tr>
<td><strong>Child (6-12)</strong></td>
<td>70 to 120/min</td>
<td>18 to 30/min</td>
<td>95 to 100%</td>
<td>70+2*age</td>
<td>N/A</td>
<td>35.8 to 37.3º C (96.4 to 99.1º F)</td>
</tr>
<tr>
<td><strong>Child (1-5)</strong></td>
<td>80 to 150/min</td>
<td>24 to 34/min</td>
<td>95 to 100%</td>
<td>70+2*age</td>
<td>N/A</td>
<td>35.8 to 37.3º C (96.4 to 99.1º F)</td>
</tr>
<tr>
<td><strong>Infant (&lt;1)</strong></td>
<td>100 to 160/min</td>
<td>30 to 60/min</td>
<td>95 to 100%</td>
<td>&gt;70</td>
<td>N/A</td>
<td>35.8 to 37.3º C (96.4 to 99.1º F)</td>
</tr>
</tbody>
</table>


Vital signs can vary slightly with certain medical conditions and age groups. The adult heart rate may be greater than 100/min with anxiety or distress. It may be less than 60/min if the patient is taking certain medications, such as beta-blockers. Assess abnormal heart rates manually using the radial or apical pulse for a full minute, especially if the heart rate is irregular.

An adult’s blood pressure may be greater than 120/80 mm Hg if the patient has essential hypertension. Reassess an abnormal blood pressure manually. An extremely high blood pressure is dangerous and can increase the risk of stroke or pulmonary edema. Hypotension (systolic blood pressure less than 90 mm Hg) is also dangerous and can result in loss of consciousness, brain injury, and organ failure. Continuously monitor the patient for symptoms of distress, including pallor, diaphoresis, headache, confusion, weakness, and nausea.
The pulse oximeter is unreliable if the patient has cold hands, colored nail polish or acrylic nails, edema, or carbon monoxide poisoning. In addition, patients with chronic respiratory ailments may function normally with SpO₂ levels below 95%. If the SpO₂ is abnormally low, assess the patient for signs of adequate perfusion such as warm skin, pink mucous membranes, strong peripheral pulses, and capillary refill that is less than 2 seconds. In addition, patients who have hypoxia (low SpO₂) may experience anxiety, confusion, and increased respiratory rate.

Patients may be tachypneic (respiratory rate greater than 20/min) if they are anxious or experiencing respiratory distress. A patient may also have bradypnea (respiratory rate less than 10/min) as a side effect of certain drugs. Abnormal respiratory rates can be serious and result in acid-base imbalance, hypoxia, brain injury, and organ failure.

Typically, temperature is measured orally, but for young children, the temperature may be obtained rectally. Rectal temperature is typically 0.4 to 0.5°C higher than the temperatures listed in the table on page 61. Older adults may have slightly lower body temperatures due to loss of body fat and muscle mass. Because older adults are less able to regulate body temperature, they are susceptible to hypothermia and hyperthermia. Fever is present if temperature is greater than 38.3°C (100.9°F).

Summary

This chapter explored various aspects of patient care. It included information on preparing the patient for different EKG procedures, including techniques for acquiring a patient’s medical, surgical, social, and medication history. It also discussed HIPAA and protected health information, monitoring and responding to patient condition during stress testing, and provided expected reference range vital signs across the life span.
Chapter drill questions

1. A patient tells the EKG technician he underwent coronary artery bypass grafting two years ago. This is an example of which of the following types of history?

   A. Medical
   B. Social
   C. Medication
   D. Surgical

2. Which of the following is the expected reference range for an adult’s resting heart rate?

   A. 30 to 40/min
   B. 60 to 100/min
   C. 100 to 110/min
   D. 80 to 130/min

3. Which of the following statements about protected health information is correct?

   A. It can be shared with anyone who asks for it.
   B. It is for health insurance companies only.
   C. It is for employer use only and used to calculate insurance rates.
   D. It can be shared with the patient and staff directly taking care of the patient.

4. Which of the following statements illustrates the patient understands Holter monitor procedures?

   A. “I can take my Holter monitor off before showering.”
   B. “I must not get the Holter monitor wet at any time.”
   C. “I can move the electrodes on my chest if they bother me.”
   D. “I should not take my medicine while wearing the monitor.”

5. Which of the following statements illustrates the need for further patient education?

   A. “I can wear jeans and boots for my stress test.”
   B. “I must not eat for several hours prior to the stress test.”
   C. “I must notify the doctor of any chest pain during the test.”
   D. “The stress test is a safe procedure with few side effects.”

6. Which of the following is the expected reference range for an adult’s respiratory rate at rest?

   A. 60 to 100/min
   B. 12 to 20/min
   C. 4 to 6/min
   D. 20 to 30/min
7. Which of the following is a sign of cardiovascular compromise?

A. Cyanosis  
B. Nausea  
C. Headache  
D. Shortness of breath

8. While acquiring a standard 12-lead EKG, a technician notices the patient stops breathing and has no pulse. What should the technician do first?

A. Call for help and begin CPR.  
B. Assess the patient’s respirations.  
C. Interpret the EKG tracing.  
D. Defibrillate the patient.

9. Which of the following is the expected reference range for an infant’s resting heart rate?

A. 60 to 100/min  
B. 12 to 20/min  
C. 100 to 160/min  
D. 20 to 30/min
Chapter drill answers

1. A patient tells the EKG technician he underwent coronary artery bypass grafting two years ago. This is an example of which of the following types of history?

A. Medical
B. Social
C. Medication
D. Surgical

A coronary artery bypass graft is a surgical procedure and would be part of a patient’s surgical history. It is not a medical procedure and is not an example of the patient’s social or medication history.

2. Which of the following is the expected reference range for an adult’s resting heart rate?

A. 30 to 40/min
B. 60 to 100/min
C. 100 to 110/min
D. 80 to 130/min

The expected reference range for an adult’s resting heart rate is 60 to 100/min.

3. Which of the following statements about protected health information is correct?

A. It can be shared with anyone who asks for it.
B. It is for health insurance companies only.
C. It is for employer use only and used to calculate insurance rates.
D. It can be shared with the patient and staff directly taking care of the patient.

PHI can only be shared with the patient and health providers directly caring for the patient. It cannot be shared with anyone who asks for it, it cannot be shared with health insurance companies, and it is not for employer use only, nor is it used to calculate insurance rates.
4. Which of the following statements illustrates the patient understands Holter monitor procedures?

A. “I can take my Holter monitor off before showering.”

**B. “I must not get the Holter monitor wet at any time.”**

C. “I can move the electrodes on my chest if they bother me.”

D. “I should not take my medicine while wearing the monitor.”

The Holter monitor should be kept dry. The patient should not remove the Holter monitor or move the electrodes. The patient should continue to take all prescribed medications while wearing the Holter monitor.

5. Which of the following statements illustrates the need for further patient education?

A. “I can wear jeans and boots for my stress test.”

B. “I must not eat for several hours prior to the stress test.”

C. “I must notify the doctor of any chest pain during the test.”

D. “The stress test is a safe procedure with few side effects.”

The stress test requires the patient to walk or run on a treadmill. The patient should not wear jeans and boots. The other options are correct statements by the patient. The patient should not eat prior to the test and should not be allowed to continue the test if chest pain develops. The stress test is safe and has few side effects.

6. Which of the following is the expected reference range for an adult’s respiratory rate at rest?

A. 60 to 100/min

B. 12 to 20/min

C. 4 to 6/min

D. 20 to 30/min

The expected reference range for an adult’s respiratory rate at rest is 12 to 20/min.

7. Which of the following is a sign of cardiovascular compromise?

A. Cyanosis

B. Nausea

C. Headache

D. Shortness of breath

Cardiovascular compromise interrupts normal tissue perfusion, causing cyanosis, so cyanosis is a sign of cardiovascular compromise. Nausea, headache, and shortness of breath would be symptoms, rather than signs.
8. While acquiring a standard 12-lead EKG, a technician notices the patient stops breathing and has no pulse. What should the technician do first?

     **A. Call for help and begin CPR.**
     B. Assess the patient’s respirations.
     C. Interpret the EKG tracing.
     D. Defibrillate the patient.

Calling for help and beginning CPR is the recommended first step according to American Heart Association guidelines. The 2010 AHA guidelines recommend compressions, airway, and breathing, in that order. Next, the technician should assess the patient’s respirations to determine if the patient is breathing. Then, the technician should interpret the EKG tracing to determine the cause of the cardiac arrest. Lastly, the technician should defibrillate the patient.

9. Which of the following is the expected reference range for an infant’s resting heart rate?

     A. 60 to 100/min
     B. 12 to 20/min
     **C. 100 to 160/min**
     D. 20 to 30/min

The expected reference range for an infant’s resting heart rate is 100 to 160/min.
Chapter terms & definitions

**HIPAA** – The Health Insurance Portability and Accountability Act was enacted in 1996 to prevent fraud, ensure privacy, and promote continuity of health insurance.

**Holter monitor** – A portable device that continuously monitors a patient’s heart rhythm.

**Protected Health Information (PHI)** – Any information that identifies a patient, including past medical history, prescriptions, and surgical history.

**Stress test** – A test designed to provoke ischemia and related EKG changes in patients who have coronary artery disease.
Stress Test

Susan, an EKG technician, is preparing for Mr. Smith’s stress test. She reads his medical file and notes that he is a 72-year-old male with no known drug allergies and a history of hypertension, for which he takes metoprolol. He has been having chest pain on physical exertion, and the cardiologist ordered an exercise stress test.

Mr. Smith is led to exam room 2, where Susan is waiting to start the stress test. She introduces herself and confirms Mr. Smith’s identity by asking him to state his full name and date of birth. Susan explains to Mr. Smith the steps of the stress test. She then cleans his skin, removes any hair necessary, applies electrodes to his chest, and instructs him to wait for the physician’s assistant to begin the test.

1. After the physician explained the procedure, Mr. Smith signed paperwork allowing providers to perform the stress test. This is an example of

   A. tort.
   B. negligence.
   C. informed consent.
   D. invasion of privacy.

2. Which of the following patients should not receive a stress test?

   A. A 67-year-old female with transient substernal chest pain and a normal EKG
   B. A 74-year-old male who has a history of a myocardial infarction
   C. A 54-year-old male with unrelieved chest pain and ST segment elevation
   D. An 82-year-old female who complains of an occasional “racing heart”

3. What modification to lead placement is made for stress testing?

   A. V6 is placed at the 5th intercostal space at the midaxillary line.
   B. Limb leads are placed on the patient’s torso instead of the limbs.
   C. A limb lead is applied to the right leg to act as a ground.
   D. In lead II, the left leg is positive and the right arm is negative.
4. During the stress test, Mr. Smith states that he feels dizzy and nauseous. His heart rate is 98. Which of the following should Susan do?

A. Decrease the treadmill speed until the dizziness resolves.
B. Stop the test immediately, let Mr. Smith sit, and notify the physician.
C. Allow Mr. Smith to rest for five minutes and then restart the test.
D. Reassure Mr. Smith that this is normal and continue the test.

5. Mr. Smith is taking metoprolol for hypertension. Which of the following is a common side effect of this beta-blocker?

A. Hypotension
B. Severe headache
C. Tachycardia
D. Constipation

6. Which of the following statements by the EKG technician correctly describes how the patient should prepare for the stress test?

A. “Discontinue your normal medication routine so it doesn’t interfere with stress test results.”
B. “Eat a small meal just before arriving for the stress test.”
C. “Wear comfortable clothes and shoes for the test.”
D. “Practice for the stress test by jogging daily for 20 minutes.”

Use the tracing below to answer questions 7 and 8:

7. Interpret Mr. Smith’s rhythm in the EKG tracing above.

A. Sinus tachycardia
B. Supraventricular tachycardia
C. Ventricular tachycardia
D. Atrial tachycardia

8. Which of the following best describes the rhythm above?

A. An irregular rhythm with ectopic beats
B. A regular rhythm of sinus origin which is faster than normal
C. 60-cycle interference
D. A ventricular rhythm which is potentially life-threatening.
Stress Test: Answers

1. After the physician explained the procedure, Mr. Smith signed paperwork allowing providers to perform the stress test. This is an example of

A. tort.
B. negligence.
C. informed consent.
D. invasion of privacy.

Informed consent is defined as explaining the procedure to the patient, ensuring an understanding of the procedure and its risks and benefits, and consenting to perform the procedure. Invasion of privacy is a wrongful intrusion into private matters. Tort refers to a wrongful act. Negligence refers to failure to take proper care.

2. Which of the following patients should not receive a stress test?

A. A 67-year-old female with transient substernal chest pain and a normal EKG
B. A 74-year-old male who has a history of a myocardial infarction
C. A 54-year-old male with unrelieved chest pain and ST segment elevation
D. An 82-year-old female who complains of an occasional “racing heart”

A 54-year-old male with unrelieved chest pain and ST segment elevation is experiencing an acute, life-threatening event and should not receive a stress test. Stress testing is indicated for the patients described in options A, B, and D.

3. What modification to lead placement is made for stress testing?

A. V6 is placed at the 5th intercostal space at the midaxillary line.
B. Limb leads are placed on the patient’s torso instead of the limbs.
C. A limb lead is applied to the right leg to act as a ground.
D. In lead II, the left leg is positive and the right arm is negative.

Limb leads are moved to the torso to eliminate the possibility of tripping on the wires and reducing artifact on the EKG during movement. V6 is normally placed at the fifth intercostal space at the midaxillary line. Leads are not placed on the limbs for stress testing, so a limb lead would not be applied to the right leg to act as a ground. A positive left leg and a negative right arm for lead II is not a modification for lead placement.
4. During the stress test, Mr. Smith states that he feels dizzy and nauseous. His heart rate is 98. Which of the following should Susan do?

A. Decrease the treadmill speed until the dizziness resolves.
B. **Stop the test immediately, let Mr. Smith sit, and notify the physician.**
C. Allow Mr. Smith to rest for five minutes and then restart the test.
D. Reassure Mr. Smith that this is normal and continue the test.

Dizziness and nausea may be symptoms of acute coronary syndrome and should prompt the technician to stop the test immediately. The stress test does not normally induce dizziness and nausea. The technician should not restart the test without notifying the physician first and obtaining orders to continue.

5. Mr. Smith is taking metoprolol for hypertension. Which of the following is a common side effect of this beta-blocker?

A. **Hypotension**
B. Severe headache
C. Tachycardia
D. Constipation

Hypotension is a common side effect of metoprolol; severe headache is not. Beta-blockers cause a decrease in blood pressure and do not cause constipation.

6. Which of the following statements by the EKG technician correctly describes how the patient should prepare for the stress test?

A. “Discontinue your normal medication routine so it doesn’t interfere with stress test results.”
B. “Eat a small meal just before arriving for the stress test.”
C. **“Wear comfortable clothes and shoes for the test.”**
D. “Practice for the stress test by jogging daily for 20 minutes.”

The stress test requires walking or running on a treadmill, so the patient should wear comfortable footwear and shoes. Patients should continue their normal medication regimen. The patient should not eat prior to the stress test, and there is no practice routine recommended for the stress test.
Use the tracing below to answer questions 7 and 8.

7. Interpret Mr. Smith’s rhythm in the EKG tracing above.

A. Sinus tachycardia  
B. Supraventricular tachycardia  
C. Ventricular tachycardia  
D. Atrial tachycardia

ST is characterized by a heart rate between 100-150/min, P waves, and narrow QRS complexes. This heart rate is too slow to be supraventricular tachycardia, and P waves are visible. It cannot be ventricular tachycardia, because P waves are visible and the QRS complexes are of normal duration. The atrial rate is too slow for this rhythm to be atrial tachycardia.

8. Which of the following best describes the rhythm above?

A. An irregular rhythm with ectopic beats  
B. A regular rhythm of sinus origin which is faster than normal  
C. 60-cycle interference  
D. A ventricular rhythm which is potentially life-threatening

This rhythm represents sinus tachycardia, which is characterized by a rate of 100-150/min and the presence of P waves. This rhythm is regular and reveals no ectopy. No artifact is present in this tracing, and the QRS complexes are too narrow to be ventricular in origin.
Juan, an EKG technician, is working in an emergency department. He has just been informed that he needs to acquire a 12-lead EKG from an 82-year-old female patient, Mrs. Singh. Juan confirms the orders for the 12-lead EKG in the patient’s electronic medical record. He notes that Mrs. Singh fainted while walking at the park. She had a similar event last year, and she was diagnosed with atrial fibrillation, for which she takes digoxin. She is allergic to penicillin.

Juan introduces himself to the patient, confirms her identity, and explains the procedure. He ensures the patient’s privacy as he applies the electrodes to the chest and limbs and acquires the 12-lead EKG. Prior to leaving the room, he places Mrs. Singh on an EKG monitor.

1. Which of the following describes proper limb lead placement for 12-lead EKG acquisition?

A. The limb leads can be applied anywhere on the torso.
B. Precise placement of the limb leads does not affect the EKG trace.
C. The limb leads are all unipolar and should go on the trunk.
D. The limb leads are applied to the wrists and ankles.

Use the tracing below to answer Question 2.

2. The EKG technician sees the artifact shown on the tracing above. What is most likely causing the artifact?

A. Patient respirations
B. Tremors of the extremities
C. Seizure
D. Cellular phones
Use the tracing below to answer questions 3 and 4.

3. Using the tracing, calculate the patient’s heart rate.

   A. 35/min
   B. 40/min
   C. 53/min
   D. 64/min

4. What is the arrhythmia in the EKG tracing above?

   A. Atrial flutter
   B. Atrial fibrillation
   C. Sinus bradycardia
   D. Junctional bradycardia

5. Mrs. Singh suddenly loses consciousness and does not appear to be breathing. Which of the following should Juan do first?

   A. Check the patient’s blood sugar level.
   B. Call for assistance and determine responsiveness.
   C. Perform a “head tilt, chin lift” to determine respiratory status.
   D. Notify the nurse that the patient is bradycardic.
12-Lead EKG: Answers

1. Which of the following describes proper limb lead placement for 12-lead EKG acquisition?

   A. The limb leads can be applied anywhere on the torso.
   B. Precise placement of the limb leads does not affect the EKG trace.
   C. The limb leads are all unipolar and should go on the trunk.
   D. **The limb leads are applied to the wrists and ankles.**

   The limb leads should be placed as far apart as possible and equidistant on the limbs. They cannot be applied anywhere on the torso or on the trunk, and the leads are bipolar. Lead placement does affect the EKG trace.

Use the tracing below to answer Question 2.

2. The EKG technician sees the artifact shown on the tracing above. What is most likely causing the artifact?

   A. Patient respirations
   B. Tremors of the extremities
   C. Seizure
   D. **Cellular phones**

   This tracing shows 60-cycle interference, the common artifact caused by cellular devices. Patient respirations cause wandering baseline. Tremors cause artifact that is more irregular and appears much more chaotic. Also, tremor artifact affects all leads. Seizure activity is chaotic and much faster than the artifact seen here. Also, artifact from seizure activity affects all leads.
3. Using the tracing, calculate the patient’s heart rate.

A. 35/min
B. 40/min
C. 53/min
D. 64/min

The heart rate should be calculated using the 1500 method. Dividing 1,500 by the number of small boxes, 27, yields an answer of 53/min.

4. What is the arrhythmia in the EKG tracing above?

A. Atrial flutter
B. Atrial fibrillation
C. Sinus bradycardia
D. Junctional bradycardia

Sinus bradycardia is characterized by the presence of P waves preceding each QRS complex, a rate of less than 60/min, a normal-duration QRS complex, and a regular R-R interval. There are no flutter waves visible in the tracing, so this is not atrial flutter. The rhythm is regular, so it can’t be atrial fibrillation. The rhythm can’t be junctional bradycardia because there are P waves.
5. Mrs. Singh suddenly loses consciousness and does not appear to be breathing. Which of the following should Juan do first?

A. Check the patient’s blood sugar level.
B. Call for assistance and determine responsiveness.
C. Perform a “head tilt, chin lift” to determine respiratory status.
D. Notify the nurse that the patient is bradycardic.

Calling for assistance and determining responsiveness are the priority action according to American Heart Association guidelines. After that, AHA guidelines recommend compression first, followed by airway assessment and breathing, so the “head tilt, chin lift” maneuver would come next among these options. The nurse and physician should be notified after CPR is initiated. The patient’s blood sugar level would be evaluated after these actions.
Holter Monitor

Mr. Lopez is a 42-year-old male who has been experiencing palpitations and dizziness. Sarah, an EKG technician, has been instructed to apply a Holter monitor on Mr. Lopez. After reading his medical file, Sarah notes that he is currently not taking any medications, has no cardiac history and has no known drug allergies.

Sarah explains the procedure to Mr. Lopez and tells him what to expect over the next 24 hours. She then prepares his skin and applies the electrodes. After she applies the Holter monitor, Mr. Lopez leaves.

1. Which of the following describes proper lead placement for a 5-lead device?

   A. Two electrodes are placed over the bone at the fourth rib to the right of the sternum and the fifth rib at the left midaxillary line.
   B. Two electrodes are placed over the ninth rib at the right midaxillary line to act as a ground.
   C. Two electrodes are placed over the manubrium.
   D. Five electrodes are placed at the position of V1 to V5.

2. Which of the following describes proper preparation of the patient prior to applying electrodes?

   A. Clean the skin with alcohol, remove any hair with a razor, and abrade the epidermis.
   B. Clean the skin with soap and water and abrade the skin vigorously.
   C. Apply an adhesive to the skin before placing the electrodes over the adhesive.
   D. Provide the patient with instructions to apply the electrodes before exercising.

3. Which of the following is considered to be a positive Holter test?

   A. Sinus rhythm with premature atrial complexes
   B. Sinus rhythm with ST segment elevation
   C. Sinus rhythm with no episodes of tachycardia
   D. Sinus rhythm with a heart rate of 84/min

4. Which of the following statements would indicate Mr. Lopez understands Holter monitor procedures?

   A. “The monitor may be removed when exercising.”
   B. “If I feel symptoms such as dizziness or palpitations, I should then attach the monitor.”
   C. “I have a pacemaker, so I can’t wear the Holter monitor.”
   D. “I should wear the monitor continuously, even during work, sleep and exercise.”
5. Which of the following statements by Mr. Lopez would indicate a need for additional education?

A. “If an electrode falls off or the monitor stops working, I should call the office.”
B. “I should press the event button on the monitor when I have symptoms.”
C. “I should not be concerned by any redness or itching that occurs around the electrodes, as this is a normal response to the conductive gel.”
D. “I should continue to take all medications as prescribed, and record when I take them in my journal.”

6. When reviewing the Holter test, Sarah notes that there are unusually long pauses in the EKG throughout the 24-hour period. What is a common cause of this artifact?

A. Movement of the electrodes
B. Loose connection of the leads
C. Dead battery
D. The monitor was placed in water

7. If Sarah releases information about Mr. Lopez’s diagnosis to his employer, which patient right has she violated?

A. Patient consent
B. Patient confidentiality
C. Access to treatment
D. Refusal of care
Holter Monitor: Answers

1. Which of the following describes proper lead placement for a 5-lead device?

   A. **Two electrodes are placed over bone at the fourth rib to the right of the sternum and the fifth rib at the left midaxillary line.**
   B. Two electrodes are placed over the ninth rib at the right midaxillary line to act as a ground.
   C. Two electrodes are placed over the manubrium.
   D. Five electrodes are placed at the position of V1 to V5.

   For a 5-lead device, two electrodes are placed over bone at the fourth rib to the right of the sternum and the fifth rib at the left midaxillary line.

2. Which of the following describes proper preparation of the patient skin prior to applying electrodes?

   A. **Clean the skin with alcohol, remove any hair with a razor, and abrade the epidermis.**
   B. Clean the skin with soap and water and abrade the skin vigorously.
   C. Apply an adhesive to the skin before placing the electrodes over the adhesive.
   D. Provide the patient with instructions to apply the electrodes before exercising.

   To prepare the patient’s skin for electrode placement, clean the skin with alcohol, remove hair with a razor, and scrape the patient’s epidermis. The skin should not be abraded vigorously. The electrodes contain the adhesive, and they should be applied directly to the skin with no additional adhesive. The EKG technician, not the patient, must apply the electrodes.

3. Which of the following is considered to be a positive Holter test?

   A. Sinus rhythm with premature atrial complexes
   B. **Sinus rhythm with ST segment elevation**
   C. Sinus rhythm with no episodes of tachycardia
   D. Sinus rhythm with a heart rate of 84/min

   ST segment elevation is a medical emergency and is considered a positive Holter test. A test displaying a sinus rhythm with premature atrial complexes, no episodes of tachycardia, or a heart rate of 84/min is considered a normal test.
4. Which of the following statements would indicate the patient understands Holter monitor procedures?

A. “The monitor may be removed when exercising.”
B. “If I feel symptoms such as dizziness or palpitations, I should then attach the monitor.”
C. “I have a pacemaker, so I can’t wear the Holter monitor.”
D. “I should wear the monitor continuously, even during work, sleep and exercise.”

The patient should wear the monitor continuously to ensure capture of any arrhythmias. The patient must not remove the monitor, and the presence of a pacemaker does not interfere with the monitor.

5. Which of the following statements by Mr. Lopez would indicate a need for additional education?

A. “If an electrode falls off or the monitor stops working, I should call the office.”
B. “I should press the event button on the monitor when I have symptoms.”
C. “I should not be concerned by any redness or itching that occurs around the electrodes, as this is a normal response to the conductive gel.”
D. “I should continue to take all medications as prescribed, and record when I take them in my journal.”

The patient should report redness or itching, as they may be signs of allergic reaction or hypersensitivity to the electrodes. The other options are correct statements by the patient. The patient should call the office if an electrode falls off or the monitor stops working, should press the event button when he/she experiences symptoms, and should continue to take and record all prescribed medications.

6. When reviewing the Holter test, Sarah notes that there are unusually long pauses in the EKG throughout the 24-hour period. What is a common cause of this artifact?

A. Movement of the electrodes
B. **Loose connection of the leads**
C. Dead battery
D. The monitor was placed in water

A loose connection can cause long pauses in the EKG recording. Movement of the electrodes does not cause long pauses. The EKG will not record at all if the battery is dead. Submersion in water will cause damage to the monitor, and no tracing will be recorded.
7. If Sarah releases information about Mr. Lopez's diagnosis to his employer, which patient right has she violated?

A. Patient consent  
B. **Patient confidentiality**  
C. Access to treatment  
D. Refusal of care

Mr. Lopez's diagnosis is confidential and may not be shared with his employer, so this is a violation of patient confidentiality. Patient consent involves educating the patient and obtaining permission to perform a procedure. Mr. Lopez was not denied access to treatment in this scenario and did not refuse treatment.
A Certified EKG Technician (CET) performs many vital tasks as a member of the health care team. These include educating patients on EKG procedures such as ambulatory monitoring, stress testing, and exam preparation; acquiring static EKGs; preparing patients for stress testing; assisting other health care workers during stress testing; preparing patients for ambulatory monitoring; assessing patients before, during, and after stress testing; recognizing life-threatening emergencies; responding to calls for and assisting during resuscitation; and performing administrative and record-keeping duties.

Earning a certification as a CET demonstrates your commitment to excellence in the field and is evidence of your desire to perform your duties in a professional manner. Not only does certification demonstrate a level of competence in the field, it also differentiates you from others without any certification, enabling you to earn higher wages than those who aren’t certified.

This CET study guide is designed to provide you with the information needed to successfully complete the CET certification examination.

The study guide presents information in five distinct sections: 1) Introduction; 2) EKG Monitoring; 3) Patient Care; 4) Case Studies; and 5) Summary. The study guide provides a list of objectives so candidates can focus their studying on the areas needed. At the end of chapters 1 and 2, and in the case study section, self-assessment questions are included to enable students to identify areas of strength and weakness. Key terms also are presented at the end of chapters 1 and 2.

The introduction presents an introduction to the certification. It includes information about the test, testing procedures, minimum passing score, test-taking strategies, and other test-preparation items. Understanding how to prepare for the exam will enable the CET candidates to achieve the highest possible score on the exam. It is also important to be familiar with the test length and anticipate the type of questions that will appear on the exam.

Chapter 1 presents information on the approach to arrhythmia interpretation, lead placement, and EKG acquisition. It presents rules of interpretation for arrhythmias that originate in the SA node, atria, AV junction, and ventricles, as well as artificial pacemakers. The chapter also presents rules for the diagnosis of heart blocks and included real EKG tracings with arrhythmias in order to promote pattern recognition. One of the most important skills the CET must possess is the ability to interpret EKG rhythms. The
information in this chapter is designed to prepare the CET candidate for the exam, but more importantly for the workplace, by introducing all the necessary information and rules for the systematic approach to arrhythmia interpretation.

Chapter 2 presents information on patient care and education, covering stress testing, Holter monitoring, and EKG monitoring. Patient monitoring and responding to medical emergencies during stress testing are also discussed. Medical-legal considerations such as patient confidentiality, protected health information, and HIPAA are presented as well. An EKG technician is required to be actively involved with patient monitoring before, during, and after cardiac exams. The technician must also possess the necessary assessment skills to determine when patients are suffering from life-threatening emergencies. Furthermore, the technician is often the first to respond to life-threatening emergencies. This chapter presents the information needed to safely monitor, assess, and respond to emergencies during and after cardiac exams.

The case study section provides candidates with three scenarios to reinforce learning and provide real-world examples of EKG acquisition, complications, and troubleshooting. Self-assessment questions with each case study provide additional exposure to the material, as well as further exposure to the test-taking process itself. One of the ways for the CET candidate to develop skills for EKG interpretation, patient assessment, and emergency response is to gain more exposure to all of those situations. This chapter is designed to expose the CET candidate to real-world situations and to promote critical-thinking skills.
REFERENCES
