UNIT NINE: DIAGNOSTIC PROCEDURES

PRINCIPLES OF ELECTROCARDIOGRAPHY

SCENARIO

Martha Reyes has worked for almost 4 years at a local family practice office, but she has decided to take a new position in the cardiology practice next door, where she will be working for Dr. Julie Lee. Martha is very enthusiastic about the new position, but she realizes that she has a great deal to learn to provide the best patient service possible in Dr. Lee's practice. Although Martha is familiar with general cardiology practices from her previous employment, she must understand and be able to perform procedures performed for cardiac patients, especially electrocardiography.

While studying this chapter, think about the following questions:

- To fulfill her job description with Dr. Lee, what does Martha need to know about the electrical conduction system of the heart?
- How does an electrocardiography (ECG) machine work?
- How should a patient be prepared for an electrocardiogram?
- How will Martha perform an ECG diagnostic procedure?
- What is the normal appearance of ECG complexes?
- What are the characteristics of common ECG arrhythmias that Martha must be able to recognize?
- What additional cardiac tests should Martha be prepared to assist with and explain to patients?

LEARNING OBJECTIVES

1. Define, spell, and pronounce the terms listed in the vocabulary.
2. Apply critical thinking skills in performing the patient assessment and patient care.
3. Illustrate the electrical conduction system through the heart.
4. Explain the concepts of cardiac polarization, depolarization, and repolarization.
5. Summarize the properties of the electrocardiograph.
6. Describe the electrical views of the heart recorded by the 12-lead electrocardiograph.
7. Discuss the process of recording an electrocardiogram.
8. Perform an accurate recording of the electrical activity of the heart.
9. Compare and contrast electrocardiographic artifacts and the probable cause of each.
10. Identify a typical electrocardiograph tracing.
11. Describe common electrocardiographic arrhythmias.
12. Summarize cardiac diagnostic tests.
VOCABULARY

atria The two upper chambers of the heart.
atrioventricular (AV) node The part of the cardiac conduction system between the atria and the ventricles.
bundle of His Specialized muscle fibers that conduct electrical impulses from the AV node to the ventricular myocardium.
cardiac arrest A condition in which cardiac contractions stop completely.
cardiodeversion The use of electroshock to convert an abnormal cardiac rhythm to a normal one.
defibrillator A machine that delivers an electroshock to the heart through electrodes placed on the chest wall.

ectopic (ék-tohp'-ık) Originating outside of the normal tissue.
infarction An area of tissue that has died from lack of blood supply.
ischemia (is-ke'{-mía}) Decreased blood flow to a body part or organ, caused by constriction or blockage of the supplying artery.
myocardial (my-oh-kar'-de-ahl) Pertaining to the heart muscle.
sinoatrial (SA) node The pacemaker of the heart; it is located in the right atrium.
ventricles The two lower chambers of the heart.

Electrocardiography is a painless, safe procedure and is the test most frequently used for the diagnosis of heart disease in the ambulatory care setting. In electrocardiography, electrodes are attached to the patient's skin and connected to wires that go to the electrocardiograph. Electrocardiography amplifies the electrical impulses from the beating heart, and a pattern of these impulses is recorded on electrocardiographic paper. This record is called the electrocardiogram (ECG). The ECG is read and evaluated by the physician and becomes a part of the patient's chart (Figure 49-1).

To accurately represent the true cardiac activity, the ECG must be performed with a high degree of accuracy and skill. A medical assistant must have an understanding of normal cardiac function and the relationship of the ECG recordings to normal function. The medical assistant is responsible for ensuring that the patient has been prepared mentally and physically and that the equipment is set up properly. When performing electrocardiography, the medical assistant must be able to recognize problems with the recording and make appropriate corrections so that the physician has a clear record of the patient's cardiac activity. The goal is to obtain the most accurate ECG possible.

HISTORY OF ELECTROCARDIOGRAPHY

Dutch physiologist Willem Einthoven developed techniques to record the electrical activity of the heart in the late 1800s. He called this recording an Electro Kardio Grammar, hence the acronym EKG. Many physicians and other health care providers still call the recording an EKG, although the newer, preferred term is ECG for electrocardiogram.

THE ELECTRICAL CONDUCTION SYSTEM OF THE HEART

The Cardiac Cycle

The cardiac cycle includes all the events that occur in the heart during one single heartbeat. Each chamber of the heart goes through two phases during the cardiac cycle: systole and diastole. During systole, both the atria and the ventricles contract and empty of blood. During diastole, the relaxation phase of the heart, the chambers refill with blood. Venous blood from the inferior and superior venae cavae empties into the right atrium during atrial diastole. As the right atrium fills, increased pressure in the chamber causes the tricuspid valve to open, and the right

FIGURE 49-1 Example of a 12-lead ECG. (From Aebhert B: ECGs made easy, ed 3, St Louis, 2006, Mosby.)
ventricle begins to fill. At the same time, blood returning from the lungs via the pulmonary veins fills the left atrium, causing the mitral valve to open, emptying blood into the left ventricle. Before systole occurs, the ventricles are already 70% filled. The cardiac cycle for a healthy adult lasts approximately 0.8 second. However, the amount of time it takes for the heart to empty and refill depends on many factors, including the condition of the myocardium and the heart's electrical system.

The electrocardiograph records both the intensity of the electrical impulses as well as the actual time it takes for each part of the cardiac cycle to occur. It measures the electrical conductive impulses of the heart muscle, allowing the physician to see any disturbances or disruptions in normal heart activity. In addition to being recorded as an ECG, the cardiac cycle can appear as a continuously moving pattern on a monitor screen, accompanied by a sound for each beat.

The specialized electrical conduction system of the heart (Figure 49-2) initiates each heartbeat. The main part of this system is the sinoatrial (SA) node, which is located in the upper back wall of the right atrium at the junction of the superior vena cava and the right atrium. The SA node controls the rate of heart...
contraction by initiating electrical impulses 60 to 100 times per minute. Each cardiac cycle, or heartbeat, starts with the SA node generating an electrical impulse that travels in a wavelike pattern across the cardiac muscle of the atria, causing them to contract almost simultaneously. This electrical impulse then stimulates the atrioventricular (AV) node, which is located in the posterior, superior portion of the right atrial septal wall, directly behind the tricuspid valve. A slight delay in conduction at this point allows the atria to empty completely. The electrical impulse then is transmitted to a special group of conduction fibers, the bundle of His, in the upper part of the interventricular septal wall. The bundle of His divides into two branches; the right bundle branch carries electrical impulses to the right ventricle, and the left bundle branch carries impulses to the left ventricle. The right and left bundle branches divide into smaller and smaller branches, ending in the Purkinje fibers, which spread across the apex of the heart and through the myocardium, stimulating ventricular contraction. The ventricles contract in a twisting sort of action, forcing the blood out of the chambers and into the pulmonary artery on the right side of the heart and the aorta on the left side.

Normal sinus rhythm (NSR) refers to a regular heart rate that falls within the average range of 60 to 80 beats per minute (beats/min). Sinus bradycardia is a heart rate below 60 beats/min; sinus tachycardia is a rate above 100 beats/min. In both of these conditions, the rhythm remains even, but the rate is pathologic. An irregular cardiac rhythm is called an arrhythmia. Conditions that interrupt the conduction pathway, SA node to AV node to bundle of His to right and left bundle branches, can cause arrhythmias.

### Polarization, Depolarization, and Repolarization

Polarization is the resting state of the myocardial wall; no electrical activity occurs in the heart during this phase, which is recorded on the ECG strip as a flatline. In this state the myocardial cells are ready for stimulation. When the electrical system of the heart stimulates a myocardial cell, depolarization occurs, resulting in the contraction of the stimulated heart muscle. After depolarization the heart muscle cells must return to a resting state before they can be electrically stimulated again. The process of reaching this resting state is called repolarization.

The electrocardiograph records a series of waves, or deflections, above or below a baseline on the ECG paper. Each deflection corresponds to a particular part of the cardiac cycle (Table 49-1). The normal ECG cycle consists of waveforms that are labeled the P wave, the Q wave, the R wave, the S wave, and the T wave. The Q, R, and S waves usually are grouped together; this is called the QRS complex. One entire cardiac cycle can be called the PQRS complex. In the next section, each part of the ECG is discussed in more detail.

### PQRS Complex

The P wave occurs during the contraction of the atria and shows the beginning of cardiac depolarization. The P wave is the first deflection from the baseline; it typically is smooth and rounded and should occur before each QRS complex. Atrial repolarization is not recorded on the ECG strip, because its electrical impulse is small and is hidden in the QRS complex. The PR segment is the return to baseline after atrial contraction. The PR interval is the time from the beginning of atrial contraction to the beginning of ventricular contraction. It contains the P wave (depolarization of the atria) and the spread of the electrical impulse through the AV node, bundle of His, right and left bundle branches, and Purkinje fibers. As the heart rate increases, the PR interval typically shortens. The QRS complex shows the contraction of both ventricles and also reflects the completion of cardiac depolarization. Repolarization of the atria also occurs during this interval.

### TABLE 49-1 The Cardiac Cycle

<table>
<thead>
<tr>
<th>STAGE</th>
<th>HEART ACTIVITY</th>
<th>ELECTRICAL CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave*</td>
<td>Atrial contraction</td>
<td>Atrial depolarization</td>
</tr>
<tr>
<td>PR interval†</td>
<td>Contraction traversing the atrioventricular (AV) node</td>
<td>Depolarization traversing the AV node</td>
</tr>
<tr>
<td>QRS complex‡</td>
<td>Ventricular contraction</td>
<td>Ventricular depolarization</td>
</tr>
<tr>
<td>ST segment</td>
<td>Time interval between ventricular contraction and the beginning of ventricular recovery</td>
<td>Time interval between ventricular depolarization and ventricular repolarization</td>
</tr>
<tr>
<td>T wave</td>
<td>Ventricular contraction subsides</td>
<td>Ventricular repolarization (electric recovery)</td>
</tr>
<tr>
<td>U wave (not always present)</td>
<td>Associated with further ventricular relaxation</td>
<td>Associated with further ventricular repolarization</td>
</tr>
<tr>
<td>Baseline§</td>
<td>The heart at rest</td>
<td>Polarization</td>
</tr>
<tr>
<td>PR interval</td>
<td>Time interval between atrial contraction and ventricular contraction</td>
<td>Time interval between atrial depolarization and ventricular depolarization</td>
</tr>
<tr>
<td>QT interval</td>
<td>Time interval between the beginning of ventricular contraction and the subsiding of ventricular contraction</td>
<td>Time interval between the beginning of ventricular depolarization and ventricular repolarization (electric recovery)</td>
</tr>
</tbody>
</table>

*Wave: A uniformly advancing deflection (upward or downward) from a baseline on a recording.
†Interval: The lapse of time between two different electrocardiographic events; represents the time needed for an electrical current to move on.
‡Complex: The portion of the ECG tracing that represents the sum of three waves (contraction of the ventricles).
§Baseline: A neutral line against which waves are valued as they deflect upward (positive) or downward (negative) from the line.
time, but it cannot be seen on the ECG because the recording of the much stronger QRS activity overshadows it. Depolarization of the ventricles results in the contraction of a much larger muscle mass than does depolarization of the atria. Therefore, the QRS complex is recorded as a much more significant electrical activity than the P wave.

The ST segment reflects the time between the end of ventricular contraction and the beginning of ventricular recovery. The T wave represents ventricular recovery or repolarization of the ventricles. After the T wave comes a period of complete heart rest, also called polarization, which is indicated on the ECG as a straight line. The QT interval is the time between the beginning of the QRS complex through the T wave. During this time the ventricles contract and relax. A U wave occasionally can be seen as a small waveform just after the T wave in patients with a low serum potassium level or other metabolic disorders.

By measuring the actual configuration and location of each wave in relation to the other waves and to the baseline, as well as the intervals between waves and segments, the physician is able to detect rhythmic disturbances of the heart and identify different types of cardiac disorders.

**THE ELECTROCARDIOGRAPH**

Most physicians now use an electrocardiograph (Figure 49-3) that can record 12 leads simultaneously, or six-channel ECG machines. Limb and chest electrodes must be placed on the patient at specific anatomical locations before the recording starts. When the ECG is started, the machine records all 12 leads automatically and marks each lead with identifying letters. These multichannel ECG tracings take seconds to perform and can be placed in the patient’s chart without mounting. Older electrocardiographs are single-channel machines that record each of the 12 leads one at a time. These strips must then be cut apart, and each lead’s recording is mounted on the adhesive area of a mounting card before placement in the patient’s chart.

**CRITICAL THINKING APPLICATION 49-1**

Martha has not yet been taught how to use the ECG machine in Dr. Lee’s office. What steps should she take to learn how to use this machine and to feel comfortable and confident using it to obtain ECGs?

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**Electrocardiograph Paper**

Electrocardiograph paper is heat and pressure sensitive, which means that either heat or pressure can cause a mark to appear. The stylus on an ECG machine makes the image on the ECG paper. When the machine is on, the stylus becomes hot and burns a marking on the paper it moves horizontally past the stylus. Because the paper is pressure sensitive, it must be handled carefully to prevent any additional markings that would blemish the tracing.

ECG paper is graph paper that has horizontal and vertical lines at 1-mm intervals. This is an agreed-upon international standard that allows physicians anywhere in the world to interpret a patient’s ECG in the same manner. A medical assistant needs to know both the size and the meaning of each square on the ECG paper to understand its significance.

The horizontal axis represents time, and the vertical axis represents amplitude. Each small square measures 1 mm on each side. Every fifth line, both vertically and horizontally, is darker than the other lines and creates a larger square measuring 5 mm on each side. When the electrocardiograph runs at normal speed, one small 1-mm square passes the stylus every 0.04 second, which means that one large 5-mm square passes the stylus every 0.2 second. Continuing this logic, in 1 second, five large squares pass the stylus. Therefore, five sequential large squares show the record of what occurred in the heart during a time span of 1 second (5 large squares × 0.2 seconds = 1 second). Another way to say this is that at normal speed, the ECG paper travels past the stylus at a rate of 25 mm per second (Figure 49-4).

The voltage, or strength, of the heartbeat also is recorded on the paper. Voltage can be displayed as either a positive or a negative deflection. One millivolt (mV) of electrical activity moves the stylus upward over 10 mm (two large squares). This is the standard normally used for obtaining an ECG, and it can be adjusted to match the strength of the electrical activity of the heart. The machine must be calibrated so that 1 mV of electrical activity produces a deflection that is 10 mm either above or below the baseline. When properly calibrated, the ECG records both the strength of the electrical activity of the heartbeat in millivolts and the speed of the heartbeat over time.
Electrodes and Leads

Ten sensors, called electrodes, are placed on the patient’s arms (two), legs (two), and chest (six) to pick up the electrical activity of the heart. Electrodes must be applied to specific locations to record the heart’s electrical activity from different angles and planes. Ten color-coded and labeled lead wires that end in a small metal clip are attached to the electrodes. The lead wires carry the signal of the heart's electrical activity to the ECG machine. Most machines require single-use, self-stick, disposable electrodes that are packaged with conductive jelly in the center. Some older ECG machines have only five leads, which means that the single chest lead must be moved to a different chest wall location to obtain each one of the chest (V) recordings. Other older machines may have metal disks or electrodes that are attached by rubber bands to the extremities with metal suction cups placed on the chest. These types of electrodes require the application of conductive jelly to the patient’s skin at the location of electrode placement to improve the transmission of the heart’s electrical activity into the ECG machine.

The leads to the electrocardiograph carry the cardiac electrical impulses into the machine, where they are magnified by an amplifier. These amplified impulses are converted into mechanical action, which is recorded on the ECG paper by the stylus and/or shown on a monitor. A single lead records the electrical activity of the heart between two different electrodes, one positive and one negative. The placement of the positive electrode determines the particular view of the heart recorded. If depolarization occurs toward the positive electrode, the deflection is upright; if it moves toward the negative electrode, the waveform is deflected downward. Each lead records the average electrical flow at a specific time in a specific location of the heart. The ECG records views of the heart on both a frontal and a transverse plane. The frontal leads include leads I, II, III, aVR, aVL, and aVF. Horizontal plane leads include the six precordial, or chest, leads (V₁ to V₆).

Lead Recordings

The standard ECG consists of 12 separate leads, or recordings of the electrical activity of the heart, from different angles.

Standard Leads

The first three leads recorded are called the standard or bipolar leads, because they each use two limb electrodes to record the heart’s electrical activity (Figure 49-5, A). The right arm electrode is the negative pole, and the left arm or left leg electrodes are the positive poles. Roman numerals I, II, and III are used to designate these leads.

- **Lead I** records tracings between the right arm and left arm, recording the electrical activity of the lateral part of the left ventricle.
- **Lead II** records tracings between the right arm and left leg, recording the electrical activity of the inferior surface of the left ventricle; this is the lead recorded on a cardiac monitor or on the rhythm strip at the bottom of the 12-lead ECG.
- **Lead III** records tracings between the left arm and left leg, as well as the electrical activity of the inferior surface of the left ventricle.

Augmented Leads

The next three leads are the augmented, or combined, leads (Figure 49-5, B). These are designated augmented voltage right arm (aVR), augmented voltage left arm (aVL), and augmented voltage left leg (aVF). Because the electrical activity recorded by these leads is relatively small, the ECG machine amplifies (or augments) the electrical potential when recorded. These are all unipolar leads with a single positive electrode that uses the right leg for grounding.

- **aVR** records the electrical activity of the atria from the right shoulder; P waves and QRS complexes are deflected below the baseline.
- **aVL** records the electrical activity of the lateral wall of the left ventricle from the left shoulder.
- **aVF** records the electrical activity of the inferior surface of the left ventricle from the left leg.

Precordial Leads

The precordial, or chest, leads are unipolar and provide a transverse plane view of the heart. They are designated V₁, V₂, V₃, V₄, V₅, and V₆. The V means chest, and each of the numbers represents a specific location on the chest. The QRS complex shows as a negative deflection in V₁ and V₆, and views with each subsequent lead become more positive. Precordial leads measure the electrical activity among six specific points on the chest wall and a point within the heart (Figure 49-6). It is important to avoid placing electrodes directly over a bony prominence.
placed in the proper position, it really makes no difference which side you use.

Small pillows are helpful for relaxing the patient and providing maximum comfort during the procedure. Offer a pillow for the head and one for under the knees. If a head pillow is used, it should not elevate the patient's shoulders.

The patient should disrobe to the waist and should put on the patient gown with the opening in the front; easy access to the patient's extremities must be available. Pantyhose must be removed.

Place the patient in a supine position with the arms comfortably at the sides and the legs not touching one another. If the patient has dyspnea or orthopnea, semi-Fowler's position should be used, or alternatively the patient can be seated on a wooden chair. However, make sure you check with the physician before obtaining an ECG in an alternative position. If a seated position is used, the patient's feet must rest comfortably on the floor or on a footstool. Note any alternative position on the ECG recording.

The patient should empty the bladder and then rest for at least 10 minutes before the ECG recording is made. Check to see whether the patient followed all the instructions provided in Figure 49-7. Record the patient's vital signs and current medications on the patient's chart. This information can be programmed into some ECG machines and automatically printed on the ECG recording.

Explain to the patient the nature and purpose of the ECG. Attempt to answer all questions and make the patient as comfortable as possible during the procedure. Stress the importance of not moving during the entire procedure, and assure the patient that there is no danger of shock. Soften the lighting in the room to obtain maximum patient comfort. When you tell the patient to lie still, observe that he or she is breathing normally. Patients often hold their breath when asked to lie still.

**Attaching Leads to the Patient**

Disposable, single-use electrodes are placed on the patient's limbs and chest in very specific locations (Figure 49-8). The lead wires from the machine then are connected to the electrodes. Making the proper connections is facilitated by specific lead markings or color coding on the end of each lead wire (Figure 49-9).

- RA lead is attached to the electrode on the patient's right arm.
- LA lead is attached to the electrode on the patient's left arm.
- RL lead is attached to the electrode on the patient's right leg.
- LL lead is attached to the electrode on the patient's left leg.
- The labeled lead wires then are placed on each precordial electrode.

**CRITICAL THINKING APPLICATION 49-3**

Two weeks later, after Martha feels much more confident in her skills at electrode placement and in taking an ECG, a new patient, Mr. Sonderford, comes to the office complaining of mild chest pain that he noted when he got out of bed this morning. What concerns might Martha have about
INSTRUCTIONS FOR PATIENT BEFORE AN ELECTROCARDIOGRAM

Name: __________________________

Your cardiogram appointment is __________________ at AM/PM

Day, Date

These instructions are simple, but it is important that you follow them. Please call us if you are unable to follow these instructions or keep your appointment so we may make another appointment.

1. There is no discomfort or sensation in having an electrocardiogram. No electricity is put into the patient in any way. Small disposable electrodes are placed on the calf of each leg and on each arm and at different places on the chest. The minute impulse generated by your heart is simply picked up by these electrodes and recorded by the machine.

2. You will be asked to lie down on a comfortable table while the test is being performed by the technician.

3. For your convenience, it is best to wear loose clothing. You will be asked to disrobe to your waist to expose the chest. It will also be necessary to expose your lower legs from the knees down and the upper arms just below the shoulders.

4. The actual test only takes about 5 minutes, but you will be asked to rest for about one-half hour before the test. It is best you do not have a heavy meal for about 2 hours before the test. You should not consume any cold drinks or ice cream or smoke just before the test. It is also advisable to refrain from excessive exercise just before the test. Do not take any medications without the physician's usual instructions and knowledge.

5. During the test, you will be asked to lie absolutely still and relax, because the slightest movement interferes with an accurate tracing. Do not talk.

6. The skin on the legs, arms, and chest must be free from skin ointments, oils, and medications.

7. The technician taking the test is specially trained to perform the test but is unable to tell you the results of the test, because he or she is neither trained nor authorized to make any interpretations of the cardiogram. This is the task of the physician.

FIGURE 49-7 ECG patient instructions.

FIGURE 49-8 Chest lead locations. (From Auhert B: ECGs made easy, ed 3, St Louis, 2006, Mosby.)

Mr. Sonderford? His vital signs are: P: 104 beats/min, weak and irregular; R: 24 breaths/min and quite shallow. Mr. Sonderford is sweating profusely. What should Martha do? Why?

Recording the Electrocardiogram

Procedure 49-1 explains how to record an ECG. It is important that you become familiar with the type of machine used in your practice. Machines vary according to the age and make of the model, but most electrocardiographs currently in use perform standardization functions and labeling automatically. You may have the option of entering specific information about the patient, such as age, gender, prescriptions, and so on. Follow office protocol when performing the procedure. After the machine has been programmed, remind the patient to lie still and press the appropriate key to run the ECG strip. Six-channel machines print and label all 12 leads, with a rhythm strip across the bottom of the paper in lead II, in a matter of seconds. Review the printout for clarity, and if it is acceptable, give the recording to the physician for review. Once approved, remove the leads and electrodes from the patient, assist him or her into a sitting position, and provide assistance in getting off the table and dressing if necessary.

II Standardization, Sensitivity, and Speed

Standardization has been determined by international agreement so that an ECG can be interpreted in the same way anywhere in the world. This requires the electrocardiograph to be calibrated according to universal measurements. Each time you record an ECG, you must make sure the machine is correctly standardized.

When a machine is in standard mode or set at 1 STD, 1 mV of electricity causes the stylus to move vertically 10 mm, or two large squares. When the machine has been properly set in this way, electrical voltages can be calculated by measuring the vertical movement of the stylus on the paper. The stylus should deflect
**ECG ELECTRODE PLACEMENT**

**RIGHT LEG:** GREEN  
**LEFT LEG:** RED  

**V1:** RED  
**V2:** YELLOW  
**V3:** GREEN  
**V4:** BLUE  
**V5:** ORANGE  
**V6:** PURPLE

**RIGHT ARM:** WHITE  
**LEFT ARM:** BLACK

**IMPORTANT**  
See section at end of chapter for detailed instructions.  
Check and cleanse site prior to electrode contact.  
Dust electrodes after each use.

**FIGURE 49-9** Color codes. (Courtesy Compumed, San Diego, Calif.)

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**PROCEDURE 49-1**

**Perform Electrocardiography: Obtain a 12-Lead ECG**

**GOAL:** To obtain an accurate, artifact-free recording of the electrical activity of the heart.

**EQUIPMENT and SUPPLIES**

- ECG machine with patient lead cable
- 10 disposable, self-adhesive electrodes
- Patient gown and drape
- ECG mounting card if necessary
- Patient's record

**PROCEDURAL STEPS**

1. Sanitize your hands.  
   **PURPOSE:** To ensure infection control.
2. Explain the procedure to the patient.  
   **PURPOSE:** To alleviate apprehension and gain the patient's cooperation.
3. Ask the patient to disrobe to the waist (including the bra for women) and remove belts, jewelry, socks, stockings, or pantyhose as necessary.  
   **PURPOSE:** Electrodes must be applied to bare skin without interference from clothing.
4. Position the patient supine on the examination table and drape appropriately.  
   **PURPOSE:** To ensure the patient's modesty and comfort.
5. Turn on the machine to allow the stylus to warm up (may not be necessary with newer machines).
6. Label the beginning of the tracing paper with the patient's name, the date, the time, and the patient's current cardiovascular medications or input this information into the machine.  
   **PURPOSE:** To identify the ECG recording properly.
7. At each location where an electrode will be placed, clean the skin with an alcohol wipe (Figure 1).  
   **PURPOSE:** To obtain good electrode adhesion to the skin.
8. Apply the self-adhesive electrodes to clean, dry, fleshy areas of the extremities (Figure 2). Extremely hairy areas may need to be shaved to achieve adequate electrode attachment, or place a piece of tape over the electrode to make sure it is secure.  
   **PURPOSE:** To secure the lead wires to the correct electrode with the alligator clips on the end of each lead. Make sure the lead wires are not crossed.  
   **PURPOSE:** To prevent artifacts.
11. Press the AUTO button on the machine and run the ECG tracing. The machine automatically places the standardization at the beginning, and the 12 leads then follow in the three-channel matrix with a lead II rhythm strip across the bottom of the page.
PROCEDURE 49-1—cont’d

12. Watch for artifacts during the recording. If artifacts are present, make appropriate corrections and repeat the recording to get a clean reading.
13. Remove the lead wires from the electrodes and then remove the electrodes from the patient.
14. Assist the patient with getting dressed as needed. Clean and return the ECG machine to its storage area.
15. Mount the ECG or give the unmounted ECG recording to the physician as directed.
16. Sanitize your hands.
17. Document the procedure in the patient’s medical record.

PURPOSE: Procedures are not considered done until they are documented in the patient’s medical record.

![Figure 1](image1)

![Figure 2](image2)

![Figure 3](image3)

9/22/XX 3:10 pm 12-lead ECG recorded without incident. Martha Reyes, CMA (AMA)

exactly 10 mm when the standardization button is depressed with a quick pecking motion. The recording of the standardization would be 2 mm wide and rectangular. Each manufacturer’s manual explains the exact method of adjustment to obtain a perfect standardization.

At minimum, standardization must be performed before the first lead is recorded. Some physicians require a separate standardization in each of the individual 12 leads.

Most machines have three sensitivity standards that can be selected: ½ STD, which deflects the stylus 5 mm, or one large square; 1 STD, which deflects the stylus 10 mm, or two large squares; and 2 STD, which deflects the stylus 20 mm or four large squares. The appropriate standard is selected as follows: if the QRS complex is too tall and is causing the stylus to move off the paper, the STD should be set to ½ STD. If the QRS complex is too short, the STD should be set to 2 STD. Figure 49-10 shows the three sensitivity standards as they appear when recorded on the ECG paper.

The usual speed for an ECG recording is 25 mm/sec. If the patient’s heart rate is very rapid or if certain parts of the complex are too close together, the paper may need to be adjusted to run at double speed, or 50 mm/sec. This extends the recording to twice the normal length. Any change in the speed must be noted on the ECG.

Mounting an Electrocardiographic Tracing

Newer ECG machines do not require mounting of the recording. However, if an older machine is used, your office will select the mount best suited to the type of ECG equipment used in that particular office. It is advisable to select a mount that allows all 12 leads to be read together on one page. The most commonly used mounts are self-adhesive mounting pages that are designed...
so that an entire test is placed on one side of one page (Figure 49-11). Tracings usually are retained in records for many years, so a mount must last a long time.

Paper clips and staples are never used, because they scratch and make a tracing. Clear tape should not be used, because it can become sticky or yellow with age. A single photocopy of the ECG can be made without damaging the original. Many offices routinely put a photocopy in the patient's medical record because it is thinner than the mounted ECG and less likely to be damaged by handling. If the practice has electronic medical records, the tracing is scanned into the patient's electronic chart.

Regardless of the particular method used, each ECG should be labeled with the following information:
- Patient's full name
- Gender
- Age
- Date and time of ECG
- List of all medications and/or supplements the patient takes
- Variations from normal sensitivity and normal speed

Additional notations should be recorded for any variation from the routine, such as the following:
- Very nervous or anxious patient
- Lack of rest before the test
- Smoking immediately before the test
- Failure to follow any pretest instructions

Care must be taken when mounting an ECG. Most tracings are easily scratched or marked, so be careful not to damage the tracing accidentally with watches, rings, fingernails, or clothing buttons. Do not stack other items on top of the open-faced type of mount.

Note: If trimming of the strip is required for mounting, do not cut off the label that identifies the lead recording. Some mounts place the precordial leads in horizontal rows, whereas others place them in vertical columns. Take great care not to mount a lead upside down. If you have been asked to show the STD in a lead, be sure to include it where requested. Do not cover the tips of the QRS complexes with the sides of the slotted-type mount. Place the mounted ECG tracing on the physician's desk for evaluation with the patient's medical record and any previous ECG tracings. Physicians nearly always want to compare the newest ECG with previous ECGs.

Some physicians want to see the entire strip before it is mounted and may even choose which sections to mount. If this
is the case, be careful to mount the sections indicated by the physician.

**Telephone Transmission**

An electrocardiograph with phone transmission capabilities can transmit a recording over a telephone to an ECG data interpretation center. The machine is equipped with a direct ECG fax transmitter. The recording is interpreted by a computer at the data center and verified by a cardiologist. Patient information that may be important to the interpretation, such as medications and vital signs, is sent with the ECG data. A printout with the computer-assisted interpretations is returned to the sender by fax or e-mail.

**Interpretive Electrocardiographs**

Interpretive electrocardiographs are equipped with a computer that analyzes the recording as it is being run. With this capability, immediate information on the heart's activity is available, which can be valuable for reaching an early diagnosis and initiating immediate treatment. Patient baseline data must be entered into the computer before the ECG is recorded. The computer analysis of the ECG and the reason for each interpretation are then printed on the top of the recording.

**Artifacts**

An artifact is an unwanted, erratic movement of the stylus on the paper caused by outside interference. The electrocardiograph is extremely sensitive to any kind of nearby electrical activity. Electrical artifacts on the tracing make accurate interpretation of the ECG difficult. The medical assistant should have a thorough understanding of the causes of and remedies for these artifacts. The main types of artifacts are wandering baseline, somatic tremor, alternating current (AC) interference, and interrupted baseline.

**Wandering Baseline**

With a wandering baseline, the stylus gradually shifts away from the center of the paper. This usually happens because of slight movement of the patient during the tracing or poor electrode attachment (Figure 49-12). A wandering baseline is resolved by reminding the patient to remain as still as possible; this can be facilitated by keeping the patient comfortable. Metal electrodes can be a major cause of this phenomenon; using disposable, stick-on electrodes should eliminate this cause.

**Somatic Tremor**

The term somatic tremor means muscle movement. Any muscle movement, including movement of skeletal muscle, produces a measurable electrical impulse. This additional input causes unwanted stylus movement during the tracing; this shows up on the recording as jagged peaks of irregular height and spacing with a shifting baseline (Figure 49-13). The most common causes include patient discomfort, apprehension, movement, or talking or a condition that causes uncontrollable body tremors. A patient with uncontrolled tremors must be as calm and comfortable as possible to minimize the somatic tremor artifact. The other causes all can be resolved after they have been identified correctly.

**Alternating Current (AC) Interference**

AC interference appears as a series of uniform small spikes on the paper (Figure 49-14). Electrical currents in nearby equipment or wiring can leak small amounts of electrical energy into the
area where the ECG machine is located. The very sensitive electrocardiograph can easily pick up this additional electrical energy signal. This can be minimized by making sure the machine is plugged into a three-pronged, grounded outlet; keeping lead wires uncrossed; unplugging other electrical appliances in the room; moving the table away from the wall; and perhaps even turning off overhead fluorescent lights. If all these measures fail, you may need to move to another examination room for the procedure. The last step is to call the manufacturer or your local service representative.

**Interrupted Baseline**
Baseline interruption occurs when the electrical connection has been interrupted. The stylus moves onto the margin of the paper erratically (Figure 49-15). It moves violently up and down across the paper, or it may record a straight line across the top or bottom of the paper. Noticeable patient movement that dislodges the electrodes causes most baseline interruptions. This cause is virtually eliminated by using disposable, stick-on electrodes. Other causes include a broken cable wire and cable tips that are attached too loosely to the electrodes.

**Critical Thinking Application 49-4**
Dr. Lee asks Martha to explain the causes of artifacts and the methods for correcting ECG recordings that show outside interference. Based on what you have learned about ECG artifacts, what are the typical causes and how would you recommend correcting each?

**Interpreting an ECG Strip**
The medical assistant working in a cardiovascular practice must be able to recognize rhythm abnormalities that may appear on the tracing. Alerting the physician to the presence of an arrhythmia while the patient is still connected to the machine may give the physician the opportunity to observe the patient while the machine is running or immediately institute some type of therapeutic or prophylactic intervention. The physician can determine two important heart functions when interpreting the ECG: heart rate and heart rhythm.

**Normal Appearance of ECG Complexes**
When you examine the ECG recording, first look at the characteristics of each of the waves in the recording (Table 49-2). Are the P waves, QRS complexes, and T waves clearly present? Do they have a consistent appearance and do they occur at regular intervals? Are any odd beats present that do not fit in with the others? Is the rate normal, fast, or slow? Is the rhythm regular or irregular?

In NSR (see Figure 49-1), each beat of the heart is initiated by an impulse from the SA node that travels without interruption along the normal conduction pathway of the heart. In NSR each beat on the ECG shows a P wave followed by a QRS complex.

**Rate**
To calculate the heart rate from the ECG recording, count the number of P waves in a 6-second strip (30 large squares) and
TABLE 49-2 Normal Appearance of ECG Waveforms and Complexes

<table>
<thead>
<tr>
<th>WAVE OR COMPLEX</th>
<th>DURATION (SEC OR AMPLITUDE)</th>
<th>CHARACTERISTICS TO EXAMINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>0.06-0.11</td>
<td>Are P waves present?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Are they normal shape (not notched or peaked) and normal size (&lt;3 mm)?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do all deflect upward (positive)? Is there one for each QRS? Are they evenly spaced from the QRS?</td>
</tr>
<tr>
<td>PR interval</td>
<td>0.12-0.20</td>
<td>Is it constant?</td>
</tr>
<tr>
<td>QRS complex</td>
<td>0.08-0.12</td>
<td>Are they evenly spaced from T waves?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do all point in same direction?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do all QRS complexes appear the same?</td>
</tr>
<tr>
<td>ST segment</td>
<td>On baseline (isoelectric line)</td>
<td>Is it on baseline?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is it constant?</td>
</tr>
<tr>
<td>T wave</td>
<td>≤5 mm in leads I, II, III</td>
<td>Is T wave present?</td>
</tr>
<tr>
<td></td>
<td>≤10 mm in V1-V6</td>
<td>Are they the same?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do all show upward deflection (positive)?</td>
</tr>
<tr>
<td>QT interval</td>
<td>Should not be more than half the RR interval if patient has a regular rhythm</td>
<td>Is it constant?</td>
</tr>
<tr>
<td>U wave</td>
<td>Rounded, upright deflection</td>
<td>Is it present?</td>
</tr>
</tbody>
</table>

multiply by 10. In the same manner, you can count the number of P waves in a 3-second strip (15 large squares) and multiply by 20. To get the ventricular contraction rate, you can count the number of complete QRS complexes that occur within 6 seconds and multiply that number by 10 to get the number of ventricular contractions in 1 minute.

The heart rate also can be calculated by counting the number of small squares between two R waves and then dividing that number into 1,500 (1 minute on an ECG strip passes 1,500 small boxes). When the number of boxes from one cardiac event to the next same event is divided into 1,500, the result is the patient’s heart rate. You can use the ECG strips in Figures 49-1 and 49-11 to practice these techniques.

Rhythm
The rhythm of a patient’s heartbeat is either regular or irregular. You may pick up an irregular heartbeat when taking the patient’s pulse. This same patient will show an irregularity (i.e., a difference in the length of time between cardiac cycles) when an ECG is recorded. If the patient’s heart is beating in a regular rhythm, each cardiac cycle occurs within the same time frame, and individual cardiac cycles occur exactly the same length of time apart. To check for ventricular rhythm, you can measure the distance between two consecutive RR intervals. Atrial rhythm is determined by measuring the distance between two consecutive PP intervals. If the heart rhythm is regular, each of these interval measurements is the same.

CALCULATING A PATIENT’S HEART RATE

To calculate the patient’s heart rate from an ECG strip, remember the following:
- 5 large boxes on the graph paper = 1 second
- 15 large boxes = 3 seconds
- 30 large boxes = 6 seconds

ANALYZING AN ECG STRIP

The ECG rhythm strip (lead II view) is evaluated from left to right. Each strip should be assessed for the following:
- Rate
- Rhythm
- P waves: There should be one P wave before each QRS complex; each is a positive deflection and similar in size and shape.
- Intervals: Assess for duration and distance.
- Appearance of the segments and waveforms: Are rhythmic PQRST cycles present? Are there any abnormalities, such as more than one P wave, QRS segments without a previous P wave, or an elevated ST segment? All of these abnormalities should be brought to the physician’s attention immediately.

### TYPICAL ECG RHYTHM ABNORMALITIES

Abnormalities in cardiac rhythm are called arrhythmias. These can result from disturbances anywhere along the electrical conduction pathway in the heart from the SA node through the right and left bundle branches. The best way to determine whether an arrhythmia is present is to know what the NSR looks like on an ECG. Study the NSRs in the mounted ECGs in Figures 49-1 and 49-11. NSR is a heart rate between 60 and 100 beats/min. Any deviations from this should be recognized during the ECG recording, and the medical assistant should notify the physician immediately.

Cardiac arrhythmias commonly fall into one of four broad categories: sinus arrhythmias, atrial arrhythmias, ventricular arrhythmias, and biochemical arrhythmias. The characteristics of several arrhythmias in each of these categories are compared in Table 49-3.

### TABLE 49-3 Characteristics of Arrhythmias

<table>
<thead>
<tr>
<th>TYPE</th>
<th>SIGNS AND SYMPTOMS</th>
<th>CAUSE</th>
<th>ECG CHANGES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sinus Arrhythmias</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bradycardia</td>
<td>&lt;60 beats/min</td>
<td>Vagal nerve stimulation; sleep; SA node ischemia; digitalis toxicity; drugs Can be normal in athletes</td>
<td>Essentially “normal” appearing, but slow</td>
</tr>
<tr>
<td>Tachycardia</td>
<td>Nonpathologic; heart rate &gt;100 beats/min is pathologic</td>
<td>Increased demand for cardiac output; ectopic pacemaker</td>
<td>P wave can be obscured by ST segment (increasing the ECG speed can reduce this problem)</td>
</tr>
<tr>
<td><strong>Atrial Arrhythmias</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAC</td>
<td>Not pathologic if only several per minute</td>
<td>Increased SA node excitability, causing premature beats of atria Can be caused by nicotine or caffeine</td>
<td>“Extra” P waves</td>
</tr>
<tr>
<td>Flutter</td>
<td>200-350 beats/min</td>
<td>Many ectopic atrial pacemakers; normally unstable and progresses to atrial fibrillation if not corrected</td>
<td>Multiple, sawtoothed P waves before essentially normal-appearing QRS complexes</td>
</tr>
<tr>
<td><strong>Ventricular Arrhythmias (see Figure 49-23)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td>Generally none</td>
<td>Ectopic pacemakers originating in ventricles from electrolyte imbalance, hypoxia, acute MI</td>
<td>Widened QRS complex</td>
</tr>
<tr>
<td>V-tach</td>
<td>Heart rate &gt;100 beats/min, always pathologic</td>
<td>Damaged tissue around one of the “bundles,” causing a difference in conduction speed between the two branches or ectopic pacemaker cells</td>
<td>Rapid rate, irregular pattern that includes “extra” or erratic, irregular, or wide QRS complexes</td>
</tr>
<tr>
<td>V-fib*</td>
<td>Shock, loss of consciousness, no pulse</td>
<td>Complete loss of synchronization of conduction system</td>
<td>Erratic deflections on the ECG (can be either coarse or fine) No identifiable ECG waves</td>
</tr>
<tr>
<td>Asystole</td>
<td>&lt;5 beats/min</td>
<td>Death imminent</td>
<td>Flatline</td>
</tr>
<tr>
<td><strong>Biochemical Arrhythmias</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digitalis toxicity</td>
<td>Abnormal bradycardia, abnormal tachycardia</td>
<td>Digitalis dose that is too high</td>
<td>“Swooping” ST segment depression and/or extended PR intervals</td>
</tr>
<tr>
<td>Hypokalemia</td>
<td>Malaise, fatigue, weakness, muscle cramps</td>
<td>Potassium too low, usually from unsupplemented diuresis, from IV fluid administration, or from excessive vomiting</td>
<td>Prominent U waves, T wave and U wave together look like a two-hump camel</td>
</tr>
<tr>
<td>Hyperkalemia¹</td>
<td>May have none</td>
<td>Potassium too high, usually from IV supplementation</td>
<td>Peaked T wave (can be as tall as R wave) with widening of all waveforms</td>
</tr>
</tbody>
</table>

*IV, Intravenous; MI, myocardial infarction; PAC, premature atrial contraction; PVC, premature ventricular contraction; SA, sinoatrial.

¹Most life-threatening arrhythmia; frequently precedes asystole if not reversed.

*Life-threatening situation that must be corrected immediately.
Sinus Arrhythmias

Sinus rhythm is considered normal; the heart’s electrical activity begins in the SA node and follows through the electrical system, ending in atrial and ventricular depolarization. In sinus arrhythmias, the pathway of the electrical charge is normal but the rate or rhythm of the heartbeat is altered. Sinus arrhythmias may be caused by the SA node firing too slowly or too quickly. In sinus bradycardia, the heart rate is below 60 beats/min. This can be a normal heart rate in well-conditioned athletes, but it is abnormal in other individuals. In sinus tachycardia, the heart rate is above 100 beats/min. This can be a normal heart rate in a person doing aerobic exercise, but it can be abnormal in a resting individual (Figure 49-16).

Atrial Arrhythmias

Problems with electrical discharge of the atria are caused by faulty electrical impulse formation or conduction defects within the atria. Premature atrial contraction (PAC) occurs when the atria contract before they should for the next cardiac cycle. This can appear on the ECG as an abnormally shaped P wave or an extra P wave. PACs can be seen in smokers and people who consume large amounts of caffeine. Occasional PACs are not abnormal, but they become a medical concern if they regularly occur more than six times a minute. In this situation, the PACs can indicate developing cardiac abnormalities.

Atrial flutter occurs when the atria beat at an extremely rapid rate, up to 300 beats/min. In atrial flutter, the impulses come from many ectopic atrial locations but are blocked at the AV node, which prevents ventricular fibrillation. Atrial flutter is reversed with medication to slow the heart or with cardioversion (electrical shock).

Ventricular Arrhythmias

Premature ventricular contractions (PVCs) occur when the ventricles contract before they should for the next cardiac cycle; that is, a QRS complex appears before a P wave. PVCs occur when an electrical charge originates in either ventricle. This can appear on the ECG as an absent P wave, an abnormally shaped T wave, and a widened QRS complex. This is followed by a pause before the initiation of the next cardiac cycle. PVCs can result from the use of tobacco, alcohol, medications containing epinephrine, and occasionally from anxiety. Infrequent PVCs are not abnormal, but they become a medical concern if they regularly occur more than six times a minute. Pathologic PVCs occur in patients with hypertension, coronary artery disease, and lung disease.

Ventricular tachycardia (commonly referred to as V-tach) is diagnosed when the ventricles beat at extremely rapid rates. It may be seen when multiple PVCs occur in a row or as a short run of fast beats, or it may persist longer than 30 seconds. The patient’s heart rate may range from 101 to 250 beats/min. V-tach can precede ventricular fibrillation if not reversed with drugs, cardioversion, or both. V-tach always reflects a pathologic state.

Ventricular fibrillation (commonly referred to as V-fib) is the most critical, life-threatening arrhythmia; it quickly results in death if not treated. V-fib is estimated to precede 85% of cases of cardiac arrest in adults. In V-fib, the electrical conduction system of the heart is in total dysfunction. The heart muscles quiver uncontrollably and is essentially ineffective at pumping any blood; therefore, there is no pulse, and the patient is unresponsive and not breathing. Cardioversion with a defibrillator is necessary to restore normal function of the electrical conduction system.

Asystole is the result of absence of a heartbeat, or cardiac cessation, which shows as a flatline on the ECG (Figure 49-17).

Biochemical Arrhythmias

Digitalis, frequently called dig (pronounced dif), is a common cardiac drug used to slow and strengthen the heartbeat. The heart is quite sensitive to digitalis, and too much can prove toxic and cause changes in the ECG (Figure 49-18). This condition can be reversed by reducing the dosage of digoxin or digitoxin (both are forms of digitalis).

Potassium is a critical mineral for normal cardiac function. Too much potassium in the blood (hyperkalemia) or too little (hypokalemia) both can cause life-threatening arrhythmias that must be corrected quickly. Intravenous administration of potas-
sium can reverse hypokalemia. Administration of a diuretic that does not effectively spare potassium can reverse hyperkalemia.

**Pacemaker Rhythms**

A pacemaker is a device implanted under the skin that stimulates the electrical activity of the heart. It consists of a small metal pulse generator with a battery and electronic leads that extend from the generator to the myocardium. The entire pulse generator is replaced when the battery wears out, usually every 5 to 10 years. Current pacemakers are rate responsive, which means that they speed up or slow the heart rate based on such factors as the breathing rate and body temperature. Biventricular pacemakers, which stimulate both the right and left ventricles to enable more efficient cardiac contractions, may be implanted in patients with congestive heart failure.

Pacemakers are implanted in a hospital setting, and local anesthesia is used. Before the patient is discharged, the device is programmed to fire according to the needs of the individual patient. The patient is instructed to telephone the physician's office periodically to transmit pacemaker readings across the phone lines. The patient may use a transmission device attached to a wristband or a wand that is placed over the pacer. Pacemakers cause wide variations in the appearance of an ECG (Figure 49-19).

**Implanted Cardioverter-Defibrillator**

An implanted cardioverter-defibrillator, or ICD, monitors the heart rhythm and delivers a shock to the heart if it detects a dangerous tachycardia or fibrillation (Figure 49-20). It is a small, battery-operated device that is implanted under the skin in the chest or abdomen. An ICD can be used to reverse V-tach and V-fib, especially after the patient has previously had a myocardial infarction (MI), or heart attack. The generator is programmed specifically to treat the patient's particular or potential cardiac arrhythmia. Just as with pacemakers, the device is programmed to meet the needs of each individual patient, the patient can telephone in periodic readings, and the device must be replaced every 4 to 7 years.

**Myocardial Infarction**

Sudden heart attack, or MI, occurs in more than 1 million Americans each year, according to the American Heart Association. Approximately 20% of these patients die before reaching the hospital, and approximately 30% die within 30 days of the heart attack. An MI occurs when a portion of the heart muscle...
becomes ischemic because the blood supply to that area has been interrupted. Ischemia eventually leads to tissue necrosis, or infarction.

The heart muscle, the myocardium, receives its oxygen supply from a network of coronary arteries (Figure 49-21) on the surface of the heart. The right coronary artery supplies much of the right side of the heart. The left coronary artery bifurcates into two main branches: the left circumflex artery, which supplies blood principally to the left lateral and posterior walls of the left ventricle, and the left anterior descending coronary artery, which supplies principally the anterior wall of the left ventricle and the interventricular septum. The left anterior descending coronary artery is sometimes called the “sudden death artery,” because it feeds such a large portion of the left ventricle.

MI causes specific, recognizable changes on the ECG recording, based on the phase the patient is in when the ECG is recorded (Table 49-4). The three most common changes are elevated ST segments, inverted (upside-down) T waves, and abnormal (pathologic) Q waves (Figure 49-22).

The sooner treatment is initiated after the patient’s first awareness of a heart attack, the more effective treatment is and the better the chances for the patient’s survival. Immediate treatment for a heart attack includes administration of nasal oxygen, sublingual nitroglycerin (to dilate the coronary arteries), a narcotic
TABLE 49-4 Phases of Myocardial Infarction with Electrocardiographic Changes

<table>
<thead>
<tr>
<th>PHASE</th>
<th>APPEARANCE OF ECG CHANGES</th>
<th>SPECIFIC CHANGES SEEN ON ECG</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (hyperacute)</td>
<td>Occurs in first few hours</td>
<td>ST segment elevated from baseline (earliest indication on ECG); peaked “hyperacute” T waves</td>
</tr>
<tr>
<td>II (fully evolved)</td>
<td>After hours or days</td>
<td>Deep T waves; pathologic Q waves appear (negative deflection)</td>
</tr>
<tr>
<td>III (resolution)</td>
<td>Days to weeks</td>
<td>ST segment returns to normal position; T waves return to normal</td>
</tr>
<tr>
<td>IV (stabilized chronic)</td>
<td>Permanent</td>
<td>Negative Q wave deflection remains</td>
</tr>
</tbody>
</table>

analgesic (to eliminate pain), aspirin (to reduce inflammation and decrease clotting time), and possibly a thrombolytic agent to dissolve the clot causing the coronary artery obstruction. Early administration of thrombolytic agents enhances the likelihood of restoring circulation to the myocardium distal to the occluding thrombus (blood clot). After discharge from the hospital, the patient should quit smoking, modify the diet as instructed by a nutritionist, and enter a cardiac rehabilitation program to improve cardiac strength and recovery through exercise.

Complications of acute MI include a sudden episode of atrial fibrillation, V-fib, or bradycardia that may necessitate implantation of a pacemaker.

RELATED CARDIAC DIAGNOSTIC TESTS

Stress Test

Cardiac stress testing is performed to observe and record the patient’s cardiovascular response to measured exercise challenges (Figure 49-23). Stress testing is done to accomplish the following:

- Diagnose cardiac disease that cannot be detected by a standard, resting ECG
- Determine an individual’s energy performance capacity
- Prescribe a specially designed exercise plan

A stress test is performed while the patient is exercising on either a bicycle or a treadmill, under careful supervision. The patient must be given the appropriate information explaining the purpose, preparation, and procedure for the test (Figure 49-24).

Cardiac arrest is a serious risk with a cardiac stress test. The medical assistant must be able to recognize symptoms of dyspnea, vertigo, extreme fatigue, severe arrhythmia, and other abnormal ECG readings that may develop during the stress test or immediately after the test during the rest period. All members of a cardiac stress testing team must be prepared to terminate testing immediately if the patient is unable to continue or if abnormalities appear on the monitor. Team members also must be certified in cardiopulmonary resuscitation (CPR) and emergency intervention. The physician must always be present during this procedure. In addition to the routine monitoring equipment, the team must have oxygen, a defibrillator, an endotracheal intubation tray, an artificial breathing bag, and emergency cardiac medications available in case of cardiac crisis. Because of the potential for life-threatening incidents, most physicians have stress tests.
Cardiac Stress Test

Cardiac stress testing (also known as an exercise tolerance test or treadmill test) is a means of observing, evaluating, and recording your heart’s response during a measured exercise test. This test determines your capacity to adapt to physical stress.

There are various reasons that your physician may suggest this test for you:

1. To aid in determining the presence of suspected coronary heart disease.
2. To aid in the selection of therapy.
   a. For angina pectoris (tightness or pain in the chest).
   b. Following a myocardial infarction (heart attack).
   c. Following coronary bypass surgery (open heart surgery).
3. To determine your physical work capacity.
4. To authorize participation in a physical exercise program.

Preparation for the Test

1. Avoid eating a heavy meal within 2 hours of your appointment.
2. Take your medications as you usually do, unless your doctor advises you not to take them.
3. Wear a shirt or blouse that buttons down the front with slacks, a skirt, jogging pants, or shorts.
4. Do not wear one-piece undergarments, jumpsuits, or dresses.
5. Tennis shoes are ideal if you have them. Otherwise, wear comfortable flat or low-heeled shoes. Do not wear clogs, sling-backs, crepe soles, boots, or high heels, as they make walking on the treadmill more difficult.

The Procedure

When you arrive in the Cardiology Department, areas of your chest may be shaved (men only) to allow the electrodes to adhere tightly to your chest. A blood pressure cuff will be wrapped around your arm, and an electrocardiogram (ECG) is taken while you are at rest. The technician will then demonstrate how to walk on the treadmill and will answer any questions you may have.

You will then perform a graded exercise test on a motor-driven treadmill. You will begin walking very gradually at a rate you can easily accomplish.

Progressively throughout the test, the speed and grade of the treadmill will be increased, and you will be walking at a faster pace up a slight incline. At no time will you be asked to jog or run, nor will you be asked to exercise beyond your capabilities.

At all times during the test, trained personnel are in the room with you, monitoring your heart rate and blood pressure and observing you for signs of fatigue or discomfort. We do not wish to exercise you to a level that is medically unsafe or physically distressing.

An ECG is taken again when you finish walking. Your cardiologist will immediately interpret the results of the test and explain his or her findings to you. If necessary, medications or treatment will be discussed. A letter with the results of the stress test will be sent to your referring physician.

The entire procedure will take 1 to 1 1/2 hours. If you have any questions regarding the cardiac stress test or any problems with your appointment, please contact us.

FIGURE 49-24 Patient information for a cardiac stress test.

CRITICAL THINKING APPLICATION 49-5

Mr. Sondorford actually had an MI when he was previously at Dr. Lee’s office. He now has completed cardiac rehabilitation and is at the office for a checkup. Dr. Lee wants him to be scheduled for a stress test. Mr. Sondorford has never had one before. He confides to Martha that he is afraid if he takes the test, he will die from another heart attack. How should Martha handle this situation?

Holter Monitor

A Holter monitor is a portable system for recording a patient’s cardiac activity over a 24-hour period or longer (Figure 49-25 and Procedure 49-2). The monitor is a small, lightweight device that the patient wears while going about the usual daily activities. The Holter monitor can be programmed to record cardiac information continuously or periodically, when activated by the patient if symptoms occur, or during periods of stress.

The entire time the monitor is worn, the patient must keep a journal of all stressful events and activities (as well as specific details about activities when any cardiologic symptoms occur). Journal entries include the time, duration, and specific activity during the cardiac event, such as rush hour traffic, bowel movements, intercourse, climbing stairs, and periods of anger or emotional distress. Some monitors can even record the patient’s voice describing a symptom or event so that it can later be correlated with the ECG recording in the same time frame.

Many cardiologists routinely use Holter monitors in their practices. A medical assistant often is responsible for fitting the monitor on the patient and for removing it after the test period.

FIGURE 49-25 Holter monitor. (Courtesy Welch Allyn, Skaneateles Falls, NY.)
The patient must have a full understanding of what is required during monitoring, particularly how to use the event marker in case a significant symptom is experienced. The patient also must know how to record the event in a written diary when the event marker is used. The patient may take only sponge baths during the 24 hours of the test. The number of electrodes and leads varies with the number of channels on the particular monitor. Electrode placement is determined by the physician or by the manufacturer's guidelines and should be followed precisely. The skin of male patients may need to be shaved so that the electrodes can be firmly attached. The lead wires are attached to the electrodes and to the Holter monitor, which is worn around the waist or on a belt or in a pouch slung over the shoulder.

At the end of the monitoring period, the patient returns to the office, the monitor is disconnected, and electrodes are removed. The recording is placed in a Holter scanner or computer, and the results are analyzed. Any part of the recording can be printed for further study.

**PROCEDURE 49-2**

**Assist the Physician with Patient Care: Fit a Patient with a Holter Monitor**

**GOAL:** To establish a possible correlation between coronary disorders and the patient's 24-hour daily activities.

**EQUIPMENT and SUPPLIES**
- Holter monitor with new battery and blank recording tape
- Disposable electrodes
- Razor
- Gauze pads or abrasive tool as needed
- Activity diary
- Carrying case with belt or shoulder strap
- Alcohol swabs
- Cloth tape (nonallergenic)
- Patient's record

**PROCEDURAL STEPS**

1. Sanitize your hands.
   **PURPOSE:** To ensure infection control.
2. Assemble the needed equipment.
3. Install a new battery or fully charged rechargeable battery in the monitor (Figure 1).
   **PURPOSE:** A new or fully charged battery ensures accurate monitor function for a 24-hour period.
4. Greet the patient and explain the procedure.
   **PURPOSE:** An informed patient helps ensure testing accuracy.
5. Ask the patient to disrobe to the waist and to sit at the end of the examination table or to lie down.
   **PURPOSE:** This places the patient at the best working level for the medical assistant.
6. Clean each electrode application site with the alcohol swab and allow the sites to air dry.
   **PURPOSE:** To remove all surface skin oil to ensure maximum electrode adherence. Clean before shaving to prevent irritation and patient discomfort.
7. If the patient has a hairy chest, dry shave the area at each of the electrode sites.
   **PURPOSE:** The skin must be hairless to provide maximum electrode adherence.
8. Fold a gauze pad over your index finger and briskly rub the sites or use an abrasive tool as indicated (Figure 2).
   **PURPOSE:** To help electrodes stick more tightly to the skin.
9. Apply the electrodes to the sites recommended by the manufacturer; use enough pressure to make sure they adhere completely to the skin. Rub the edges of each electrode a second time to make sure the electrode will stay in place (Figures 3 and 4).

**PURPOSE:** Secure attachment of the electrodes is absolutely necessary to produce an accurate tracing.

10. Attach the lead wires to the electrodes and connect the end terminal to the patient cable.

11. Place a strip of cloth tape over each electrode.

**PURPOSE:** To help secure the electrodes in place in case the wires are pulled during the testing period.

12. Attach the test cable to the monitor and plug it into the electrocardiograph. Run a baseline test tracing as directed by the manufacturer's guidelines.

**PURPOSE:** To ensure proper connections of the electrodes and running of the monitor.

13. Help the patient get dressed without disturbing the connected electrodes. Make sure the cable extends through the buttoned front or out the bottom of the shirt or blouse.

14. Place the monitor in the carrying case, and attach it to the patient's belt or place it over the shoulder. Be sure the wires are not being pulled or bent.

**PURPOSE:** Taut or badly bent wires may loosen or malfunction.

15.Plug the electrode cable into the monitor.

16. Record the patient's name and date of birth and the starting date and time in the patient's activity diary.

**PURPOSE:** To establish the starting time of the test and cardiac activity.

17. Give the patient the activity diary and advise him or her to begin by writing in his or her present activity (Figure 5). Include patient education information on the importance of continually recording activities in the diary; using the event marker on the monitor if he or she experiences any symptoms; and correlating the event with a recording in the diary, including the time and details of the related activity before or during the event.

**PURPOSE:** The diary must correlate the patient's activity with the cardiac activity.

18. Schedule the patient for a return appointment in 24 hours.

19. Sanitize your hands.

**PURPOSE:** To ensure infection control.

20. Record the procedure in the patient's medical record.

**PURPOSE:** A procedure is not considered done until it is recorded in the patient's medical record.

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**FIGURE 3**

9/29/XX 3:10 pm Holter monitor applied per physician order. Pt. given instructions to leave leads in place until he returns to office tomorrow. Understands to record cardiac symptoms in diary, to use event marker if symptoms occur, and not to shower until monitor is removed.

Martha Reyes, CMA (AAMA)
Mrs. Jamison was fitted with a Holter monitor at the office yesterday at 4 pm. When Martha arrived at the office at 8 o’clock this morning, she found that Mrs. Jamison had left a message with the answering service to call her as soon as possible. When Martha returns the call, Mrs. Jamison tells her that she had taken a shower last night, and she noticed that when she got up to go to the bathroom, “the light was not on” on the monitor. How should Martha handle this situation?

Cardiac Event Monitor

The cardiac event monitor is a small recording device that can be worn up to 30 days to catch events that are difficult to record in a 24-hour period on a Holter monitor, such as vertigo, weakness, and palpitations. Patients are instructed to trigger the recording when they feel any indication of a cardiac event. Using the information gathered during the recording period, the physician can diagnose heart abnormalities and design the most effective treatment. The monitor must be removed during bathing, so the patient must be taught how to remove and reapply the electrodes throughout the test period. Patient education for using an event monitor includes the following instructions:

- Protect the monitor from damage and wear it at all times except when bathing.
- Do not alter your lifestyle; regular activities need to be maintained to reflect the cause of cardiac symptoms.
- Trigger the recording by pushing the event monitor when symptoms occur.
- Use the diary to record activities when events occur.
- Change the electrodes daily and the batteries at the same time each day.
- To prevent skin irritation, do not put replacement electrodes in the same spot.
- Put the electrodes on the rib cage under the left breast and in the midaxillary region under the right shoulder.
- Most event monitor recordings can be transmitted by telephone; you will be given instructions for transmitting recordings.
- If you have any questions, use the contact information provided.

Heart Scan

A noninvasive method of assessing possible cardiac risk is a specialized type of computed tomography (CT) called an electron beam tomography (EBT) heart scan (also called an ultrafast CT). The heart scan takes less than 5 minutes and does not require any needles or injections. It is a screening tool that allows physicians to see the amount of plaque in the coronary arteries by showing the presence of calcium deposits. Calcium makes up approximately 20% of arterial plaque deposits. The EBT heart scan is read, and the physician assigns the patient a calcium score that can be a predictor of future cardiac problems.

Closing Comments

Patient Education

Heart disease and stroke account for more than one third of all deaths. Genetic predisposition and detrimental lifestyle habits, such as smoking, lack of exercise, high-fat diets, and obesity, play significant roles in the development of heart disease. The medical assistant should talk to the patient about factors that can be changed or modified and should encourage any attempt by the patient to make these changes.

Before you can successfully counsel a patient to change a habit, you need to familiarize yourself with possible techniques and approaches to use. Such information can be obtained from the American Heart Association and reputable Internet sites.

Many patients like visual aids when they are learning new information, and brochures with pictures or posters in the office are effective means of promoting learning and eliciting questions from patients. Make a note in the medical record of the educational items you give the patient on each visit. It is a good idea to ask about the helpfulness of the information, whether the patient tried any modifications, and what the results were. Ask for any suggestions that might help another patient in a similar situation.

Legal and Ethical Issues

An ECG is a valuable diagnostic tool, and it continues to be one of the most common procedures used in the diagnosis of cardiac diseases and conditions. The cardiologist measures the heart’s activity and compares the results with known values by analyzing the ECG tracing. Comparing an ECG tracing with previous tracings can identify changes in the condition of the patient’s heart.

The physician must be able to interpret the ECG tracing accurately and to establish its value in correctly diagnosing the patient’s condition; the medical assistant, therefore, has the ethical obligation to complete the task as accurately and carefully as possible. Diagnostic procedures have a profound effect on a patient’s subsequent treatment. When you are entrusted with performing testing procedures, you assume full responsibility for the accuracy and precision of each test you perform. This is a critical role in the medical assisting profession. The results you submit strongly influence each patient’s therapeutic treatment plan. No test is ever just routine.

Summary of Scenario

Martha has worked in Dr. Lee’s office for almost 8 months. She has become quite confident in her ability to perform electrocardiography quickly and accurately. She also has learned to communicate effectively with patients about their fears and concerns about various cardiac diagnostic tests. She never forgets to emphasize to a patient the importance of not taking a shower during the 24-hour Holter monitoring period. In 2 months she and Dr. Lee will attend a national meeting of cardiologists in Chicago. Two days of continuing education classes will be offered for medical assistants who work in cardiology. Martha is very excited to be able to continue learning and to sharpen her skills as a medical assistant in cardiology.
SUMMARY OF LEARNING OBJECTIVES

1. Define, spell, and pronounce the terms listed in the vocabulary. Spelling and pronouncing medical terms correctly bolster the medical assistant's credibility. Knowing the definitions of these terms promotes confidence in communication with patients and co-workers.

2. Apply critical thinking skills in performing the patient assessment and patient care. Completing the Critical Thinking Application exercises throughout the chapter can help the student medical assistant become more adept at critical analysis of real-life situations.

3. Illustrate the electrical conduction system through the heart. The heart beats in response to an electrical signal that originates in the SA node in the right atrium, spreads over the atria, and causes atrial contraction. This impulse continues to the AV node, through the bundle of His, through the right and left bundle branches, and into the Purkinje fibers, eventually causing ventricular contraction.

4. Explain the concepts of cardiac polarization, depolarization, and repolarization. Polarization is the resting state of the myocardial cell, when there is no electrical activity in the heart. When the electrical system of the heart stimulates a myocardial cell, depolarization occurs, resulting in contraction of the stimulated heart muscle. The heart muscle cells must then return to a resting state; the process of reaching this resting state is repolarization.

5. Summarize the properties of the electrocardiograph. A six-channel ECG machine records all 12 leads simultaneously within seconds. Limb and chest electrodes with leads must be placed on the patient at specific anatomic locations before the recording starts. ECG paper is standardized to represent amplitude and time. The horizontal lines allow determination of the intensity of the electrical activity, and the vertical lines represent time; each of the large squares represents 0.2 second; five of them equals 1 second.

6. Describe the electrical views of the heart recorded by the 12-lead electrocardiograph. Lead I records the electrical activity of the lateral part of the left ventricle; leads II and III record the electrical activity of the inferior surface of the left ventricle. The augmented lead aVR records the electrical activity of the atria with negative deflection of the P waves and QRS complexes; aVL records the electrical activity of the lateral wall of the left ventricle; and aVF records the electrical activity of the inferior surface of the left ventricle. The precordial leads provide a transverse plane view of the heart. They include V1, V2, V3, V4, V5, and V6, with each numbered representing a specific location on the chest. The QRS complex is a negative deflection in V1 and V2 views, and each subsequent lead becomes more positive.

7. Discuss the process of recording an electrocardiogram. Recording an ECG requires a knowledge of where to place the electrodes and connect the leads to obtain the most accurate recording possible; the ability to recognize and correct the most common types of artifacts on the ECG recording; and proper use of the machine available.

8. Perform an accurate recording of the electrical activity of the heart. Procedure 49-1 outlines the steps for performing a 12-lead ECG recording.

9. Compare and contrast electrocardiographic artifacts and the probable cause of each. An artifact is an unwanted, erratic movement of the stylus on the paper caused by outside interference. The main types include wandering baseline artifacts, in which the stylus gradually shifts away from the center of the paper because of slight movement or poor electrode attachment. Somatic tremor artifacts are a result of muscle movements in the patient that cause jagged peaks of irregular height and spacing and a shifting baseline. AC interference causes a series of uniform, small spikes on the paper because of electrical energy in the area. Interrupted baseline artifacts occur when the electric connection between the electrode and the lead is interrupted.

10. Identify a typical electrocardiograph tracing. Table 49-2 summarizes the normal appearance of ECG waveforms and complexes. The ECG tracing is made up of repeated cardiac cycle (PQRST) recordings. The heart rate is calculated from the ECG recording by counting the number of P waves in a 6-second strip (30 large squares) and multiplying by 10. For the ventricular contraction rate, the number of complete QRS complexes within 6 seconds is counted and multiplied by 10 to get the number of ventricular contractions in 1 minute. The rhythm of the patient's heartbeat indicates whether it is regular. If the patient's heart is beating at a regular rhythm, each cardiac cycle occurs within the same time frame and individual cardiac cycles occur exactly the same length of time apart.

11. Describe common electrocardiographic arrhythmias. In sinus rhythm, the heart's electrical activity begins in the SA node and follows through the electrical system, ending in atrial and ventricular depolarization. In sinus bradycardia, the heart rate is less than 60 beats/min; in sinus tachycardia, the rate is more than 100 beats/min. A PAC occurs when the atria contract before they should for the next cardiac cycle. Atrial flutter occurs when the atria beat at an extremely rapid rate, up to 300 beats/min. PVCs occur when the ventricles contracts before they should for the next cardiac cycle. VT causes the ventricles to beat at an extremely rapid rate, from 101 to 250 beats/min. VT is the most critical, life-threatening arrhythmia and results in death if not effectively treated. Asystole is the result of no heartbeat. Biochemical systemic problems also can cause arrhythmias.

12. Summarize cardiac diagnostic tests. Cardiac diagnostic tests include an ECG; a stress test to determine the patient's cardiac response to exercise; a 24-hour Holter monitor to pick up abnormalities during the patient's routine day; a 30-day event monitor to record infrequent cardiac symptoms; and a heart scan to provide noninvasive diagnostic information.

CONNECTIONS

Study Guide Connection: Go to the Chapter 49 Study Guide. Read and complete the activities.

Evolve Connection: Go to the Chapter 49 link at evolve.elsevier.com/kinn to complete the Chapter Review and Chapter Quiz. Peruse other resources listed for this chapter to increase your knowledge of Principles of Electrocardiography.