EKGs / ECGs

Basics

- The abbreviation **EKG** comes from the German word *elektrokardiogramm*; both EKG and ECG can be used to mean "electrocardiogram"; however, EKG will be used throughout this guide
- An **EKG** is a recording of the heart's electrical activity; this activity is produced by **cardiac cells**
- There are two basic types of cardiac cells: myocardial cells and specialized cells
  - **Myocardial cells** are the working machinery of the heart and compose the majority of heart tissue
    - They form the muscular layer of the atrial and ventricular walls
    - Filaments inside these cells slide together causing the cells to contract
  - **Specialized cells** are the conduction system of the heart
    - **Pacemaker cells** activate and regulate myocardial cells; they do not contain filaments, so they cannot contract; they generate and conduct electrical impulses throughout the heart
    - **Electrical conducting cells** conduct impulses generated by pacemaker cells throughout the heart; they are the hardwiring of the heart
- In a cardiac cell's resting state, the inside of the cell is negatively charged when compared to the outside of the cell; the electronegativity inside the cell is maintained by ion pumps in the cell membrane
  - These pumps control the distribution of electrolytes, such as potassium, sodium, chloride, and calcium ions, which are vital to maintaining the negative polarity inside the cell
- The measurement of the difference in electrical charge on either side of a cell membrane is called **action potential**
  - The exchange of electrolytes through the cardiac cell membrane produces this electrical activity
- When cardiac cells lose their negative polarity, depolarization occurs; **depolarization** is an electrical event caused by positively charged ions crossing the cell membrane
  - Depolarization is transmitted from cell to cell, producing a wave of electrical activity across the heart, which can be sensed by electrodes placed on a patient's skin; depolarization initiates the cycle of cardiac contraction
- Depolarization is followed by a reversal of the flow of ions across the cell membrane called **repolarization**, or the restoration of negative polarity inside the cell
  - Repolarization initiates the relaxation phase of cardiac muscle, which is also detected by electrodes placed on the chest

Conduction Pathway

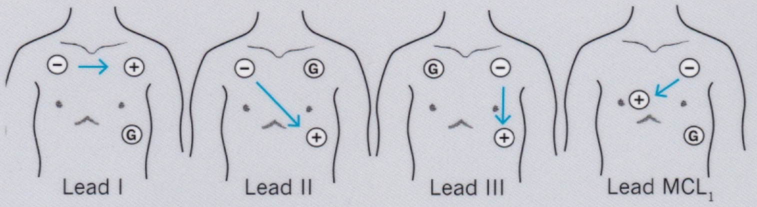
- The path of conduction begins at the **sinoatrial (SA) node**, or **sinus node**, whose job is to pace the heart; generally, the dominant pacemaker cells are located in the SA node
  - These cells have the fastest firing rate (approx. 60–100 bpm) but can vary tremendously based on the demands placed on the heart, such as exercise

bpm = beats per minute

- The signal is then sent to the **atrioventricular (AV) node**, located in the lower area of the right atrium
  - The main function of the AV node is to delay the electrical impulse; this allows for the atria to contract and ventricles to fill before they contract
- The impulse is then transmitted through the **bundle of His**, located in the upper part of the septum that separates the ventricles
  - The bundle of His has pacemaker cells that can transmit at a rate of 40–60 bpm
  - This area connects the AV node with the right and left bundle branches—an area called the **AV junction**
- The right bundle branch sends messages to the right ventricle; the left bundle branches divide and supply transmission to the left ventricle
  - The right and left bundle branches divide into smaller branches and connect to the **Purkinje fibers**, which penetrate the ventricular muscle; when electrical impulses are sent through the Purkinje fibers, this causes ventricular contraction
  - These fibers have pacemaker cells that have an intrinsic pace of 20–40 bpm

Electrocardiogram

- An EKG is recorded by electrodes inside adhesive pads that are placed on the patient's chest
- Several electrodes are placed on the chest to view the heart from different angles; a **lead** is a view of the heart from a particular angle
- A simple EKG can be seen with three electrodes known as **lead I**, **lead II**, and **lead III**
  - An EKG records the electrical activity between the electrodes
  - The electrodes are often color-coded black, white, and red
    - One electrode is positive, the second is negative, and the third is the "ground," which minimizes electrical interference from other sources
    - When electricity flows toward the positive electrode, the pattern on the graph will be upright
    - Consequently, when electricity flows away from the positive electrode, the pattern will deflect downward



Lead I Monitoring

- The positive electrode is placed on the left upper apex of the chest, just below the clavicle; the negative electrode is placed below the right clavicle
- The flow of electricity is from the negative to the positive electrode
  - This causes the deflection, or **QRS complex**, to be upright
- Lead I accesses information on the lateral wall of the heart

Lead II Monitoring

- The positive electrode is placed on the left side of the chest below the pectoral muscle; the negative electrode is placed below the right clavicle
- This is the most common lead for cardiac monitoring because it resembles the normal pathway of electrical depolarization across the heart
- Lead II accesses information on the inferior wall of the heart

Lead III Monitoring

- The positive electrode is placed on the left side of the chest below the pectoral muscle; the negative electrode is placed on the left side also but below the clavicle
- Lead III accesses information on the inferior wall of the heart

Lead MCL$_1$ Monitoring

- MCL$_1$ = modified chest lead
- The negative electrode is on the left side of the chest below the clavicle; the positive electrode is on the right side of the sternum in the 4th intercostal space
- Lead MCL$_1$ accesses information on the anterior wall of the heart

12-Lead EKG

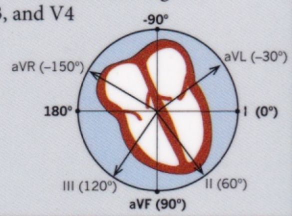
- Provides more angles of the heart because it utilizes 12 leads: I, II, III, aVL, aVR, aVF, V1, V2, V3, V4, V5, and V6
- The 12 views are taken from 10 electrodes
  - One electrode is placed on each arm and each leg
  - Six precordial electrodes (V1–V6) are placed on the chest horizontally

Precordial Electrodes

- V1 is placed in the 4th intercostal space to the right of the sternum and lies over the right ventricle
- V2 is placed in the 4th intercostal space to the left of the sternum
- V3 is placed between V2 and V4, which is located at the 5th intercostal space midclavicular line
- V5 is placed between V4 and V6, which is located at the 5th intercostal space midaxillary line
- V6 is placed at the 5th intercostal space midaxillary line

Augmented Leads

- There are three augmented limb leads, which are created by making one electrode positive and the others negative; for example:
  - **Lead aVL** is created by making the left arm positive and the other limbs negative
  - **Lead aVR** is created by making the right arm positive and the other limbs negative
  - **Lead aVF** is created by making the legs positive and the other limbs negative
- The anterior part of the heart is viewed in leads V2, V3, and V4
- The inferior part of the heart is viewed in leads II, III, and aVF
- The left lateral side of the heart is viewed in leads I, aVL, V5, and V6
- The right ventricular part of the heart is viewed in leads aVR and V1

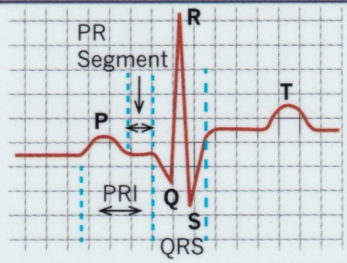


EKG Paper

- In order to assess waveforms, it is necessary to understand EKG graph paper
- The graph paper is made out of small and large squares
  - Each small square represents approx. 0.04 second
  - There are five small squares in a large square; each large square represents 0.20 second
  - Five large squares equal 1 second
  - The standard rate or speed of an EKG is 25 mm per second
- The vertical lines on EKG paper measure the voltage, or amplitude, which is the strength of the electrical current
  - A strong current will have a greater deflection than a weaker current
  - When calibrated correctly, one small square is 1 mm high, which equals 0.1 millivolt; one large square, which is equal to five small squares, is 5 mm high and equals 0.5 millivolt

Waveforms

- The cardiac cycle begins with the SA node sending an impulse that depolarizes the right and left atria; this forms the **P wave**; the P wave should:
  - Be small and rounded
  - Be upright in leads I and II
  - Be 0.5–2.5 mm in amplitude, or height
  - Not be longer than 0.11 second
- This is followed by a **PR segment**, which is flat (or isoelectric, meaning very little electrical activity is detected) and represents a delay; this delay is the conduction through the AV node; this allows for the atria to contract and the ventricles to fill; therefore, it is the end of the depolarization and contraction of the atria before the ventricles depolarize and contract; the electrical impulse then travels to the bundle of His and Purkinje fibers
- The **PR interval** (PRI) is the P wave plus the PR segment; this represents the beginning of depolarization of the left and right atria and the delay as the impulse travels through the AV node, before ventricular depolarization
  - The PR interval is normally 0.12–0.20 second
  - A **long PR interval** indicates a delay in the impulse through the AV node; this could be normal or abnormal; in abnormal situations, it could indicate a first-degree heart block or digitalis toxicity
  - A **shortened PR interval** could indicate the electrical impulse has taken an abnormal pathway, such as bypassing the AV node; this is seen with Lown-Ganong-Levine or Wolff-Parkinson-White syndrome



- The **QRS complex** is produced by ventricular depolarization; the **Q wave** is the first downward turn after the PR interval, which is caused by the depolarization of the ventricular septum; this is followed by the **R wave**, which is a positive deflection upward; the **S wave** is the negative deflection after the R wave; the R and S waves are the depolarization of the right and left ventricles; the atria repolarize during this time, but it is not seen on the EKG due to the QRS complex
  - The normal duration of the QRS complex is 0.04–0.12 second; a QRS complex greater than 0.12 second indicates the electrical impulse originates in the ventricular area; if the impulse originates in the bundle branch, the QRS complex may be slightly greater than 0.12 second
  - The amplitude of the Q wave is 25% or less of the R wave
  - A normal QRS complex can be positive, negative, or biphasic (i.e., partly positive, partly negative)
- The section of the EKG after the QRS complex and before the next wave (the T wave) is the **ST segment**; the ST segment is the beginning of repolarization of the ventricles
  - Normally, the ST segment is isoelectric, but it can have a 1–2 mm elevation in leads I, II, and III; an ST segment elevation can suggest acute myocardial infarction, whereas an ST segment depression can be caused by ischemia or digitalis
- The **T wave** follows the ST segment and represents repolarization of the ventricles
  - Normally, in leads I, II, and III, the T wave is not greater than 5 mm in amplitude but can be asymmetrical; inverted T waves can indicate myocardial ischemia, and peaked T waves are common with hyperkalemia
- The **QT interval** is from the beginning of the QRS complex to the end of the T wave; the QT interval is the depolarization and repolarization of the ventricles
  - A normal QT interval is 0.36–0.44 second but can vary depending on the heart rate, age, and sex of the patient
- A **U wave**, which is not always seen because of its low amplitude, is believed to be the repolarization of the Purkinje fibers; a U wave will follow a T wave and go in the same direction
  - A U wave that is taller than 2 mm in amplitude often indicates hypokalemia or the effects of digitalis
  - A U wave in the opposite direction of the T wave could be due to cardiac disease

Analyzing EKG Rhythms

1. **Determine the heart rate.** There are many methods to determine heart rate; one method is to count the number of boxes between two R waves and divide into 300; this method works as long as the rhythm is regular; for irregular rhythms, the 6-second method can be used: count the number of QRS complexes in 6 seconds (30 large boxes) and multiply by 10
2. **Determine if the rhythm is regular or irregular.** This is done by comparing the distance between the R waves; if the R-to-R intervals are the same, the ventricular rhythm is regular; then compare the distance between the P waves; if the P-to-P intervals are the same, the atrial rhythm is regular
3. **Determine if P waves are present and if they precede each QRS complex.** If no P waves are present, then the impulse must originate somewhere other than the SA node, such as the AV node or the ventricles; the P wave should be less than 2.5 mm in amplitude (height) and no more than 0.11 second in duration
4. **Determine if the PR interval is normal.** The PR interval should be 0.12–0.20 second; a PR interval less than 0.12 second may be seen if the impulse originates in an area of the atria closer to the AV node or AV junction or if the impulse progresses through an abnormal pathway; a PR interval greater than 0.20 second indicates a delay as the impulse passes through the AV node
5. **Determine if QRS complexes are wide or narrow.** A wide QRS complex is greater than 0.12 second and implies the origin of impulse is the ventricles; therefore, the pathway of the impulse is not the most efficient and takes more time, making the QRS complex wider; a narrow QRS complex indicates the origin of impulse must be above the AV node following the normal pathway

By following these steps, rhythms can be analyzed and interpreted; **arrhythmia** means "without rhythm"; there are **five main types** of arrhythmias: sinus rhythms, atrial rhythms, junctional rhythms, ventricular rhythms, and heart blocks

Sinus Rhythms

Normal Sinus Rhythms

Originate in the SA node and follow the normal conduction pathway

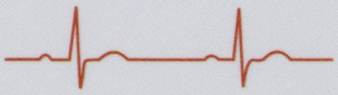
- **Rate:** 60–100 bpm
- **Rhythm:** Regular
- **P wave:** Normal (i.e., smooth and rounded) proceeding each QRS complex
- **PR interval:** 0.12–0.20 second
- **QRS complex:** ≤0.12 second

Sinus Bradycardia

Occurs when the SA node fires at a rate less than 60 bpm; the conduction pathway following the SA node is normal, which leads to depolarization of the atria and ventricles but at a slower rate

Causes: Can be normal in some patients without cardiac disease, such as athletes; however, can occur with acute myocardial infarction, increased vagal tone (increased intracranial pressure, vomiting, carotid massage), hypothermia, and administration of drugs such beta-blockers, calcium channel blockers, and digitalis

- **Rate:** <60 bpm
- **Rhythm:** Regular
- **P wave:** Normal proceeding each QRS complex
- **PR interval:** 0.12–0.20 second
- **QRS complex:** Generally ≤0.12 second



Sinus Tachycardia

Occurs when the SA node fires at a rate greater than 100 bpm; the impulse from the SA node follows the normal conduction pathway leading to depolarization of the atria and ventricles but at a faster rate

Causes: Can be a normal response to hypoxia, fever, pain, anxiety, infection, exercise, and fright; however, can be present with congestive heart failure, acute myocardial infarction, shock, hypovolemia, and dehydration

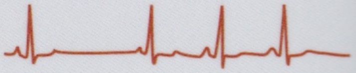
- **Rate:** Generally 100–160 bpm
- **Rhythm:** Regular
- **P wave:** Normal proceeding each QRS complex
- **PR interval:** 0.12–0.20 second
- **QRS complex:** Generally ≤0.12 second

Sinoatrial Block

Occurs when an impulse generated in the SA node is blocked as it exits the SA node; this results in a periodically absent PQRST complex; with the exception of the blocked impulse, the rhythm appears normal otherwise; the pause is the same as two or more P-P intervals

Causes: May be temporary with no signs or symptoms experienced by the patient; however, can occur due to acute myocardial infarction, disease of the SA node, coronary artery disease, myocarditis, congestive heart failure, and administration of drugs such as digitalis, quinidine, or procainamide

- **Rate:** Generally normal but varies because of pause
- **Rhythm:** Irregular; the pause is the same as two P-P intervals
- **P wave:** Normal proceeding each QRS complex
- **PR interval:** 0.12–0.20 second
- **QRS complex:** Generally ≤0.12 second

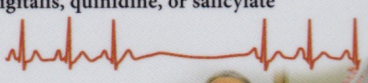


Sinus Arrest

Occurs when the SA node fails to fire and there is an absent PQRST complex; normally, when the SA node fails to fire, the AV junction or ventricles assume responsibility for pacing the heart; in sinus arrest, this fails to happen, leading to the absent PQRST complex

Causes: May be temporary with no signs or symptoms; however, can occur due to myocardial infarction, coronary artery disease, myocarditis, rheumatic heart disease, and administration of drugs such as digitalis, quinidine, or salicylate

- **Rate:** Generally normal but varies because of pause
- **Rhythm:** Irregular because of the variable length of the pause; the pause is longer than the distance of two P-P intervals
- **P wave:** Normal proceeding each QRS complex
- **PR interval:** 0.12–0.20 second
- **QRS complex:** Generally ≤0.12 second



Atrial Rhythms

Premature Atrial Complexes

Premature atrial complexes or beats appear before the next beat should appear; the impulse can originate in the atria or AV junction; the premature atrial contraction (PAC) can be followed by either a normal QRS complex if it travels through the AV junction or a wide QRS complex if the impulse follows another pathway; if the PAC is not conducted through the heart, an abnormal P wave will appear and will not be followed by a QRS complex

Causes: Congestive heart failure; myocardial ischemia; pulmonary embolism; fatigue; digitalis toxicity; hypokalemia; hypomagnesemia; excessive caffeine, tobacco, or alcohol use

- **Rate:** Generally normal but varies because of underlying rhythm
- **Rhythm:** Regular with premature beats
- **P wave:** Premature and differ in shape from sinus wave
- **PR interval:** Varies; 0.12–0.20 second when impulse originates near SA node; 0.12 second when impulse originates near AV junction
- **QRS complex:** Generally ≤0.12 second but may be prolonged if the rhythm is abnormally conducted

Supraventricular Tachycardia (SVT)

A rapid rhythm that originates in the atria; SVT rate overrides the SA node and paces the heart; P waves may not be visible due to proceeding T waves; QRS complex is usually narrow, since the impulse follows normal conduction to the ventricles

May also be called "paroxysmal supraventricular tachycardia" if the rhythm starts and ends abruptly; if the cessation is not observed, this rhythm is simply called "supraventricular tachycardia"

Causes: Can be a normal response in a healthy heart due to physical or psychological stress; hypoxia; hypokalemia; or excessive use of caffeine, nicotine, or other stimulant; can also occur with rheumatic heart disease, coronary heart disease, acute myocardial infarction, mitral valve prolapse, digitalis toxicity, or respiratory failure

- **Rate:** 150–250 bpm
- **Rhythm:** Regular
- **P wave:** Atrial P waves may be seen or may be hidden by T waves; P waves will differ in shape from sinus P waves
- **PR interval:** May not be measurable, but if seen, will usually be 0.12–0.20 second
- **QRS complex:** Generally <0.12 second unless ventricular problem exists, which would increase it

Multiformed Atrial Rhythm

Also known as "wandering atrial pacemaker"; an irregular rhythm with impulses originating from various sites, such as the SA node, atria, and AV junction; usually, three or more differently shaped P waves are seen, which is a requirement for diagnosis; has irregular P-P, R-R, and PR intervals because of different impulse origin sites

Causes: Digitalis toxicity, rheumatic heart disease, atrial hypertrophy, acute myocardial infarction, chronic obstructive pulmonary disease; can be seen in patients without cardiac disease

- **Rate:** 60–100 bpm; if >100 bpm, it is known as "multifocal atrial tachycardia"
- **Rhythm:** Atrial irregular; ventricular irregular
- **P wave:** Size and shape differ; at least three different P waves
- **PR interval:** Variable
- **QRS complex:** Generally <0.12 second but may be wider if ventricular conduction problem exists

Atrial Flutter

Occurs when the atria fire at a rapid rate; resembles a sawtooth pattern between the QRS complexes; the AV node protects the ventricles by blocking some of these impulses; therefore, all the atrial impulses are not transmitted to the ventricles; when the ventricular rate is less than 100, the atrial flutter is considered controlled; when greater than 100, the atrial flutter is considered uncontrolled

Causes: Acute myocardial infarction, ischemic heart disease, mitral or tricuspid valve disease, pulmonary embolism, hypoxia, digitalis or quinidine toxicity

- **Rate:** Atrial rate 200–350 bpm; ventricular rate will vary based on the number of blocked atrial beats but usually is not >180 bpm
- **Rhythm:** Atrial regular; ventricular may be regular or irregular
- **P wave:** Not visible; sawtooth pattern or flutter observable
- **PR interval:** Not measurable
- **QRS complex:** Generally <0.12 second but may be wider if ventricular conduction problem exists

Atrial Fibrillation

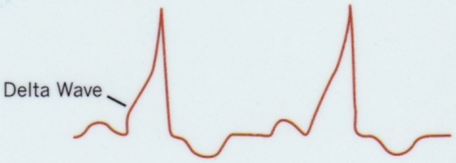
Occurs when several irritable sites in the atria fire; essentially, the atria are quivering and are not effectively contracting; as with atrial flutter, the AV node is protecting the ventricles by blocking many of these impulses; when the ventricular rate is less than 100 bpm, the atrial fibrillation is considered controlled; when greater than 100 bpm, the atrial fibrillation is considered uncontrolled

Causes: Acute myocardial infarction, ischemic heart disease, mitral or tricuspid valve disease, pulmonary embolism, hypoxia, digitalis or quinidine toxicity

- **Rate:** Atrial rate >350–400 bpm; ventricular rate varies
- **Rhythm:** Ventricular irregular, usually between 120–180 bpm but can be faster or slower
- **P wave:** Not visible, just fibrillation
- **PR interval:** Not measurable
- **QRS complex:** Generally ≤0.12 second but may be wider if ventricular conduction problem exists

Wolff-Parkinson-White Syndrome

Also known as "preexcitation syndrome" or "bundle of Kent syndrome"; during fetal development, myocardial strands are formed and connect the atria with the ventricles; normally, this pathway becomes nonfunctional after birth; however, in Wolff-Parkinson-White syndrome, this abnormal pathway continues to function; this pathway conducts impulses faster than the AV node; this makes for a short PR interval and a longer QRS complex that forms a delta wave caused by the ventricles receiving an impulse from outside the normal pathway; this syndrome may lead to atrial tachydysrhythmias, such as atrial fibrillation, since there is no protection of the AV node; Wolff-Parkinson-White syndrome is associated with a rapid ventricular rate, which can lead to symptoms such as dizziness, palpitations, weakness, anxiety, fainting, chest pain, and even shock



- **Rate:** 60–100 bpm if underlying rhythm is sinus in origin
- **Rhythm:** Regular
- **P wave:** Normal
- **PR interval:** <0.12 second
- **QRS complex:** Often >0.12 second with delta wave seen in one or more leads

Junctional Rhythms

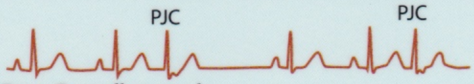
Junctional rhythms refer to rhythms in which the impulse originates in the AV junction; these rhythms occur if the SA node fails to fire or fires at a rate slower than the AV junction; the AV junction then becomes the pacer of the heart; when the AV junction initiates the impulse, the atria may not be stimulated and the impulse must travel backward to the atria; when the impulse travels backward, the P wave will be negative or inverted in leads II, III, and aVF, since the impulse is traveling away from the positive electrode

The P wave will appear before the QRS complex if depolarization of the atria occurs prior to depolarization of the ventricles; the P wave will be hidden by the QRS complex if the atria and ventricles depolarize at the same time; however, if the atria depolarize after the ventricles, the P wave will be inverted and will appear after the QRS complex

Premature Junctional Complexes (PJCs)

Appear when the AV junction fires before the next expected sinus beat; the QRS complex is normal, since the impulse travels through the ventricles in the usual manner

Causes: Excessive caffeine, tobacco, or alcohol use; exercise; valvular disease; congestive heart failure; hypoxemia; ischemia; digitalis toxicity; rheumatic heart disease



- **Rate:** Generally normal
- **Rhythm:** Generally regular with premature beats
- **P wave:** Can occur before, during, or after QRS complexes; may be inverted in leads II, III, and aVF
- **PR interval:** If P wave is present, PR interval will usually be <0.12 second
- **QRS complex:** Generally ≤0.12 second

Junctional Escape Beats

Occur when the SA node and the AV junction fail to fire and the beat appears late; the escaped beat originates in the AV junction later than expected

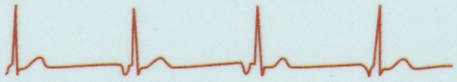
Causes: Myocardial infarction, rheumatic heart disease, digitalis toxicity, hypoxia, disease of the SA node, valvular disease, administration of calcium channel blockers or beta-blockers

- **Rate:** Generally normal
- **Rhythm:** Generally regular with late beats
- **P wave:** Can occur before, during, or after QRS complexes; if P waves are seen, they will be inverted in leads I, II, and aVF
- **PR interval:** If P wave occurs before QRS complex, PR interval will be ≤0.12 second
- **QRS complex:** Generally ≤0.12 second

Junctional Escape Rhythm

Occurs if several junctional escape beats occur sequentially

Causes: Inferior-wall myocardial infarction, rheumatic heart disease, digitalis toxicity, hypoxemia, disease of the SA node, valvular disease, post-cardiac surgery, administration of calcium channel blockers or beta-blockers

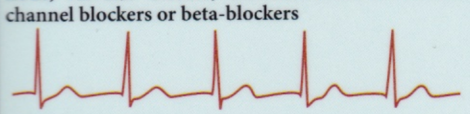


- **Rate:** 40–60 bpm
- **Rhythm:** Regular
- **P wave:** Can occur before, during, or after QRS complexes; if P waves are seen, they will be inverted in leads II, III, and aVF
- **PR interval:** If P wave occurs before QRS complex, PR interval will be ≤0.12 second
- **QRS complex:** Generally ≤0.12 second

Accelerated Junctional Rhythm

Occurs due to an increased automaticity of the bundle of His; this leads to an increased ventricular response

Causes: Myocardial infarction, rheumatic heart disease, digitalis toxicity, hypoxia, disease of the SA node, valvular disease, administration of calcium channel blockers or beta-blockers



- **Rate:** 60–100 bpm
- **Rhythm:** Regular
- **P wave:** Can occur before, during, or after QRS complexes; if P waves are seen, they will be inverted in leads II, III, and aVF
- **PR interval:** If P wave occurs before QRS complex, PR interval is usually ≤0.12 second
- **QRS complex:** Generally ≤0.12 second

Junctional Tachycardia

Occurs when the AV junction fires at an increased rate; the rhythm will be regular and is believed to occur because of increased automaticity; at ventricular rates of 150 bpm or more, patients may complain of anxiety or a racing heart; ventricular rates that are very high may not allow enough time for the ventricles to fill and thus may decrease cardiac output

When junctional tachycardia starts and ends abruptly, the rhythm is termed "paroxysmal junctional tachycardia"; however, if the onset or ending of junctional tachycardia is not observed, the rhythm is termed "junctional tachycardia"

Causes: Myocardial ischemia or infarction, congestive heart failure, digitalis toxicity

- **Rate:** 100–180 bpm
- **Rhythm:** Regular
- **P wave:** Can occur before, during, or after QRS complexes; if P waves are seen, they are inverted in leads II, III, and aVF
- **PR interval:** If P wave occurs before QRS complex, PR interval is usually ≤0.12 second
- **QRS complex:** Generally ≤0.12 second

Ventricular Rhythms

Ventricular rhythms and beats occur when the impulse originates in the ventricle; when ventricles depolarize from an impulse that originated outside the SA node, AV junction, or atria, the QRS complex measures greater than 0.12 second; ventricular beats can occur when the SA node or AV junction fails to fire or when an area of either ventricle is irritable and produces an impulse; the QRS complex of an impulse that originates in the ventricle will be wide, usually greater than 0.12 second; in fact, the ventricles are the heart's least efficient pacemaker and usually depolarize at a rate of 20–40 bpm

Premature Ventricular Contraction (PVC)

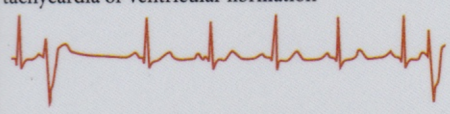
Not a rhythm but an ectopic beat that originates in an irritable area located on either ventricle; often, the beat occurs earlier than expected and looks much different than the other QRS complexes; the T wave is usually in the opposite direction of the QRS complex (e.g., if the QRS complex is upright, the T wave will be inverted)

Causes: Hypoxia; anxiety; exercise; congestive heart failure; myocardial ischemia; digitalis toxicity; electrolyte imbalances; alcohol, tobacco, and caffeine use; acid-base imbalances; can be a normal variation

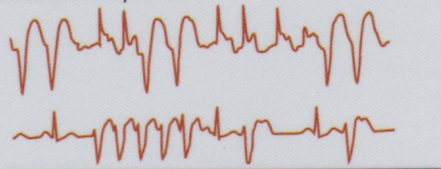
- **Rate:** Generally normal but depends on underlying rhythm
- **Rhythm:** Regular with premature beats
- **P wave:** None associated with the PVC
- **PR interval:** None associated with the PVC
- **QRS complex:** >0.12 second for the PVC; T wave following the PVC is frequently in the opposite direction

PVCs that are identical are called uniform; **multiformed PVCs** are those that differ from one to another; multiformed PVCs vary in appearance because they have different sites of ventricular origin

R-on-T phenomenon occurs when a PVC falls on the T wave of the previous beat (a vulnerable area of the cardiac cycle), which could trigger ventricular tachycardia or ventricular fibrillation



Two PVCs that occur in succession are called **coupled or paired**; coupled PVCs indicate that area of the ventricle is extremely irritable; if three or more PVCs occur successively, this is termed a "run" or "burst" of ventricular tachycardia

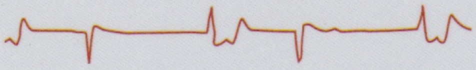


Sometimes PVCs have a particular pattern and are termed based on this pattern; for instance, when a strip shows one normal beat and then one PVC repeatedly across the entire strip, this is referred to as **bigeminy** (when two sinus beats occur followed by one PVC, two sinus beats, and then another PVC); a **trigeminy** is when every third beat is a PVC; a **quadrigeminy** is when every fourth beat is a PVC

Ventricular Escape Beat

Originates in the ventricle because a supraventricular (i.e., above the ventricle) impulse is not initiated; has a wide QRS complex because the impulse originates in the ventricle and occurs late in the cardiac cycle; this beat or rhythm occurs as a protective mechanism and to prevent the heart from slowing even more significantly

Causes: Myocardial infarction, digitalis toxicity, metabolic imbalances; the patient may have hypotension, disorientation, syncope, or loss of consciousness because of the decrease in heart rate and cardiac output

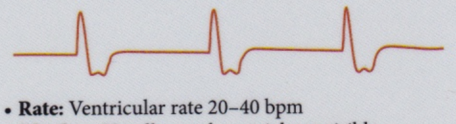


- **Rate:** Depends on underlying rhythm
- **Rhythm:** Irregular; ventricular escape beats occur after expected sinus beat
- **P wave:** None associated with escape beat
- **PR interval:** None associated with escape beat
- **QRS complex:** >0.12 second for escape beat because it originates in the ventricle; T wave is in the opposite direction of the QRS complex

Idioventricular Rhythm

Occurs when the SA node and AV junction either fail to fire or fire at a rate that is less than the ventricular rate; the ventricles respond by initiating their own impulses; the QRS complexes are wide because the impulse originates in the ventricle by avoiding the normal conduction pathway

Causes: *See* Ventricular Escape Beat causes

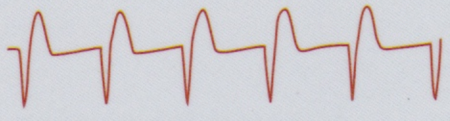


- **Rate:** Ventricular rate 20–40 bpm
- **Rhythm:** Usually regular; atrial not visible
- **P wave:** None
- **PR interval:** None
- **QRS complex:** >0.12 second; T wave is in the opposite direction of the QRS complex

Accelerated Idioventricular Rhythm (AIVR)

A ventricular rhythm with a rate of 50–100 bpm; if the rate falls below 50 bpm, it is referred to as "idioventricular rhythm"; this rhythm looks similar to ventricular tachycardia, and the rate should be counted to differentiate; can appear when the sinus rate slows and then disappear when the sinus rate speeds up; this can be benign and is rarely sustained; the patient is often asymptomatic

Causes: Acute myocardial infarction, digitalis toxicity



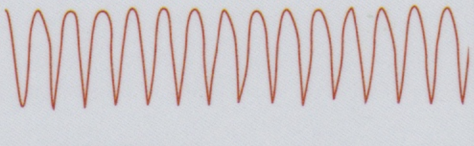
- **Rate:** Ventricular rate 50–100 bpm
- **Rhythm:** Usually regular; atrial not visible
- **P wave:** None
- **PR interval:** None
- **QRS complex:** >0.12 second; T wave is in the opposite direction of the QRS complex

Ventricular Tachycardia (VT)

Occurs when three or more PVCs follow one another at a rate greater than 100 bpm; short runs lasting less than 30 seconds are termed "nonsustained"; longer runs lasting more than 30 seconds are termed "sustained"; sustained pulseless VT is an emergent situation preceding cardiac arrest; with a pulse, the rhythm is stable; without a pulse, the rhythm is unstable

Has wide QRS complexes because the impulses originate in the ventricles; the rhythm may be regular or slightly irregular; if P waves are seen, they have no relationship to the QRS complexes

Causes: Myocardial infarction; acute myocardial ischemia; acid-base abnormality; electrolyte imbalances; hypoxia; use of CNS stimulants (cocaine, amphetamines); toxicity from cardiac drugs such as digitalis, quinidine, and procainamide; VT can be caused by myocardial irritability precipitated by a PVC that occurred during a T wave (R-on-T phenomenon)



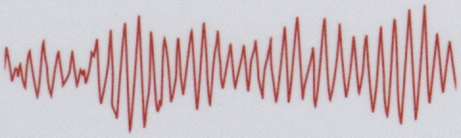
- **Rate:** 100–250 bpm
- **Rhythm:** Ventricular rhythm may be regular or slightly irregular
- **P wave:** May be present or absent but have no relationship to QRS complexes
- **PR interval:** None
- **QRS complex:** >0.12 second

Polymorphic Ventricular Tachycardia

Similar to ventricular tachycardia except the QRS complexes have more than one shape, amplitude, and width; **torsades de pointes** is a type of polymorphic ventricular tachycardia that has a prolonged QT interval and appears to twist around the isoelectric line, similar to a spindle

Torsades de pointes is often preceded by a slow heart rate and can be caused by either drugs or an electrolyte imbalance that prolongs the QT interval; a lengthened QT interval may be the only indicator of impending torsades

Causes: Electrolyte imbalances (hypomagnesemia, hypokalemia, hypocalcemia); bulimia; anorexia; can be drug induced (cyclic antidepressants, phenothiazines, quinidine, procainamide)



- **Rate:** Ventricular rate 150–250 bpm
- **Rhythm:** Ventricular rhythm may be regular or irregular
- **P wave:** None
- **PR interval:** None
- **QRS complex:** >0.12 second; alteration in amplitude, shape, and width of QRS complexes

Ventricular Fibrillation

A rhythm in which many foci in the ventricles are firing in a chaotic manner and the heart muscle is unable to contract in response; the heart muscle is quivering, and there are no discernible waveforms; this is a lethal rhythm, and the patient has no pulse; ventricular fibrillation often has low-amplitude waves in a chaotic rhythm

Causes: Acute myocardial infarction, untreated ventricular tachycardia, electrolyte imbalances, acid-base imbalance, hypothermia, R-on-T phenomenon, electrocution

- **Rate:** Unable to determine due to lack of discernible waves
- **Rhythm:** Irregular and chaotic
- **P wave:** Not discernible
- **PR interval:** Not discernible
- **QRS complex:** Not discernible

Asystole

Total absence of cardiac electrical activity; the patient will have no pulse with this rhythm

Causes: Massive cardiac damage, ventricular aneurysm, respiratory failure, shock, traumatic cardiac arrest

- **Rate:** Not discernible
- **Rhythm:** Not discernible
- **P wave:** Not discernible
- **PR interval:** Not measurable
- **QRS complex:** None

Pulseless Electrical Activity

A clinical situation in which a rhythm is displayed on the monitor but there is no myocardial contraction or response of myocardial fibers; although a rhythm may be present on the cardiac monitor, the patient has no pulse

Causes: Massive myocardial infarction; tension pneumothorax; cardiac tamponade; hypovolemia; hypoxemia; hyperkalemia; hypothermia; pulmonary embolus; acidosis; drug overdose with calcium channel blockers, beta-blockers, digitalis, or cyclic antidepressants

Heart Blocks

Heart blocks are delays or obstructions in the flow of electrical impulses through the normal pathway of the heart; atrioventricular (AV) blocks are divided into the three categories: first degree, second degree, and third degree; diagnosis is based on the relationship of the P wave to the QRS complex

First-Degree AV Block

Has all the components of a normal EKG tracing except a longer than normal PR interval; the impulse begins at the SA node and continues through the atria, but there is often a delay in the AV node; all impulses are transmitted, but there is delay before the impulse is transmitted to the ventricles; the patient can be completely asymptomatic

Causes: Can be a normal finding in many individuals but can also occur due to drug therapy such as procainamide, quinidine, beta-blockers, calcium channel blockers, and digitalis; rheumatic fever; myocardial infarction; or increased vagal tone

- **Rate:** Atrial and ventricular rates are the same
- **Rhythm:** Regular
- **P wave:** Normal proceeding each QRS complex
- **PR interval:** >0.20 second
- **QRS complex:** Generally ≤0.12 second

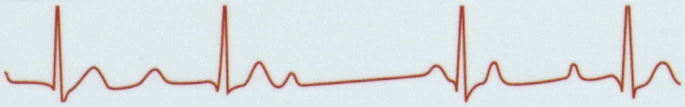
Second-Degree AV Block

Occurs when some impulses generated by the SA node fail to reach the ventricles; the result is more P waves than QRS complexes; the P waves occur at regular times, but not every P wave is followed by a QRS complex; there are two types of second-degree AV block: type I and type II; the key to differentiating them is the PR interval

Second-Degree AV Block Type I (Mobitz Type I, Wenckebach)

Occurs at the AV node; impulses generated in the SA node take longer to conduct through the AV node until finally an impulse is completely blocked; this will appear on the EKG tracing as a P wave with no QRS complex after it, then this cycle starts again; the patient is usually asymptomatic because ventricular rate and cardiac output remain fairly normal

Causes: Ischemic heart disease; inferior-wall myocardial infarction; effects of drugs such as digitalis, beta-blockers, and verapamil; increased parasympathetic stimulation



- **Rate:** Atrial rate greater than ventricular rate; both usually in normal limits
- **Rhythm:** Atrial regular; ventricular irregular
- **P wave:** Normal in size and shape
- **PR interval:** Lengthens with each QRS complex until a P wave appears without a QRS complex, then cycle begins again
- **QRS complex:** Generally ≤0.12 second but periodically dropped

Second-Degree AV Block Type II

A conduction delay that occurs below the AV node either at the bundle of His or the bundle branches; more serious and often progresses into complete AV block; the SA impulses will be generated and will appear in the normal interval on the EKG strip; however, not every P wave will be followed by a QRS complex; the PR interval may be normal or lengthened but will be constant for each conducted beat; then a P wave appears with no QRS complex following it; since QRS complexes are periodically dropped, atrial rate will not be the same as ventricular rate, which will be irregular

Causes: Coronary artery disease, acute myocarditis, anteroseptal myocardial infarction

NOTE: The patient's symptoms are related to his/her ventricular rate; if the ventricular rate is normal, the patient may by asymptomatic; however, if the ventricular rate is decreased significantly, the patient may have low blood pressure, shortness of breath, congestive heart failure, decreased level of consciousness, or pulmonary congestion due to decreased cardiac output

- **Rate:** Atrial rate greater than ventricular rate; ventricular rate is usually slow
- **Rhythm:** Atrial regular; ventricular irregular
- **P wave:** Normal in size and shape
- **PR interval:** Normal or prolonged but always constant on conducted beats; some may be shorter following a nonconducted P wave
- **QRS complex:** Generally ≥0.12 second but periodically absent following some P waves

Conduction Ratios

With second-degree AV block type II, a **2:1 conduction ratio** means that for every two P waves, only one is conducted; consequently, if every third P wave is conducted, this is referred to as a 3:1 conduction ratio; conduction ratios can also be 4:3, 5:4, etc., but there will always be more P waves than QRS complexes

- **Rate:** Atrial rate greater than ventricular rate
- **Rhythm:** Atrial regular; ventricular regular
- **P wave:** Normal in size and shape; every other P wave is followed by a QRS complex
- **PR interval:** Constant
- **QRS complex:** Normal if block occurs above the bundle of His; wide if block occurs below the bundle of His; dropped after every other P wave

Third-Degree (Complete) AV Block

Occurs when the atria and the ventricles beat independently of each other; impulses generated in the SA node are blocked completely and do not reach the ventricles; the block may be present in the AV node, bundle of His, or bundle branches; the ventricles are stimulated by impulses that originate in the ventricles or AV junction; therefore, the QRS complexes could be either wide or narrow; if impulses originate in the junctional area, the QRS complex is narrow; an impulse that originates in the ventricles has a wide QRS complex

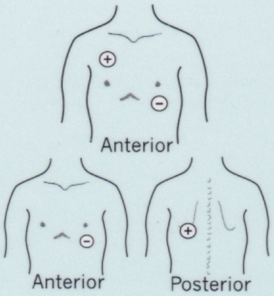
Causes: Inferior-wall myocardial infarction; increased parasympathetic tone; drugs such as digitalis, propranolol, and verapamil; damage to the AV node; disease of the conduction system of the heart; major anterior myocardial infarction

NOTE: A patient may or may not be symptomatic based on the ventricular rate and the patient's response to this rate; also, symptoms may depend on whether the impulse is junctional or ventricular, which determines whether the QRS complex is wide or narrow

- **Rate:** Atrial rate greater than ventricular rate; ventricular rate determined by origin on impulse pacing the ventricles
- **Rhythm:** Atrial and ventricular both regular but have no relationship to each other
- **P wave:** Normal size and shape
- **PR interval:** None; atria and ventricles are beating independently of each other
- **QRS complex:** Narrow or wide depending on the origin of the impulse that is pacing the ventricles; junctional is narrow; ventricular is wide

Pacemaker Pacing

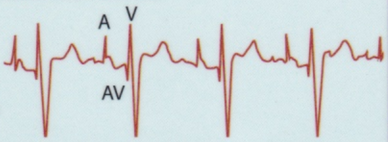
- A **pacemaker** is a device that delivers an electric current to the heart to cause stimulation leading to depolarization
  - Can be temporary or permanent
  - Can run on batteries or wall current
- A **temporary pacemaker**, whether it is transcutaneous (through the skin) or transvenous (through the vein), is often used in acute situations usually for less than three days; transcutaneous pacemakers have two electrodes that are placed on the patient's thorax; these can be placed in one of two ways:
  - In the first method, the positive electrode is placed on the right anterior upper thorax midclavicular area, and the negative electrode is placed on the left anterior thorax, just lateral of the left nipple line
  - In the second, the negative electrode is placed on the left anterior of the chest, and the positive electrode is placed on the left posterior of the chest



- **Permanent pacemaker** electrodes can be placed transvenously or surgically implanted
  - The pulse generator is then surgically placed in the subcutaneous tissue of the anterior thorax
  - Most permanent pacemakers are powered by lithium batteries that last 8–12 years
- A pacemaker that stimulates one chamber of the heart has only one electrode placed
  - **Atrial pacing** has an electrode placed in the right atrium; atrial pacing can be identified on an EKG strip by a pacer spike followed by a P wave; atrial pacing may be used if the SA node is damaged but the rest of the conduction system and ventricles are functioning

  - **Ventricular pacing** may be needed if an AV block is present; the electrode would be placed in the right ventricle; ventricular pacing on an EKG strip would appear as a pacer spike followed by a wide QRS complex; every deflection of the EKG strip may not have a pacer spike

- **Demand pacemakers** stimulate the heart only when the patient's heart rate falls below a rate that is set in the pacemaker generator; when spontaneous ventricular depolarization occurs, the pacemaker is inhibited
- **Dual-chamber pacemakers** pace both the atrium and ventricle
  - These have two leads: one in the right atrium and one in the right ventricle
  - An **AV sequential pacemaker** is an example of a dual-chamber pacemaker
  - When spontaneous atrial depolarization does not occur within a preset interval, the pacemaker fires an impulse to the atrium at a preset rate; the pacemaker is programmed to wait for a period called the **AV interval**, which is similar to the PR interval; if the ventricle does not spontaneously depolarize after this interval, the pacemaker fires an impulse to the ventricle at a preset rate



Key Terms

atrioventricular (AV) node: Located in the right atrium and composed of specialized cells that delay the impulse to the ventricles to allow the atria to contract and the ventricles to fill

AV junction: The AV node and the bundle of His

AV sequential pacemaker: An example of a dual-chamber pacemaker that stimulates the atrium and then the ventricle

bigeminy: A dysrhythmia in which every other beat is a premature ectopic beat

biphasic: Waveforms that are part positive and part negative

bradycardia: A heart rate less than 60 bpm

bundle branch block: An abnormal electrical conduction through the right or left bundle branches

complex: Having several waveforms

conductivity: The ability of cardiac cells to receive electrical impulses and to send impulses to adjacent cells

contractility: The ability of cardiac cells to contract in response to electrical impulses

couplet: Two consecutive premature contractions

delta wave: Slurring or widening of the beginning of the QRS complex caused by preexcitation of the ventricle

demand pacemaker: A pacemaker that discharges only when the heart rate drops below a preset rate

depolarization: The movement of ions across the cell membrane that causes the inside of the cell to become more positive, which usually leads to contraction

dual-chamber pacemaker: A pacemaker that stimulates the atrium and ventricle

dysrhythmia: An abnormal cardiac rhythm

ectopic: An impulse originating from an area other than the SA node

escape: When the sinus node fails to initiate the impulse and another pacemaker site produces the electrical impulse to pace the heart

fine ventricular fibrillation: Ventricular fibrillation with fibrillation waves that are less than 3 mm in height

fixed-rate pacemaker: A pacemaker that discharges at a preset rate regardless of the patient's heart rate

ischemia: A decrease in oxygenated blood supply to an organ or tissue

junctional escape rhythm: A dysrhythmia in which the impulse originates in the AV junction due to failure of the SA node or AV conduction; rhythmic rate of 40–60 bpm

junctional tachycardia: A dysrhythmia in which the impulse originates in the AV junction with a ventricular response greater than 100 bpm

multiformed atrial rhythm: A dysrhythmia that occurs when the impulse originates at various sites, such as the SA node, atria, and AV junction; requires at least three different P waves in the same lead for diagnosis

myocardial infarction: A necrosis of cardiac tissue caused by inadequate blood flow

nonconducted PAC: A premature atrial complex that is not followed by a QRS complex and is therefore blocked or not conducted

PAC: Premature atrial contraction

pacemaker: An artificial generator that delivers an electrical current to the heart to cause depolarization or contraction

pacemaker generator: The power source that contains a battery and controls the pacemaker

paroxysmal: Beginning suddenly and occurring repeatedly

paroxysmal supraventricular tachycardia (PSVT): Supraventricular tachycardia that begins and ends abruptly

polymorphic: Occurring in more than one shape

preexcitation: Term used for rhythms that originate from impulses above the ventricles but travel through an abnormal pathway other than the AV node and bundle of His, leading to impulses that stimulate the ventricles prematurely

premature complex: A beat occurring earlier than the next anticipated beat

pulseless electrical activity: An arrhythmia that shows electrical activity with no palpable pulse

Purkinje fibers: The web of fibers throughout the ventricular myocardium

PVC: Premature ventricular contraction

quadrigeminy: A dysrhythmia in which every fourth beat is a premature ectopic beat

repolarization: The movement of ions through the cell membrane that returns the negative charge to the inside of the cell

run: Three or more sequential ectopic beats; also known as "salvo" or "burst"

sick sinus syndrome: Term used when sinus node dysfunction is present, which is indicated by sinus bradycardia, sinus block, or sinus arrest

sinoatrial (SA) node: The pacemaker of the heart; located in the right atrium; discharges at a rate of 60–100 bpm

sinus bradycardia: A dysrhythmia in which the impulse originates in the SA node followed by a ventricular response with a rate less than 60 bpm

sinus tachycardia: A dysrhythmia in which the impulse originates in the SA node followed by a ventricular response with a rate greater than 100 bpm

supraventricular: Originating from an area above the bundle branches

syncope: An episode of fainting

tachycardia: A heart rate greater than 100 bpm

torsades de pointes: A type of polymorphic ventricular tachycardia that demonstrates a prolonged QT interval; the QRS complex changes width, shape, and amplitude, resembling a spindle around the isoelectric line

trigeminy: A dysrhythmia in which every third beat is a premature ectopic beat

ventricular tachycardia: A dysrhythmia in which the impulse originates in the ventricles with a rate greater than 100 bpm

wandering atrial pacemaker: *See* **multiformed atrial rhythm**

Wolff-Parkinson-White syndrome: Preexcitation syndrome indicated by a wide QRS complex with a slurred upstroke (delta wave)

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ISBN-13: 978-142321862-3
ISBN-10: 142321862-0