Objectives:

By the end of this continuing education module the clinician will be able to:

1. recognize common characteristics of abnormal heart rhythms
2. accurately identify abnormal heart rhythms
3. differentiate between life threatening and non-life threatening EKG

Purpose

The purpose of this continuing education module is to give the clinician a review of EKG interpretation and the recognition of life threatening cardiac arrhythmias.

The basic premise of EKG interpretation lies in the ability to recognize patterns. This is a skill that is developed through practice and variety. In other words, you need to see the same patterns over and over again, but you also need to see variants in the pattern to be able to recognize subtle differences. It is important to review EKG strips in a systematic way and not take any shortcuts as this can lead to missing important details or a life threatening arrhythmia. Then, the key becomes regular practice to maintain the skills that are developed. Once you find yourself in an emergency situation, you will have less than a minute to analyze a heart rhythm and act accordingly. It is important to remember that while the EKG provides a picture of how the heart is doing electrically, it does nothing to tell us how the heart is able to pump blood through the body. Always treat your patient, not the rhythm strip.

The Conduction System and Nodal Pathways

The electrical conduction system of the heart is a system of interconnected structures that allow the passage of electrical impulses through the heart muscle. These electrical impulses are generated in a specific sequence, and are the impulses that generate the wave tracing that comprise the cardiac rhythm strip. This specific sequence gives us the basic foundation by which rhythm strip analysis in conducted.
The **sinoatrial node** (SA) is the primary pacemaker of the heart. The SA node is located in the upper right atrium and beats at a rate of 60-100 beats per minute. The impulses are then directed through the **internodal pathways**. These cells direct the impulses from the SA node to the **AV node** and then conduct them across the muscles of the atrium.

The AV node (or atrioventricular node) comprises a portion of the tissues of the AV junction; which includes some surrounding tissue and the bundle of His. The AV node slows down the conduction process, which results in a slight delay before the electrical impulse reaches the ventricles. The AV node has an intrinsic rate of 40-60 beats per minute.

The **bundle of His** is located at the top of the cardiac wall that separates the ventricles creating the electrical bridge between the atria and the ventricles. Since there are two ventricles, the electrical impulses that cause the contraction must be conveyed to both ventricles. This is where the **bundle branches** come into play. The bundle of His splits into two separate conduction systems, one for each ventricle called the right and left bundle branches. This allows the electrical impulses to be carried to the ventricles at the same time.

The bundle branches end with the Purkinje system. This system has an intrinsic rate of 20-40 beats per minute. This network of fibers transmits electrical impulses through the muscles of the ventricles.

**Depolarization**

The spread of electrical impulses and their conduction across the heart occurs through a process called depolarization. All ions in the body carry an electrical charge. The process of depolarization involves the buildup of ions inside the cell until enough energy is built up to cause the cells to fire a stimulus to the muscle fibers of the heart, which causes the contraction.

As confusing as the terminology may be, a cell in the resting state is polarized, and depolarization occurs at the precise moment of muscle contraction. After depolarization, the muscle cells return to their baseline electrical state and begin the process of recharging all over again. This pattern of depolarization and repolarization is what is seen as wave forms on the EKG.

In reading an EKG there are a few important points to remember:

There can be many views to the electrical system of the heart called leads. A lead measures the changes in voltage or energy between different points of the body.
Leads I, II, and III are bipolar and measure both positive and negative impulses of the heart. This lead also has a ground which minimizes electrical activity from sources other than the heart.

Leads aVR, aVL, and aVF measure positive electrical charges through a single electrode and a reference point having zero activity.

Leads V1 through V6 are unipolar leads consisting of a single positive lead and a negatively charged reference point.

**Components of the EKG Tracing**

An EKG tracing is a series of boxes upon which positive and negative deflections or waves that represent the electrical impulses of the heart are recorded. Each EKG has a baseline or isoelectric line, which represents the absence of electrical activity.

P Wave - the first small upright wave seen on the EKG. This represents contraction of the atrium.

PR interval - The distance between the P wave and the start of the QRS complex. This represents the travel of the electrical impulse between the atrium and the ventricles.

QRS Complex - This image on the EKG tracing is actually made up of three waves. The Q wave is the first negative deflection (below the isoelectric line), the R wave which is the first upward or positive deflection, and the S wave which is the next negative deflection immediately after the R wave. This wave indicates contraction of the ventricles.

ST segment - The portion of the isoelectric line immediately after the S wave and prior to the next positive deflection (T wave). Measures the time between depolarization and repolarization of the ventricles.

T Wave - Rounded upward deflection immediately after the QRS complex. Signifies ventricular repolarization.

QT interval - measured from the start of the QRS complex to the end of the T wave. This measurement represents total activity of the ventricles.

U Wave - small rounded upright wave after the T wave. This wave represents repolarization of the Purkinje fibers of the heart. This wave is most frequently seen in slow heart rhythms.
Determining the Heart Rate

If a rhythm is regular, meaning that the QRS complexes are occurring at the same intervals, then you can quickly determine the heart rate by counting the number of large boxes between the spikes or R waves on the QRS complexes and dividing that number into 300 (the number of large boxes present on a 60 second rhythm strip).

A more accurate method is to measure the number of small boxes between the R waves and divide that number into 1500 to determine the heart rate. If the R to R interval is irregular, the best way to measure the rate is to count the number of R waves in a 6 second strip, including PVC’s and other irregular beats, and multiply by 10.

<table>
<thead>
<tr>
<th>Rate</th>
<th>The bpm is commonly the ventricular rate. If atrial and ventricular rates differ, as in a third-degree block, measure both rates. Normal: 60–100 bpm Slow (bradycardia): &lt;60 bpm Fast (tachycardia): &gt;100 bpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regularity</td>
<td>Measure R-R intervals and P-P intervals. Regular: Consistent intervals Regularly irregular: Repeating pattern Irregular: No pattern</td>
</tr>
<tr>
<td>P Waves</td>
<td>If present: Same in size, shape, position? Does each QRS have a P wave? Normal: Upright (positive) and uniform Inverted: Negative Notched: P’ None: Rhythm is junctional or ventricular.</td>
</tr>
<tr>
<td>PR Interval</td>
<td>Constant: Intervals are the same. Variable: Intervals differ. Normal: 0.12–0.20 sec and constant</td>
</tr>
<tr>
<td>QRS Interval</td>
<td>Normal: 0.06–0.10 sec Wide: &gt;0.10 sec</td>
</tr>
</tbody>
</table>
None: Absent

<table>
<thead>
<tr>
<th>QT Interval</th>
<th>Beginning of QRS to end of T wave</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Variates with HR.</td>
</tr>
<tr>
<td></td>
<td>Normal: Less than half the R-R interval</td>
</tr>
</tbody>
</table>

Dropped beats | Occur in AV blocks. |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Occur in sinus arrest.</td>
</tr>
</tbody>
</table>

Pause | Compensatory: Complete pause following a PAC, PJC, or PVC |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Noncompensatory: Incomplete pause following a PAC, PJC, or PVC</td>
</tr>
</tbody>
</table>

QRS Complex grouping | Bigeminy: Repeating pattern of normal complex followed by a premature complex |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trigeminy: Repeating pattern of 2 normal complexes followed by a premature complex</td>
</tr>
<tr>
<td></td>
<td>Quadrigeminy: Repeating pattern of three normal complexes followed by a premature complex</td>
</tr>
<tr>
<td></td>
<td>Couplets: 2 consecutive premature complexes</td>
</tr>
<tr>
<td></td>
<td>Triplets: 3 consecutive premature complexes</td>
</tr>
</tbody>
</table>

**Sinoatrial Node Arrhythmias**

All sinus rhythms originate at the sinoatrial node. Common characteristics of sinus rhythms include: upright P waves that are similar in appearance, PR intervals of normal duration, and normal QRS complexes provided that no ventricular abnormalities are present.

*Rate:* Normal (60–100 bpm)  
*Rhythm:* Regular  
*P Waves:* Normal (upright and uniform)  
*PR Interval:* Normal (0.12–0.20 sec)  
*QRS:* Normal (0.06–0.10 sec)

**Sinus Bradycardia**

Slow Impulse Discharge From the SA Node
Sinus Tachycardia

More frequent impulse discharge from the SA node than in Normal Sinus Rhythm.

Sinus Arrhythmia

Irregular Discharge from the Sinus Node with an irregular R-R interval.
Rate: Usually normal (60–100 bpm); frequently increases with inspiration and decreases with expiration; may be < 60 bpm

P Waves: Normal (upright and uniform)  PR Interval: Normal (0.12–0.20 sec)  QRS: Normal (0.06–0.10 sec)

Rhythm: Irregular; varies with respiration; difference between shortest R-R and longest R-R intervals is > 0.12 sec

Sinus Arrest or Sinus Pause

The SA node fails to discharge and then resumes.
- Electrical activity resumes either when the SA node resets itself or when a lower latent pacemaker begins to discharge.
- The pause (arrest) time interval is not a multiple of the normal P-P interval.

Rate: Normal to slow; determined by duration and frequency of sinus pause (arrest)

P Waves: Normal (upright and uniform) except in areas of pause (arrest)

Rhythm: Irregular whenever a pause (arrest) occurs

PR Interval: Normal (0.12–0.20 sec)  QRS: Normal (0.06–0.10 sec)

SinoAtrial (SA) Block

The block results in a dropped beat that is a multiple of the P-P interval, after the dropped beat, the rhythm continues regularly.

Rate: Normal to slow; determined by duration and frequency of SA block

P Waves: Normal (upright and uniform) except in areas of dropped beats

Rhythm: Irregular whenever an SA block occurs

PR Interval: Normal (0.12–0.20 sec)  QRS: Normal (0.06–0.10 sec)
Atrial Arrhythmias

Common EKG Features:

P waves with a differing appearance from sinus P waves
normal-duration QRS complexes if no ventricular conduction disturbances are present

Wandering Pacemaker

Pacemaker sites transfer from the SA Node to other sites in the atrium and the AV junction and back to the SA Node.

Rate: Normal (60–100 bpm)  Rhythm: Irregular
P Waves: At least three different  PR Interval: Variable; determined
forms, determined by focus in atria by focus  QRS: Normal
(0.06–0.10 sec)

Preamature Atrial Contraction (PAC’S)

The atrial impulse fires earlier than expected; afterwards normal sinus rhythm usually continues.
Rate: Depends on rate of underlying rhythm  
Rhythm: Irregular whenever a PAC occurs  
**P Waves:** Present; in the PAC,  
**PR Interval:** Varies in the PAC; otherwise normal  
may have a different shape  
**QRS:** Normal (0.06–0.10 sec)

**Atrial Tachycardia**

The SA node impulse is overridden by the more rapid atrial rate. Abnormalities of the ST wave and the T wave may be seen.

**SUPRAVENTRICULAR TACHYCARDIA (SVT)**

P waves may not be discernable due to the extremely rapid rate

**PAROXYSMAL SUPRAVENTRICULAR TACHYCARDIA (PSVT)**
PSVT is a rapid rhythm that starts and stops suddenly.
• For accurate interpretation, the beginning or end of the PSVT must be seen.
• PSVT is sometimes called paroxysmal atrial tachycardia (PAT).

**Rate:** 150–250 bpm  **Rhythm:** Irregular  
**P Waves:** Frequently buried in preceding T waves and difficult to see  
**PR Interval:** Usually not possible to measure  
**QRS:** Normal (0.06–0.10 sec) but may be wide if abnormally conducted through ventricles

**ATRIAL FLUTTER**

• The AV node conducts impulses to the ventricles at a 2:1, 3:1, 4:1, or greater ratio (rarely 1:1).  
• The degree of AV block may be consistent or variable.

**Rate:** Atrial: 250–350 bpm; ventricular: variable.  
**Rhythm:** Atrial: regular; ventricular: variable  
**P Waves:** Flutter waves have a saw-toothed appearance; some may not be visible, being buried in the QRS  
**PR Interval:** Variable  
**QRS:** Usually normal (0.06–0.10 sec), but may appear widened if flutter waves are buried in QRS

**ATRIAL FIBRILLATION**
Rapid, erratic electrical discharge comes from multiple atrial ectopic foci.  
No organized atrial depolarization are detectable.
WOLFF-PARKINSON-WHITE (WPW) SYNDROME
An accessory conduction pathway is present between the atria and the ventricles, with rapid conduction of electrical impulses to the ventricles. These rapid impulses create a slurring of the initial portion of the QRS; the slurred effect is called a delta wave.

Junctional Rhythms
The AV node can act as a backup pacemaker in the event of failure of the SA node. The internodal pathways conjoin with the cells of the AV junction. EKG features that are common to all junctional rhythms include: lack of P waves, or P waves that are inverted or buried within the QRS complexes, or that come after the QRS complex. The PR interval can be absent, short, or retrograde.

Junctional Rhythm
ACCELERATED JUNCTIONAL RHYTHM

Rate: 61–100 bpm
P Waves: Absent, inverted, buried, or retrograde
PR Interval: None, short, or retrograde
QRS: Normal (0.06–0.10 sec)

JUNCTIONAL TACHYCARDIA

Rate: 101–180 bpm
P Waves: Absent, inverted, buried, or retrograde
PR Interval: None, short, or retrograde
QRS: Normal (0.06–0.10 sec)
JUNCTIONAL ESCAPE

**Rate:** Depends on rate of underlying rhythm  
**Rhythm:** Irregular whenever an escape beat occurs  
**P Waves:** None, inverted, buried, or retrograde in the escape beat  
**PR Interval:** None, short, or retrograde  
**QRS:** Normal (0.06–0.10 sec)

PREMATURE JUNCTIONAL CONTRACTION (PJC)

**Rate:** Depends on rate of underlying rhythm  
**Rhythm:** Irregular whenever a PJC occurs  
**P Waves:** Absent, inverted, buried, or retrograde in the PJC  
**PR Interval:** None, short, or retrograde  
**QRS:** Normal (0.06–0.10 sec)

Ventricular Arrhythmias

When a rhythm arises from the ventricles, the ventricles conduct impulses slowly causing a QRS complex that is wide and longer than 0.10 sec in duration. P waves are either absent or disassociated from the QRS complex.

IDIOVENTRICULAR RHYTHM
Rate: 20–40 bpm  
**Rhythm:** Regular  
**P Waves:** None  
**PR Interval:** None  
**QRS:** Wide (>0.10 sec), bizarre appearance

**ACCELERATED IDIOVENTRICULAR RHYTHM**

Rate: 41–100 bpm  
**Rhythm:** Regular  
**P Waves:** None  
**PR Interval:** None  
**QRS:** Wide (>0.10 sec), bizarre appearance

**PREMATURE VENTRICULAR CONTRACTION (PVC)**

PVCs result from an irritable ventricular focus. PVCs may be uniform (same form) or multiform (different forms). Usually a PVC is followed by a full compensatory pause because the sinus node timing is not interrupted. Normally the sinus rate produces the next sinus impulse on time. In contrast, a PVC may be followed by a noncompensatory pause if the PVC enters the sinus node and resets its timing; this enables the following sinus P wave to appear earlier than expected.
**PREMATURE VENTRICULAR CONTRACTION: UNIFORM**

![Image of a uniform premature ventricular contraction ECG trace.]

**PREMATURE VENTRICULAR CONTRACTION: MULTIFORM**

![Image of a multiform premature ventricular contraction ECG trace.]

**PREMATURE VENTRICULAR CONTRACTION: VENTRICULAR BIGEMINY**

- In ventricular bigeminy, the PVC occurs with every other beat.

![Image of a ventricular bigeminy ECG trace.]

---

**Rate:** Depends on rate of underlying rhythm  
**Rhythm:** Irregular whenever a PVC occurs  
**P Waves:** None associated with the PVC  
**PR Interval:** None associated with the PVC  
**QRS:** Wide (≥0.10 sec), bizarre appearance
PREMATURE VENTRICULAR CONTRACTION: VENTRICULAR TRIGEMINY
In ventricular trigeminy, the PVC occurs with every third beat.

PREMATURE VENTRICULAR CONTRACTION: VENTRICULAR QUADRIGEMINY
In ventricular quadrigeminy, the PVC occurs with every fourth beat.

PREMATURE VENTRICULAR CONTRACTION: COUPLETS
- In a rhythm with PVC couplets, the PVCs occur in pairs.
PREMATURE VENTRICULAR CONTRACTION: R ON T PHENOMENON
The PVCs occur so early that they fall on the T wave of the preceding beat. These PVCs occur during the refractory period of the ventricles, a vulnerable period because the cardiac cells have not fully repolarized.

Rate: Depends on rate of underlying rhythm
Rhythm: Irregular whenever a PVC occurs
P Waves: None associated with the PVC
PR Interval: None associated with the PVC
QRS: Wide (>0.10 sec), bizarre appearance

PREMATURE CONTRACTION: INTERPOLATED PVC
The PVC occurs between two regular complexes; it may appear sandwiched in between two normal beats. An interpolated PVC does not interfere with the normal cardiac cycle.

Rate: Depends on rate of underlying rhythm
Rhythm: Irregular whenever a PVC occurs
P Waves: None associated with the PVC
PR Interval: None associated with the PVC
QRS: Wide (>0.10 sec), bizarre appearance

VENTRICULAR TACHYCARDIA (VT): MONOMORPHIC
In monomorphic VT, QRS complexes have the same shape and amplitude

It is important to confirm the presence or absence of pulses because monomorphic VT may be perfusing or nonperfusing.

Monomorphic VT will probably deteriorate into VF or unstable VT if sustained and not treated
Rate: 100–250 bpm  Rhythm: Regular  
P Waves: None or not associated  PR Interval: None  
QRS: Wide (~0.10 sec), bizarre appearance

VENTRICULAR TACHYCARDIA (VT): POLYMORPHIC
In polymorphic VT, QRS complexes vary in shape and amplitude. The QT interval is normal or long.

Rate: 100–250 bpm  Rhythm: Regular or irregular  
P Waves: None or not associated  PR Interval: None  
QRS: Wide (~0.10 sec), bizarre appearance

TORSADE DE POINTES
The QRS reverses polarity and the strip shows a spindle effect. This rhythm is an unusual variant of polymorphic VT with long QT intervals. In French the term means twisting of points.
VENTRICULAR FIBRILLATION (VF)

Chaotic electrical activity occurs with no ventricular depolarization or contraction. The amplitude and frequency of the fibrillatory activity can be used to define the type of fibrillation as coarse, medium, or fine. Small baseline undulations are considered fine; large ones are coarse.

PULSELESS ELECTRICAL ACTIVITY (PEA)

The monitor shows an identifiable electrical rhythm, but no pulse is detected. The rhythm may be sinus, atrial, junctional, or ventricular. PEA is also called electromechanical dissociation (EMD).

ASYSTOLE
FIRST-DEGREE AV BLOCK

Rate: None
Rhythm: None
P Waves: None
PR Interval: None
QRS: None

SECOND-DEGREE AV BLOCK: TYPE I (MOBITZ I OR WENCKEBACH)

PR intervals become progressively longer until one P wave is totally blocked and produces no QRS complex.
After a pause, during which the AV node recovers, this cycle is repeated.
**Rate:** Depends on rate of underlying rhythm  
**Rhythm:** Atrial: regular; ventricular: irregular

**P Waves:** Normal (upright and uniform), more P waves than QRS  
**PR Interval:** Progressively longer until one P wave is blocked and a QRS is dropped  
**QRS:** Normal (0.06–0.10 sec)

---

**SECOND-DEGREE AV BLOCK: TYPE II (MOBITZ II)**

Conduction ratio (P waves to QRS complexes) is commonly 2:1, 3:1, 4:1, or variable. QRS complexes are usually wide because this block usually involves both bundle branches.

---

**Rate:** Atrial: usually 60–100 bpm; ventricular: Rhythm: Atrial regular and ventricular may be slower than atrial rate regular or irregular

**P Waves:** Normal (upright and uniform); more P waves than QRSs

**PR Interval:** Normal or prolonged but constant

**QRS:** May be normal, but usually wide (0.10 sec) if the bundle branches are involved

---

**THIRD-DEGREE AV BLOCK**

Conduction between the atria and the ventricles is totally absent because of complete electrical block at or below the AV node. This is known as AV dissociation. Complete heart block is another name for this rhythm.

---

**Rate:** Atrial: 60–100 bpm; ventricular: 40–60 bpm if escape focus is junctional, <40 bpm if escape focus is ventricular
**Rhythm:** Usually regular, but atria and ventricles act independently

**P Waves:** Normal (upright and uniform); may be superimposed on QRS complexes or T waves

**PR Interval:** Varies greatly

**QRS:** Normal if ventricles are activated by junctional escape focus; wide if escape focus is Ventricular

**BUNDLE BRANCH BLOCK (BBB)**

Either the left or the right ventricle may depolarize late, creating a “wide” or “notched” QRS complex.

**Rate:** Depends on rate of underlying rhythm

**P Waves:** Normal (upright and uniform) with or without a notched appearance

**PR Interval:** Normal (0.12–0.20 sec)

**QRS:** Wide (_0.10 sec)