1.5: Rhythm Interpretation

Each EKG rhythm has “rules” that differentiate one rhythm from another. Rules for each rhythm include parameters for measurements like rate, rhythm, PR interval length, and ratio of P waves to QRS complexes. Today we will focus only on lead II. Each "lead" takes a different look at the heart. Because the heart is a 3 dimensional figure and electricity flows through numerous structures, multiple leads are helpful and even necessary in some instances. This segment will focus on lead II. As a reminder, lead II looks like this, anatomically:

Figure \(\PageIndex{1}\): Image 1, Lead 2

Remember the normal flow of electricity in a heart in a normal sinus rhythm:
Electricity first flows in a down-leftward fashion, from the SA node to the AV node. This is the P wave. This is a positive inflection on the EKG graph because the electricity is flowing toward the positive electrode on the EKG and away from the negative. The QRS complex is similar - the electricity flows from the AV node down the bundle of His (and to the ventricle tissue immediately adjacent to the AV node - accounting for the negative inflection of the Q wave), which registers as a large positive wave as electricity is flowing toward the positive electrode. The electricity eventually reaches the purkinje fibers and begins to travel back upward to the remainder of the ventricles, which is away from the positive electrode and toward the negative one, resulting in a negative S wave. The T wave then represents repolarization, which usually happens in approximately the order of the R wave (i.e. in a top-down fashion) and is normally a positive wave, as the repolarization flows toward the positive electrode and away from the negative.

While lead II interpretation is generally grasp-able without fully understanding how a positive or negative electrode effects the EKG, it is important to understand this concept as we will eventually start learning to interpret EKGs in many other leads. Understanding why the waves on the EKG are positive or negative and what that means will help you understand what each wave means, how they differ in both normal and abnormal rhythms, and help you interpret more complex rhythms that require more than one lead in the future.

**Lead II Rhythms and Rules**

This section will focus entirely upon interpreting rhythms in lead II. Each rhythm has a set of "rules" that helps you determine what the rhythm is. It is always important to look at your PATIENT and not your MONITOR when assessing.
Rhythms can easily be misinterpreted due to patient factors like artifact, poorly attached or misplaced leads, and many other factors, and it is important to verify both the veracity of the EKG reading and the patient’s condition before making a clinical decision based on the patient’s EKG.

The visual diagram used to display the rules for each type of rhythm will differ somewhat from the one used in the previous chapter, however the content is largely the same.

### Normal Sinus Rhythm Rules

<table>
<thead>
<tr>
<th>Rate:</th>
<th>60-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhythm:</td>
<td>Regular</td>
</tr>
<tr>
<td>P wave:</td>
<td>Upright Inverted Biphasic</td>
</tr>
<tr>
<td>P wave to QRS complex ratio:</td>
<td>1:1</td>
</tr>
<tr>
<td>PR Interval:</td>
<td>0.12 to 0.2 sec</td>
</tr>
<tr>
<td>QRS:</td>
<td>0.12 sec or less</td>
</tr>
</tbody>
</table>

1 P wave for every QRS; 1 QRS for every P wave

Normal PR Interval (PRI) (0.12-0.2 sec), normal QRS (<0.12 sec)

Rates:
- 60-100 = normal sinus rhythm
- >100 = sinus tachycardia
- <60 = sinus bradycardia

Rhythm: Regular, except in:

Sinus arrhythmia: Follows sinus rhythm rules except: Mild fairly gradual increases and decreases in QRS spacing, usually follows pattern of patient’s breathing. Example (sinus arrhythmia):

![Figure 3, Normal Sinus Rhythm Rules](https://med.libretexts.org/Bookshelves/Nursing/An_EKG_Interpretation_Primer_(Christianson_et_al.)/01%3A_Chapters/1.05...Updated: Sun, 11 Sep 2022 00:37:15 GMT)
An atrial pacemaker refers to any rhythm in which an area above the AV node but NOT the SA node is the pacemaker for the heart. This usually presents as notched, sometimes inverted, or unusual looking non-rounded P waves, but has a normal PRI.

Multiple P waves for every QRS; saw tooth-like appearance of P waves, which are called “flutter” or F waves in this specific rhythm only

No measurable PRI; QRS normal lengths

Rate: Can be regular or irregular, usually about normal rate of 60-100 but not necessarily

Rhythm: Can be regular or irregular
Example: Atrial flutter with regular rhythm, 4:1 conduction rate (4 flutter waves to 1 QRS complex)

![Image 8, Atrial Flutter with Regular Rhythm](image8)

Example: Atrial flutter with irregular rhythm due to variable conduction rate

![Image 9, Atrial Flutter with Irregular Rhythm due to Variable Conduction Rate](image9)

Notice that some of the Flutter waves (similar to P waves, but faster and with a sawtooth shape) are buried under the QRS.

![Image 9, Flutter Waves](image9)

In atrial flutter, the SA node is often working as normal. The rhythm appears abnormally because another part of the heart in the atrium becomes irritable. Irritability, remember, is usually caused by deficiency of oxygen or nutrients, causing the part of the muscle to contract out-of-sync with the rest of the heart as it tries to supply itself with needed nutrients by pumping more. Cardiac muscle tissue is designed to synchronize contraction, so when the irritable part of the atrium starts to contract at a rate faster than the SA node, that portion of the atrium can override the SA node’s electrical impulses and take over as pacemaker for the heart.

The flutter waves (F wave) can vary somewhat in shape depending upon the part of the atrium that is fluttering. A sawtooth appearance is common because electricity flows both in a downward direction toward the positive electrode and upward toward the negative electrode. Additionally, electricity from the atria often flows in a more circumferential manner around the atria, rather that directly through it as it does with normal conduction originating from the SA node. These factors make the F wave look more peaked compared to a normal rounded P wave.

The QRS complex appears normal because the AV node is functioning as normal. The AV node acts as a gatekeeper when the atria take over as pacemaker; it allows some electrical impulses through but not all of them. The rhythm of
QRS complexes with atrial flutter is not always completely regular because the AV node is not entirely designed to be an effective gatekeeper, so it is not always a set ratio of F waves to QRS complex (i.e., 4:1 F wave to QRS ratio as the strip above). The rhythm does, however, have a pattern to its irregularity (if there is irregularity), making it regularly irregular.

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**Atrial Fibrillation Rules**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate:</td>
<td><code>&lt;100 - controlled, &gt;100 - uncontrolled</code></td>
</tr>
<tr>
<td>Rhythm:</td>
<td><strong>Irregularly Irregular</strong></td>
</tr>
<tr>
<td>P wave:</td>
<td><em>Upright Inverted</em></td>
</tr>
<tr>
<td>P wave to QRS complex ratio:</td>
<td><em>No P waves</em></td>
</tr>
<tr>
<td>PR Interval:</td>
<td><em>None</em></td>
</tr>
<tr>
<td>QRS:</td>
<td><em>Usually &lt;0.12 sec</em></td>
</tr>
</tbody>
</table>

Figure \(\PageIndex{10}\): Image 10, Atrial Fibrillation Rules

No discernible P waves; PRI not measurable, QRS usually normal length

Rate: Variable. Rates <100 are referred to as “controlled,” rates >100 are referred to as “uncontrolled”

Rhythm: Irregularly irregular; no pattern to irregularity. **This is the only irregularly irregular rhythm**

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Atrial fibrillation is similar in physiology to atrial flutter. The major difference is that in atrial fibrillation there are multiple irritable sites on the atria, where there is typically only one in atrial flutter.

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The atria are functionally “quivering” because multiple atrial sites are irritable and trying to fire out-of-sync with the rest of the heart or the SA node. The SA node, if it is functioning at all, is overridden as pacemaker. The AV node does allow
some of the impulses through, but due to the irregularity of the unsynchronized atrial depolarizations, the AV node does not always allow impulses through at a regular interval. The bundle of His and purkinje fibers are functioning normally, so the QRS complex and often the T waves look normal in this rhythm despite the disorganized activity. The AV node is functionally acting as a gatekeeper, allowing the ventricles to pump effectively despite the dysfunction occurring in the atria.

Atrial fibrillation is the only consistently irregularly irregular rhythm, meaning it has no pattern to its irregularity. If you find a rhythm that is irregularly irregular, it is usually atrial fibrillation.

Both atrial fibrillation and atrial flutter decrease cardiac output. Anatomically, this is because the atria are not pumping optimally. With atrial flutter, the atria are rapidly contracting; while the contractions of the atria may be effective, the atria are not refilling between contractions, which limits their efficacy. All chambers of the heart do need time to re-fill before pumping again to maximize the pump’s efficacy - a concept that will be revisited when you have CPR or BLS training/recertification. In atrial fibrillation, the atria are not contracting together in a coordinated manner, so the pump itself is not effective. While the atria are not responsible for pumping blood to the peripheral circulatory system, the atria are responsible for receiving blood from the periphery and priming the ventricles by mechanically filling them. The ventricles do still work without priming, and they will continue to pump blood to the periphery, but they will not do so as effectively as they will with the extra fill-up from the atria.

Figure \(\PageIndex{13}\): Image 13, Pumping Ventricles

Both atrial fibrillation and atrial flutter make a patient more predisposed to thrombosis (primarily pulmonary emboli), because blood that is not being actively pumped fairly continuously starts to coagulate (clot) if it is allowed to stay stationary for long enough. Ineffective pumps allow blood to become stationary in the chamber of the heart, which starts the coagulation process.
The primary distinguishing characteristic of supraventricular tachycardias (SVT) is a rate >160 with a normal QRS complex.

SVT happens when an area of the heart above the AV node begins to beat rapidly and the AV node allows most or all impulses through. There are some other unique circumstances, such as abnormal electrical pathways that bypass the AV node, that can also cause SVT. This type of anomaly will be discussed in a later chapter.
Junctional Rhythms

Same rules as sinus rhythms, EXCEPT:

PR interval <0.12

P wave may be inverted, biphasic (goes both above and below the baseline), absent entirely, or occur after the QRS complex:

Note about junctional rhythms: Cardiology may label as “accelerated junctional” or “junctional tachycardia”; focus primarily on identifying as junctional and the heart rate, don’t worry about labeling it further at this point. Each originating node (ie: the SA node, AV node/junction, and ventricles) have a “rate;” the true definition of tachycardia is dependent upon the rate of the originating node. The normal rate of the AV node/junction is 40-60, so a rate of 60 or greater is technically considered to be “junctional tachycardia” even though the rate is less than 100. This concept will also be true when we discuss ventricular rhythms.

Junctional rhythms and premature junctional contractions originate from the AV node or the AV junction. The P wave in this case is inverted. The P wave is inverted because, instead of electricity flowing from the SA node downward toward the AV node (and toward the positive electrode in lead II), the electricity is originating in the AV node and flowing upward toward the negative electrode.

The PRI is short because, instead of the AV node receiving the electricity that originated elsewhere (and holding it for a

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fraction of a second, as the AV node normally does), the electricity is originating from the AV node, resulting in a minimized or absent pause (depending on what part of the AV node has taken over as the heart’s pacemaker in place of the SA node). This is also why the P wave is sometimes absent in junctional rhythms; the P and QRS complex sometimes occur simultaneously, or the P can even take place after the QRS complex depending upon the specific location in the AV junction that has taken over as the dominant pacemaker.

The QRS complex is normal in appearance compared to a normal sinus rhythm because the bundle of His and purkinje fibers are behaving normally.

**AV Blocks**

AV blocks are what happen when the AV node is not functioning correctly or when the AV node and bundle of His are not communicating correctly. An AV block is an add-on to an underlying rhythm, ie: you don’t have a 1st degree block, you have a sinus rhythm with a 1st degree block.

**1st Degree AV Block**

PR interval >0.20 every time
Rhythm otherwise identical to underlying rhythm

A first degree block is usually a minor dysfunction of the AV node. A sinus rhythm with a first degree AV block is one of the most common arrhythmias and is sometimes considered a normal variant, particularly among athletes and young adults. Most patients with a first degree AV block have no symptoms.

**2nd Degree Block – Type I**

More P waves than QRS complexes: PR interval elongates over several beats, QRS complex is eventually dropped, then PR interval resets to baseline.

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Also referred to as Wenkebach or Mobitz I.

In a 2nd degree type I block, the AV node is similarly malfunctioning. This time, the AV node is holding the impulse received from the SA node for an increasingly prolonged duration, until eventually it drops the impulse entirely for one beat. Then the cycle usually repeats, starting at a normal or nearly-normal PR interval, increasing over the process of one or more depolarizations, then dropping. When the depolarizations are allowed through, the QRS complex is normal in appearance because the bundle of His and purkinje fibers are functioning normally.

2nd Degree Block – Type II

More P waves than QRS complexes; QRS complexes occasionally dropped from P waves. PRI may or may not be >0.20 seconds.

Rate of dropped QRS complexes can be regular (ex: 2:1 ratio with every other P wave generating a QRS complex) or variable (QRS complexes are dropped at random)

Also referred to as Mobitz II

You differentiate this rhythm from Wenckebach (Mobitz I) because the PR interval do not get longer in preceding beats before the beat drops.
degree type II block that only allows every other QRS complex through, like this:

Figure \(\PageIndex{21}\): Image 21, 2nd Degree Block Type 2

Or you can have 2nd degree type II blocks that do not have a particular pattern to the dropped QRS complexes, like this:

Figure \(\PageIndex{22}\): Image 22, 2nd Degree Block Type 2 Without Pattern

## 3rd Degree Block

P waves all march out, QRS complexes all march out; no association between rhythm of P waves and QRS complexes.

Note: P waves do sometimes get “lost” in QRS complexes; they’re still there, they’re just not visible when they happen at the same time a QRS is occurring.

QRS complexes may be narrow or wide, wide usually indicates electrical impulse is coming from the ventricles where narrow usually indicates electricity is originating from the lower AV node or upper portion of the bundle of His (as this indicates the electricity in the ventricles is flowing semi-normally in a top-to-bottom fashion).

Also referred to as a complete heart block.

**These patients usually require emergent intervention**

Third degree block is a complete dysfunction of the AV node. Remember that the AV node is the gatekeeper and the only route between the atria and ventricles. The AV node stops transmitting any impulses, functionally cutting off communication between the atria and ventricles. The SA node, atria, and ventricles are all are still functional, but they are unable to communicate and work in synchrony.
The SA node is usually functioning normally with a 3rd degree block. The AV node, which normally functions as the gatekeeper between the atria and the ventricles, is not transmitting any electricity between the two. As a result, the ventricles are not stimulated to depolarize. The ventricles become irritable, and one or more areas of the ventricles will start to depolarize and take over as the pacemaker for the ventricles.

When a ventricle takes over as their own pacemaker (because they are not receiving their usual impulses through the AV node), the QRS complexes are wide (>0.12 sec) and bizarre looking compared to a normal QRS complex. This is because the bundle of His and Purkinje fibers, which is normally somewhat insulated and transfers electricity faster than the ventricles themselves, are usually not transmitting because they are not receiving electricity from the AV node. The slower transmission and the change in direction of electrical flow both prolongs the QRS complex (making it wider) and changes the shape of the QRS complex (making it look bizarre).

Of note in the particular strip above is the easy visibility of a P wave buried in the first visible QRS complex. Compare the QRS complex to the other 2 QRS complexes and note the extra bump upward toward the end of the first QRS complex - this is your P wave that is “buried.” Some QRS complexes completely bury a P wave rendering it completely invisible, but this particular strip is a good example of a buried-yet-visible P wave that occurred at the same time as a QRS complex. For a better view, compare the red circled area of the QRS complex to the next QRS complex - the upward inflection in the second half of the complex that is not seen in the other complexes is the P wave. While it is impossible to know with 100% certainty when a P wave is buried in a QRS complex, you can often make an educated guess on where the P wave should be based on the rhythm of the surrounding P waves.

**Ventricular Rhythms**

None of the above rhythms discussed thus far have significantly affected the ventricles or caused dysfunction of the ventricular electrical conduction system. The AV node often acts as a gatekeeper or barrier, which means that atrial and junctional arrhythmias often do not cause changes to the QRS complex. This is a helpful fail-safe system for the heart, as the ventricles are responsible for circulation to the lungs and periphery (and dysfunction of ventricular conduction therefore can be far more catastrophic to patient health). The next set of arrhythmias will sometimes affect the ventricles or even be caused by the ventricles. Many (but not all) of the following arrhythmias are life-threatening and require urgent or emergent intervention.
Ventricular rhythms can occur under several circumstances. Sometimes the ventricles take over as pacemaker because all other pacemaker sites have failed. Other times, the ventricles become so irritable they begin to depolarize faster than all of the other nodes and therefore take over as pacemaker, even though the other nodes may be functioning.

A ventricular escape rhythm typically occurs when both the SA and AV nodes have failed, so there is no transfer of electricity from the atria to the ventricles; this forces the ventricles to take over as pacemaker. In a ventricular escape rhythm, the rate is typically 20-40 BPM, there are no P waves, and the QRS complexes are wide and bizarre:
In an accelerated ventricular rhythm, the irritable ventricular site that has taken over as pacemaker is contracting at a rate >40, but is not a true ventricular tachycardia. The physiology of this rhythm is similar, but is accelerated due to increased irritability of the pacemaker site:

Ventricular tachycardia is essentially the ventricular version of atrial flutter. With ventricular tachycardia the irritable ventricular site has taken over as pacemaker by depolarizing rapidly. Ventricular tachycardia is not always an indicator that the SA and AV nodes have failed, as is usually the case with ventricular escape and accelerated ventricular rhythms; instead the ventricle has taken over as pacemaker by depolarizing at a rate faster than the SA node.

Ventricular tachycardia is sometimes pulseless, but not always. If you see or suspect ventricular tachycardia, it is important to check a pulse before intervening.

A patient can also have “runs” of ventricular tachycardia. A run of ventricular tachycardia refers to a rhythm that converts from the underlying rhythm to ventricular tachycardia for >4 QRS complexes, then reverts to the underlying rhythm. The reversion is important; it is not a “run” of ventricular tachycardia if it never converts back out of ventricular tachycardia.

Ventricular tachycardia can also have variable QRS morphology, as in this example of a specific type of v tach called Torsades de Pointes (“turning of the points”):
Ventricular fibrillation is a rhythm in which the ventricles are quivering. There will be no true discernible waves or QRS complexes. This is universally a life-threatening rhythm that requires both high quality CPR and defibrillation.

Ventricular fibrillation is a lethal arrhythmia if it is not corrected via electricity and CPR. It is sometimes correctable via electricity because defibrillating the patient emulates the depolarization process in the entire heart all at the same time. The cells must all repolarize before depolarizing again, which gives the cells in the SA node a chance to become the pacemaker for the heart again while the ventricles are repolarizing and unable to spontaneously depolarize.
Ventricular fibrillation can be classified as “coarse” or “fine.” This distinction is somewhat helpful because coarse VF has higher amplitudes and, therefore, larger amounts of electrical activity compared to fine VF. A patient in VF is undergoing cardiopulmonary resuscitation, so it can be helpful to differentiate coarse vs fine VF if termination of resuscitation efforts is a consideration.

Fine VF and asystole with external artifact can be difficult to distinguish from one another. It is important to have all hands off the patient while the rhythm is being interpreted so the interpretation can be made without mistaking artifact for fine VF. Movement from external sources, such as compressions or performing other interventions while rhythm is being interpreted, can cause artifact. **While CPR interruptions do need to be minimized to improve the likelihood of resuscitation, distinguishing fine VF from asystole does impact clinical decision making**

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**Agonal/Asystole**

- **Rate:** N/A
- **Rhythm:** N/A
- **P wave:** Usually absent
- **P wave to QRS complex ratio:** N/A
- **PR Interval:** N/A
- **QRS:** None

**"Flat line"**

- **P wave, no QRS complexes**

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Asystole is an absence of electrical activity in the heart. An agonal rhythm is similar, but occasionally has present P waves. Asystole and agonal rhythms are distinguished by absence of any kind of QRS complex.

**Premature Contractions**

Premature contractions, whether they come from the atria, junction, or ventricles, are caused by irritability. Premature contractions are not a rhythm by themselves, they are additional beats within an underlying rhythm. An underlying sinus rhythm with a PVC should be labeled with both interpretations.

**Premature Atrial Contraction**

Looks morphologically like a sinus or atrial beat, but is out-of-place with regards to rhythm. P wave may look different from the others but will still be upright and present and have a normal PR interval:

![Image 38, Premature Atrial Contraction](https://med.libretexts.org/Bookshelves/Nursing/An_EKG_Interpretation_Primer_(Christianson_et_al.)/01%3A_Chapters/1.05...

Premature atrial contractions “reset” the heart rhythm, so the rhythm starts up again from the QRS complex of the PAC:

![Image 39, Premature Atrial Contraction](https://med.libretexts.org/Bookshelves/Nursing/An_EKG_Interpretation_Primer_(Christianson_et_al.)/01%3A_Chapters/1.05…)

**Premature Junctional Contraction**

Fairly uncommon; looks similar to a sinus beat, but is out-of-place with regards to rhythm and has an inverted, absent, or biphasic P wave. It may fall after the QRS, between the QRS and the T wave. If it falls before the QRS, it will have a short PR interval similarly to the short PR interval in a junctional rhythm.
Unlike PACs, the underlying rhythm will stay at the same intervals, the PJC will just take the place of an expected beat, as here:

PJC, note it did not interfere with overall pattern of underlying sinus rhythm

PVCs can be unifocal, which means they come from the same part of the ventricle and are similar in appearance, or multifocal, which means they come from different parts of the ventricle and look totally different from one another:

PVC will not reset the underlying rhythm:
To distinguish PACs, PJC, and PVCs, the following flow chart can be used:

1. **Is the QRS wide or narrow?**
   - **Wide**
     - PVC
   - **Narrow**
     - **Does it reset the underlying rhythm to synchronize with the premature beat?**
       - **Yes**
         - PAC
       - **No**
         - PJC