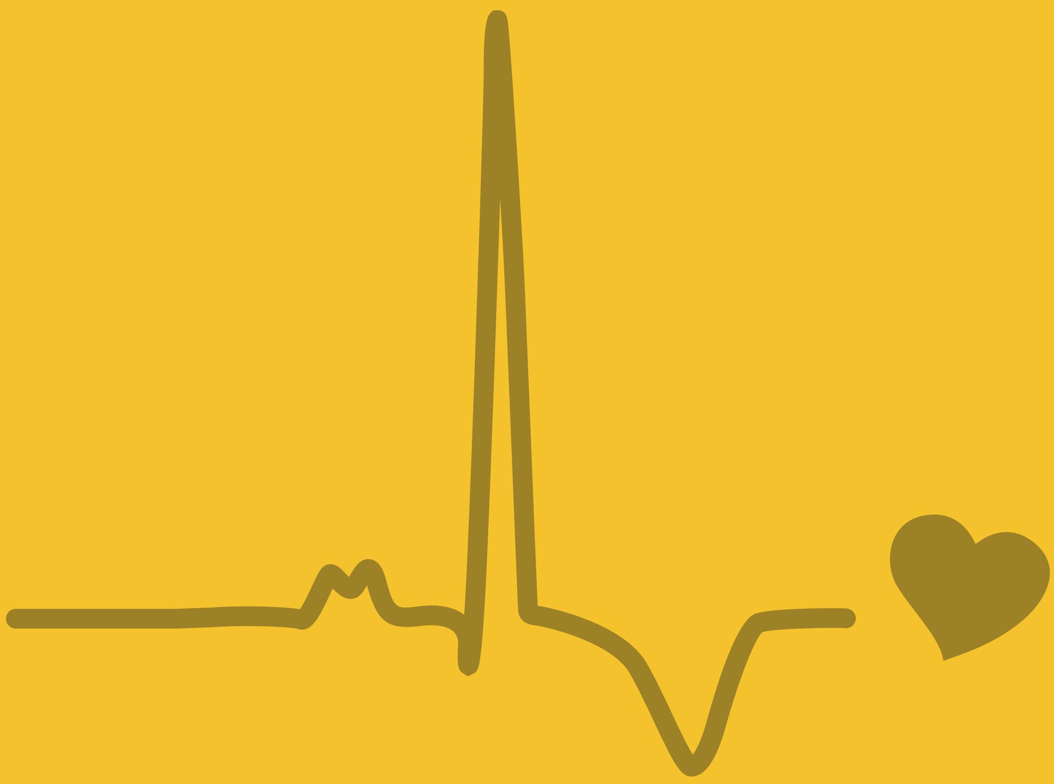
ECG Mastery



YELLOW BELT WORKBOOK

ECG Mastery: Yellow Belt Workbook

by Peter Kühn, MD, Clemens Lang, and Franz Wiesbauer, MD MPH

http://www.medmastery.com

An innovative approach to mastering the ECG

Welcome to the Yellow Belt Workbook, a handy companion to the award-winning ECG Mastery program—brought to you by Medmastery. The ECG Mastery program is an interactive, case-based online course that makes learning the ECG simple, hands-on, and fun. ECG Mastery is open for registration a couple of times per year. If you're not already enrolled, go to **www.medmastery.com** to register for a free training sequence and find out all about the full program.

Just like the ECG Mastery Program, the Yellow Belt Workbook is based on real-life cases that will teach you how to interpret the ECG like a pro. It presents the information visually so that it is clear and immediately understandable. It leaves out the jargon and sticks to the practical information that's really important. And it includes highly effective quizzes based on actual cases. (Solutions to the quizzes, including expert analysis, are available to anyone enrolled in the ECG Mastery online course.)

The Yellow Belt section of the ECG Mastery Program teaches the basics of the ECG language and how to recognize many common and dangerous diseases. With just this training you'll be able to follow a case discussion among your colleagues and begin using the ECG in your daily clinical practice. Enrollees in the online course also get access to the ECG Mastery Blue Belt section, which teaches how to diagnose more than 95 percent of pathologies without the help of a more senior colleague.

With Medmastery as your guide, you have ECG mastery at your fingertips.

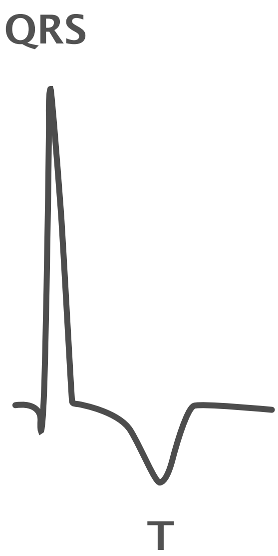
Enjoy the learning!

Contents

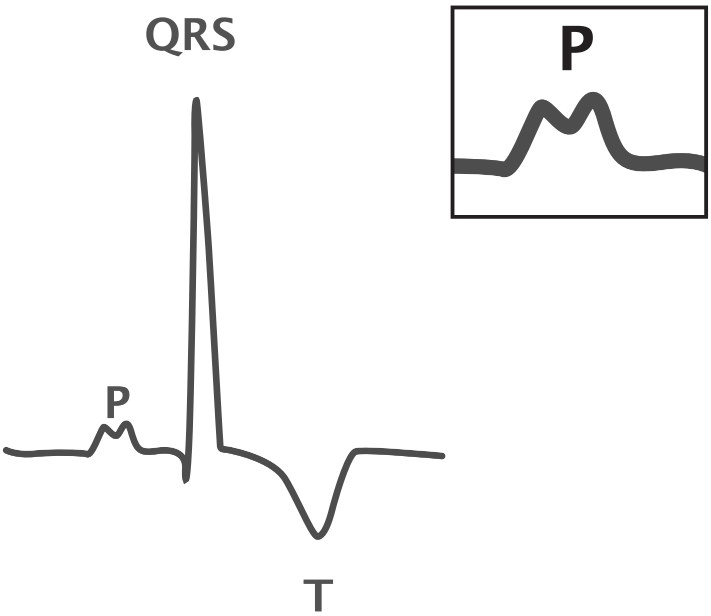
Level 1: Deconstructing the ECG curve—the components of the tracing

In this first chapter, you will learn about the different waves on the ECG and how to recognize them.

Electrical **depolarization of the ventricles** leads to sharp deflections in the ECG called **QRS complexes**. Every depolarization is followed by a phase of repolarization. **Repolarization of the ventricles** is represented by the so-called **T waves**. The T wave can be positive or negative.



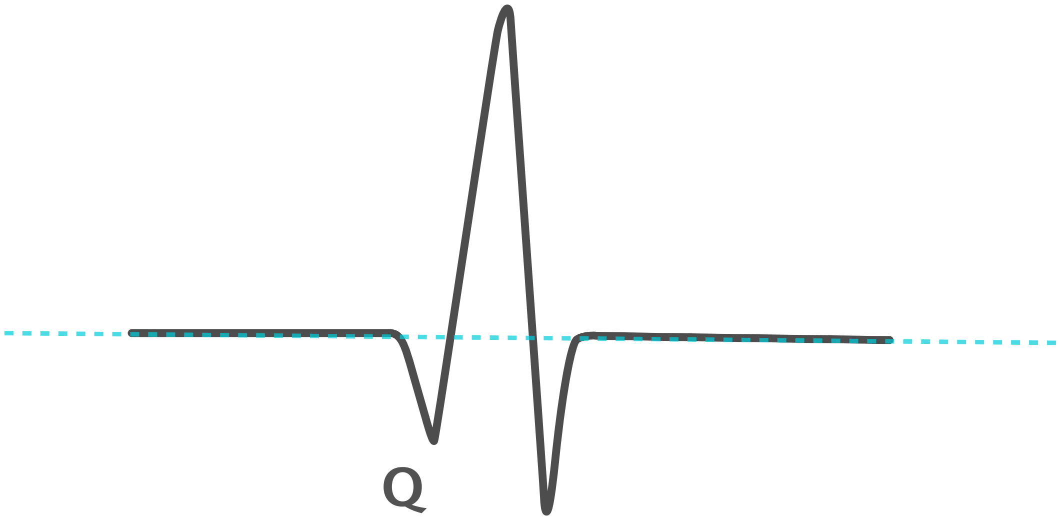
Atrial depolarization is depicted by the **P wave**, which is steeper than the T wave but flatter than the QRS complex. We said that every depolarization is followed by a phase of repolarization. But since atrial repolarization happens at the same time as the QRS complex, it cannot be recognized on the ECG.



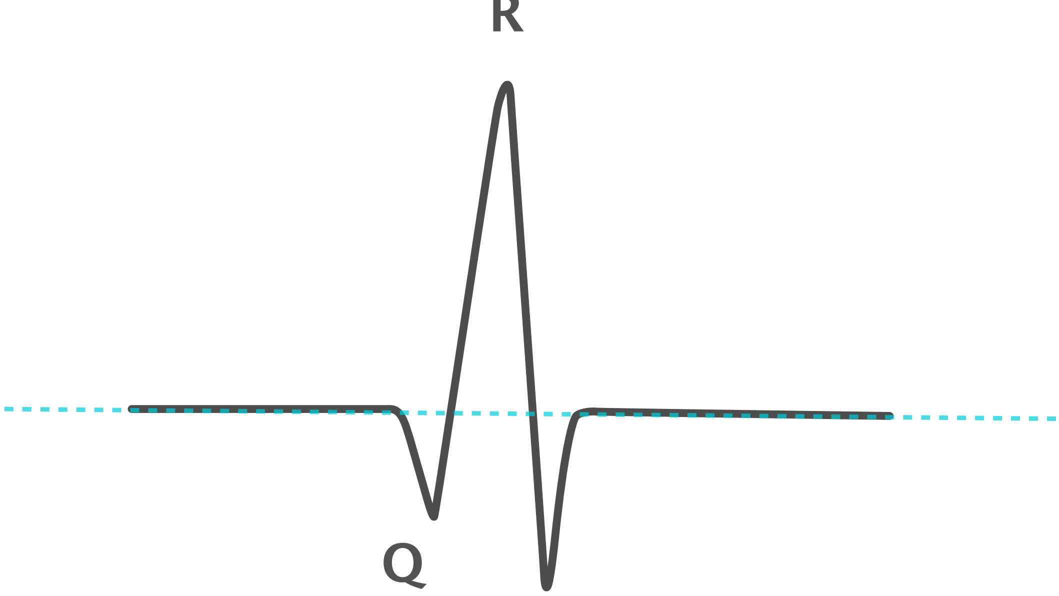
Identifying the components of the QRS complex

There are five concepts that will help you to identify the different components of the QRS complex.

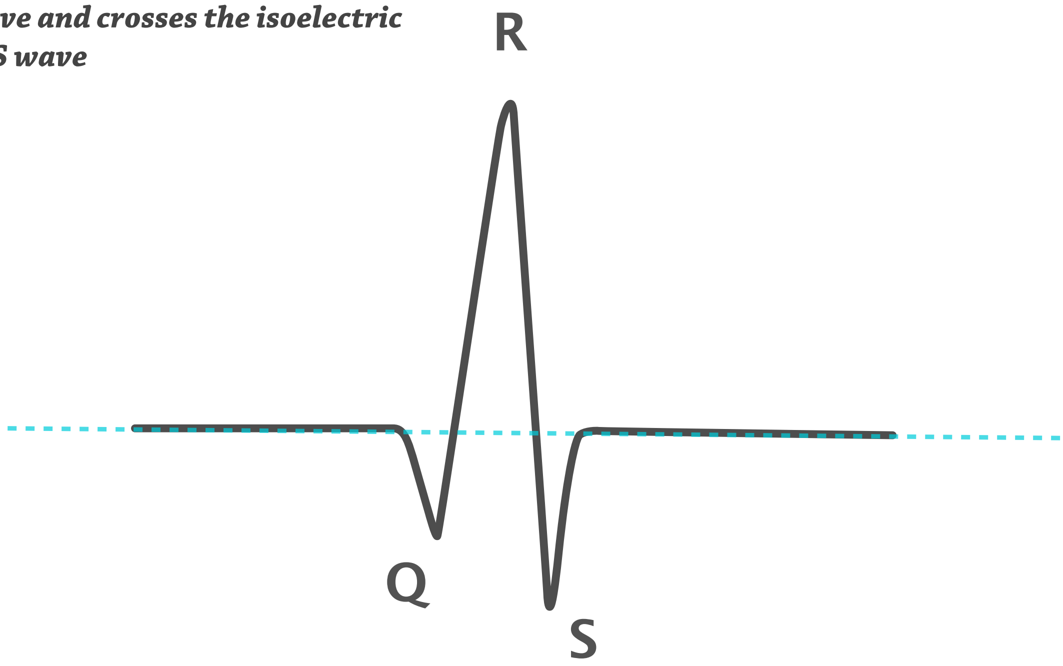
Concept #1:
The first downward deflection is called a Q wave



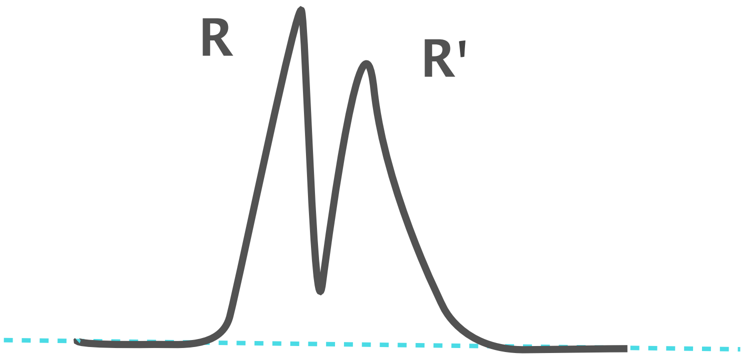
Concept #2:
Any upward deflection is called an R wave

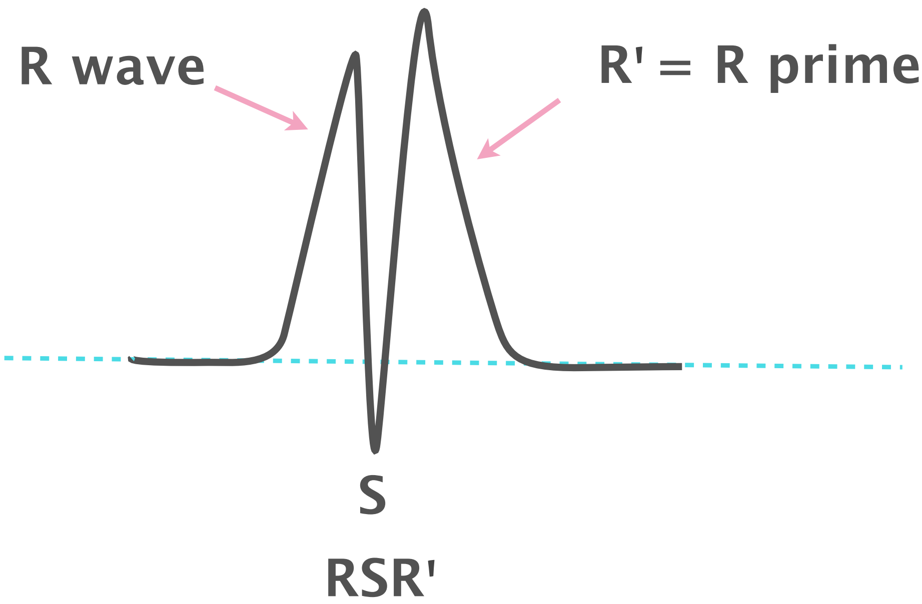


Concept #3:
Any downward deflection that comes after an R wave and crosses the isoelectric line is called S wave

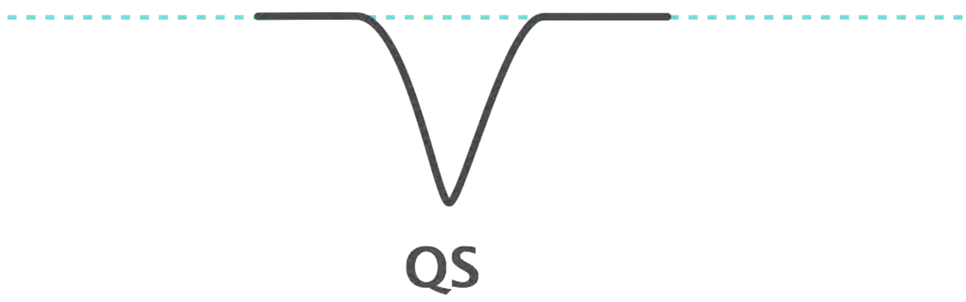


Concept #4:
A second upward deflection is called R prime (R')



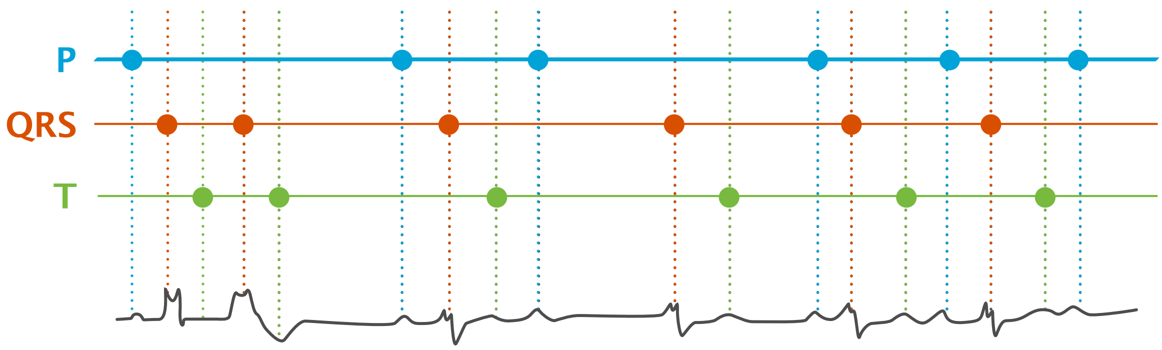


Concept #5:
If the entire QRS complex consists of one large downward deflection, then this is called a QS complex



Example: identifying P waves, QRS complexes, and T waves

Based on the concepts outlined above, we can now identify the P waves, QRS complexes, and T waves in an example exercise. Notice that the second wave is steep and edgy; it has sharper deflections than the other curves and therefore has to be the QRS complex.

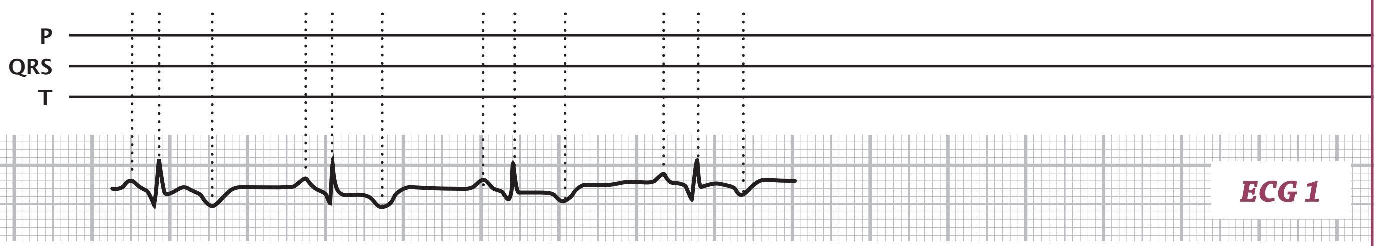


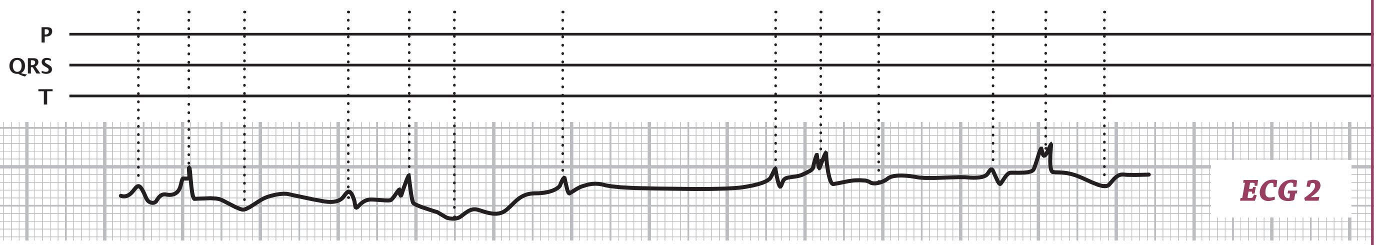
Dotted vertical lines originate from the different waves of the ECG. They intersect with horizontal lines identifying P, QRS, and T. In this example we have already identified the different waves for you.

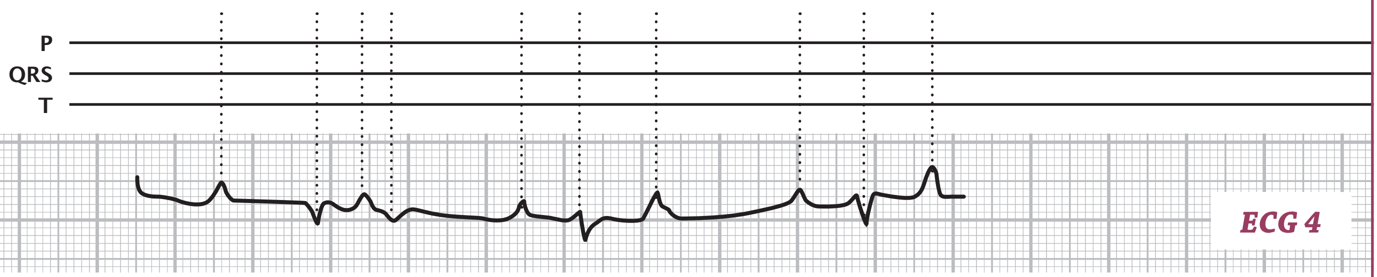
Level 1

QUIZ SECTION

Now it is your turn. If in doubt, start looking for the QRS complex (focus on sharp deflections!). Also keep in mind that every QRS complex is followed by the T wave after 200-400ms (equivalent to 5-10mm on this ECG paper). Then you should be able to identify the P wave, as the steepness of its deflection is in between the QRS and the T wave.



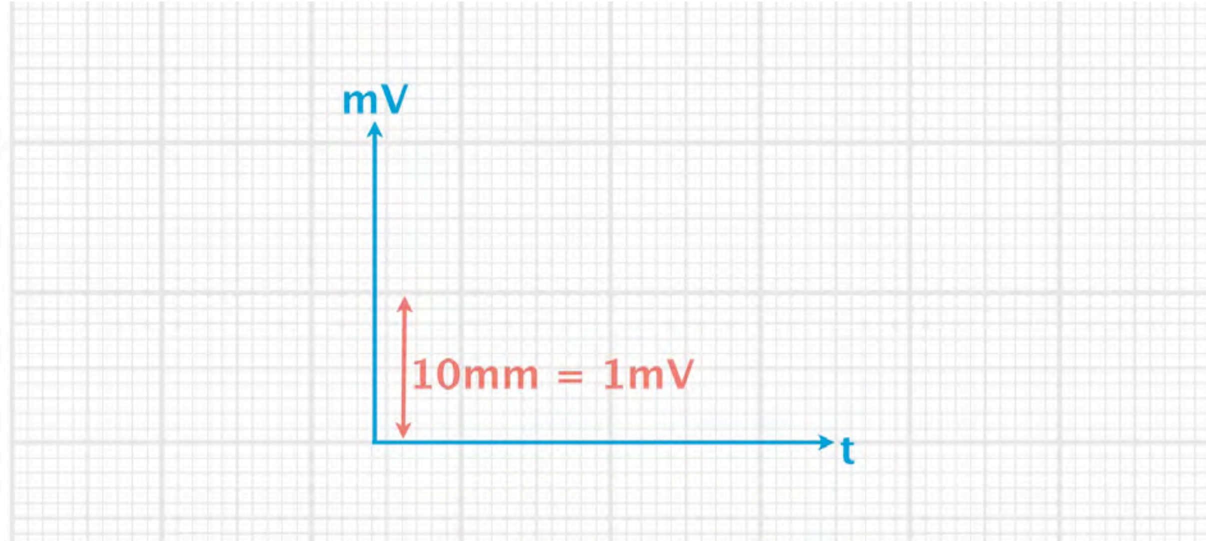


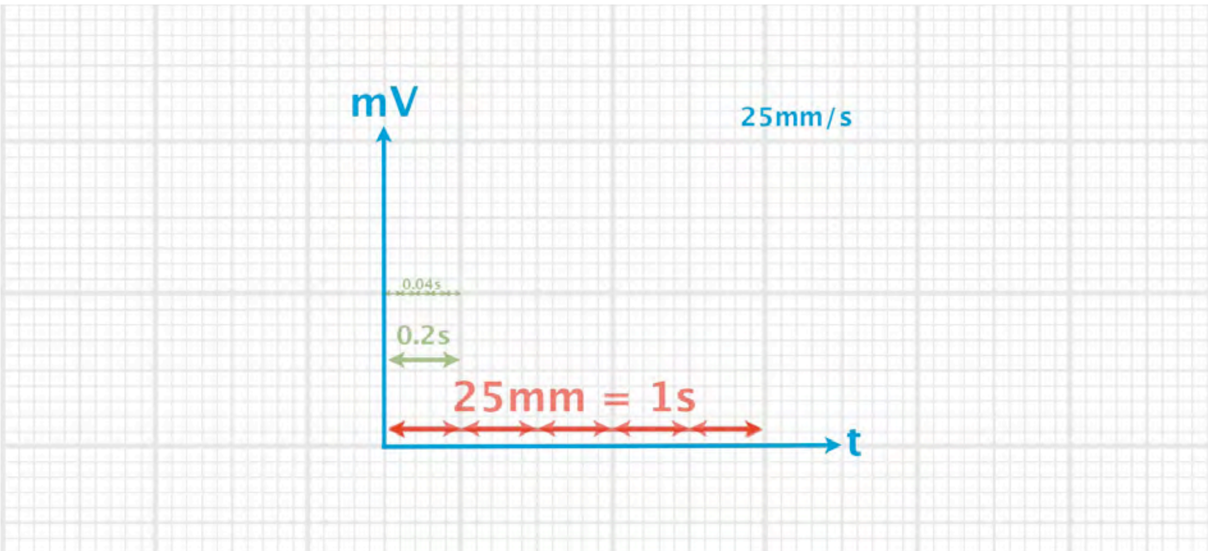


Level 2: Interval (time) and amplitude (voltage) measurements

In this chapter, you will learn about the duration and amplitudes of the various waves and how to measure them.

You can measure in two dimensions on the ECG paper. The **Y-axis** shows **amplitudes** (i.e., **voltage**), while the **X-axis** shows **time**.





Measuring is not always necessary in order to come up with the right diagnosis. Some diseases just require pattern recognition (e.g., acute myocardial infarction), while others require measurements (e.g., ventricular hypertrophy, bundle branch blocks, etc.).

The Y-axis—amplitude measurement

Amplitude or voltage is measured on the Y-axis; **10mm** represent **1 millivolt (mV)** with standard calibration.

Good to know: Occasionally, calibration is set at double standard (20mm = 1mV) or half standard (5mm = 1mV). However, this is only rarely done. So just remember that **10mm = 1mV** and you'll be fine in 99.9% of cases.

Here's how you can tell if the ECG is adjusted to standard calibration. Almost every ECG printout also has a rectangular calibration signal on it. If the machine is set to standard calibration (10mm = 1mV), this calibration signal will be exactly 10mm high as shown in the example.

The X-axis—time measurement

Most ECG machines print at a speed of 25mm per second. Therefore, a **25mm** distance on the X-axis corresponds to a duration of **1 second**.

So remember:

25mm on the X-axis = 1 second

5mm (large box) on X-axis = 1/5 of a second or 0.2 seconds

1mm (small box) on X-axis = 1/5 of 0.2 seconds or 0.04 seconds

Good to know: Occasionally, paper speed is set at 50mm/second in which case all ECG intervals are twice as long as normal (large box = 0.1s instead of 0.2s, small box = 0.02s instead of 0.04s). So whenever all intervals look too long, check for an increase of paper speed to 50mm/s.

Measuring intervals

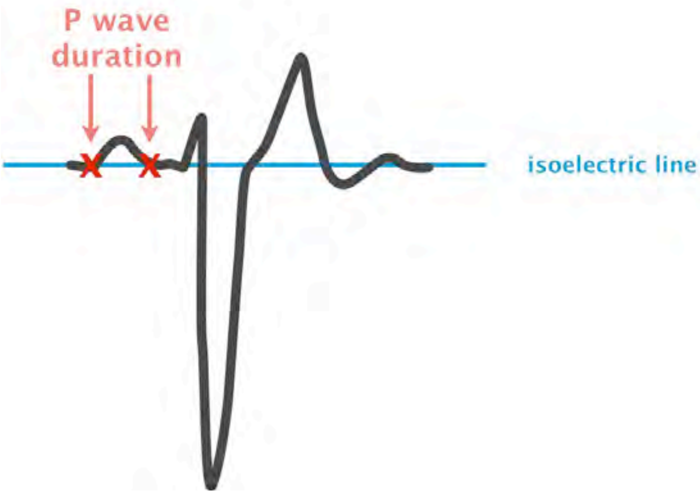
Now it's time to carry out some measurements. The **duration** of a wave is measured from its initial deviation from the isoelectric line until the point where it returns to the isoelectric line again. The **amplitude** of the wave is the distance between the isoelectric line and the peak or nadir of that wave.

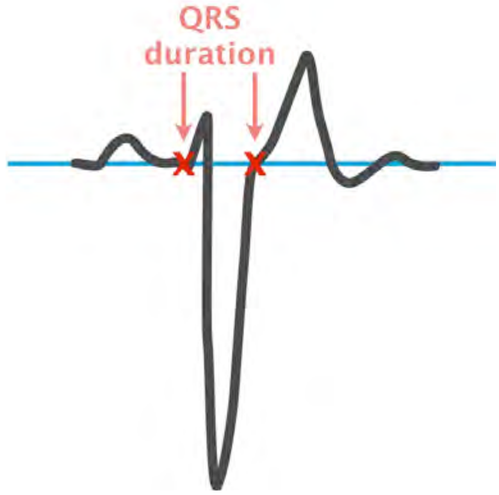
You should try to evaluate and measure each ECG in a systematic way, one step after the other. In later chapters we will introduce such an approach, which we call the "ECG Cookbook."

Here is how to measure the different intervals:

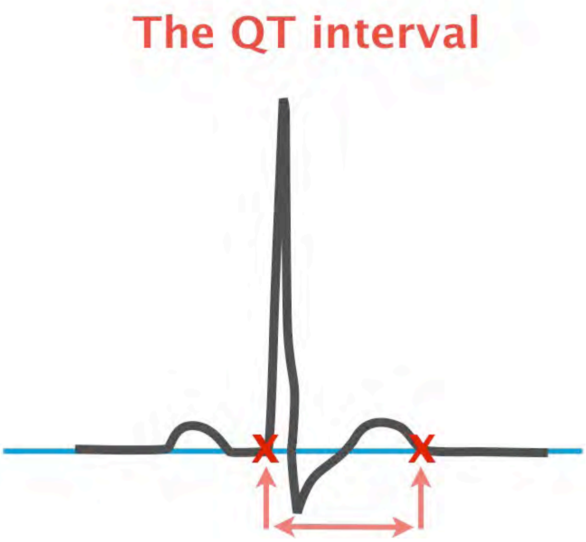
Measurement of P wave duration starts at the point where the P wave leaves the isoelectric line until it returns to the isoelectric line again.

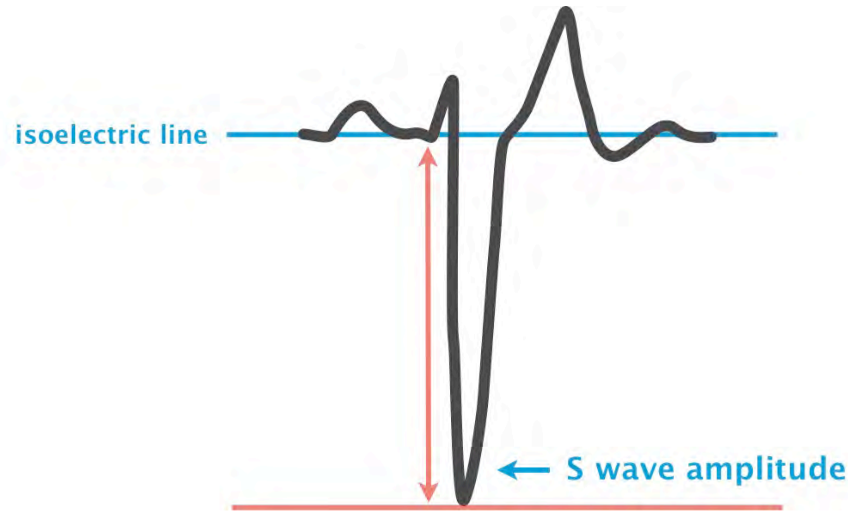
Measurement of QRS duration starts at the point where the QRS complex leaves the isoelectric line until it returns to the isoelectric line again.





Measurement of the QT interval starts at the beginning of the QRS complex until the end of the T wave.



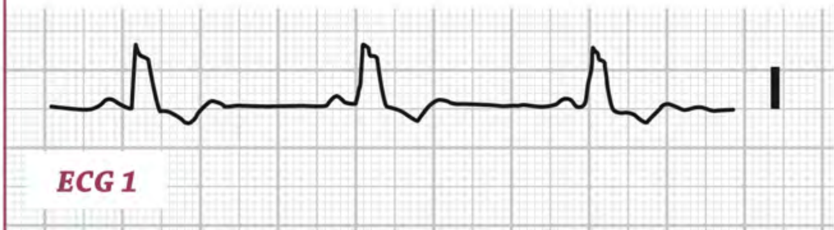


Measurement of amplitudes: start measuring at the isoelectric line until the nadir or peak of the curve.

Level 2

QUIZ SECTION

Now it is again your turn, perform the measurements mentioned above.



ECG 1

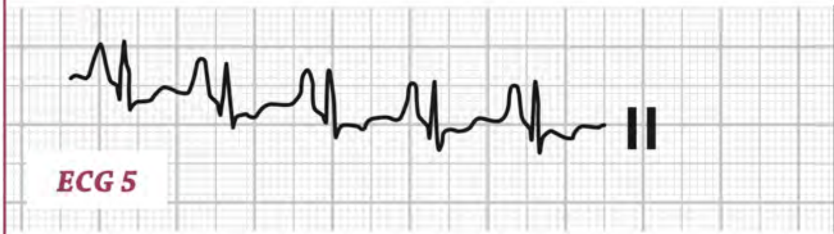
ECG 2

ECG 3

Duration (sec.)				Amplitude of the highest positive deflection (mV)	
P	PR	QRS	QT	P	QRS

Duration (sec.)				Amplitude of the highest positive deflection (mV)	
P	PR	QRS	QT	P	QRS

ECG 4



ECG 5

ECG 6

ECG 7

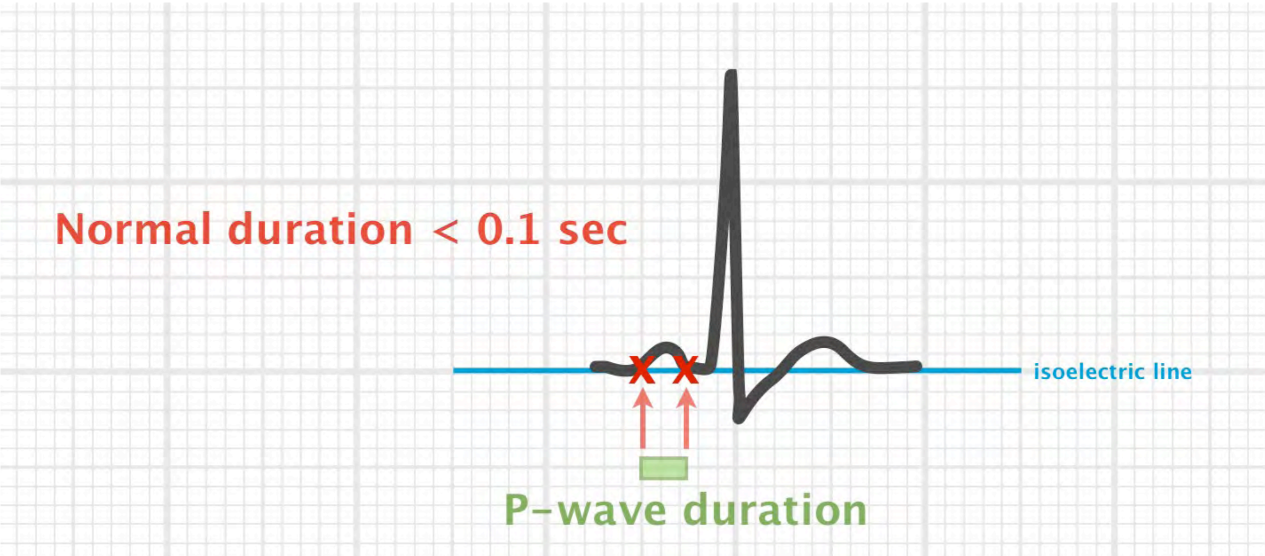
ECG 8

Level 3: When the timing is off—the foundations of interval interpretation

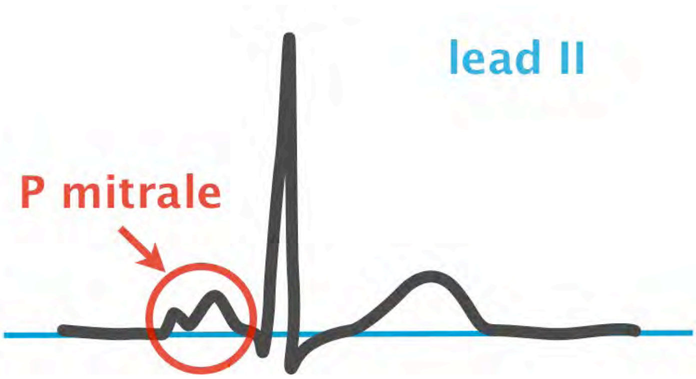
In this chapter, you are going to learn about the normal values of the different time intervals and what it means if they are off.

Duration of the P wave

Depolarization of the atria (i.e., P wave duration) usually takes **less than 0.10 seconds**. If the left atrium is dilated (enlarged), depolarization takes longer and **P wave duration will increase to ≥ 0.12s**.

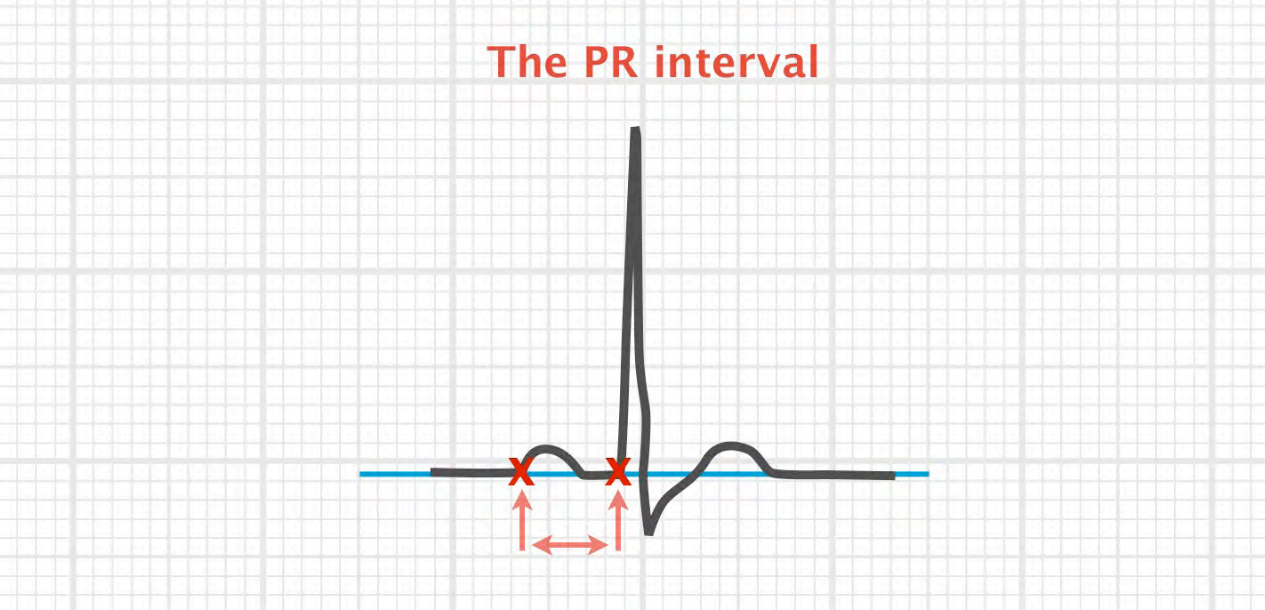


The prolonged P wave seen in atrial enlargement has a "double peak" in lead I and lead II and is called **P mitrale** (see image). We are going to learn more about it in Level 11.



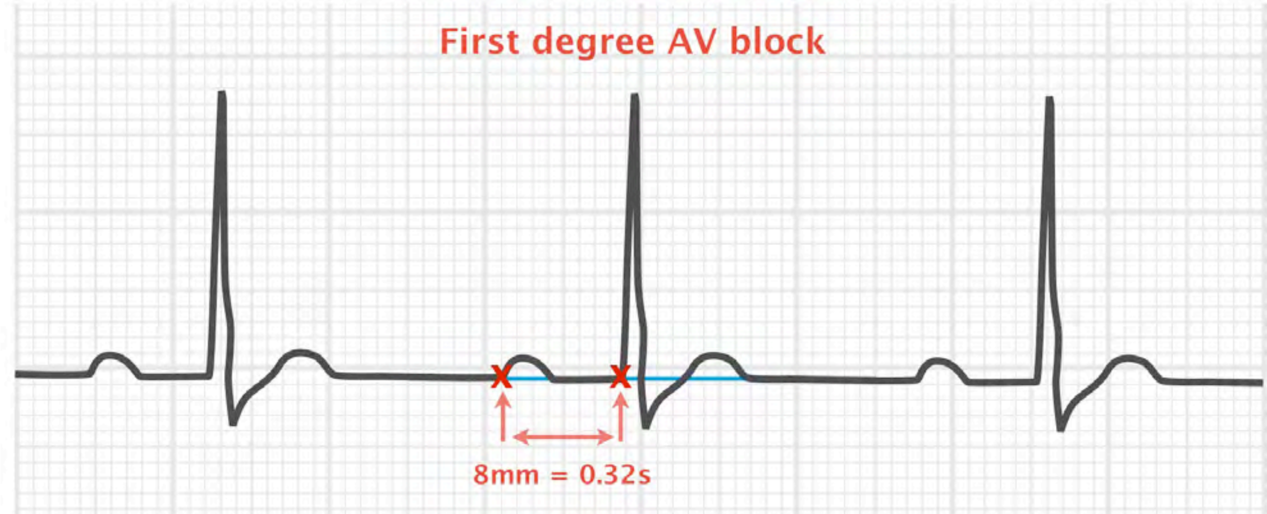
Duration of the PR interval

The **PR interval** represents the duration the impulse takes to travel from the atria to the ventricles. It's measured from the beginning of the P wave until the beginning of the QRS complex. **Normal values** are between **0.12 and 0.2 seconds**. Any duration below or above this range is regarded as abnormal.



When the PR interval is > 0.2 seconds

When the PR interval is longer than 0.2 seconds AND if there's a QRS complex after each P wave, we have what's called a **first degree AV block** (or AV block I), as seen on the image.

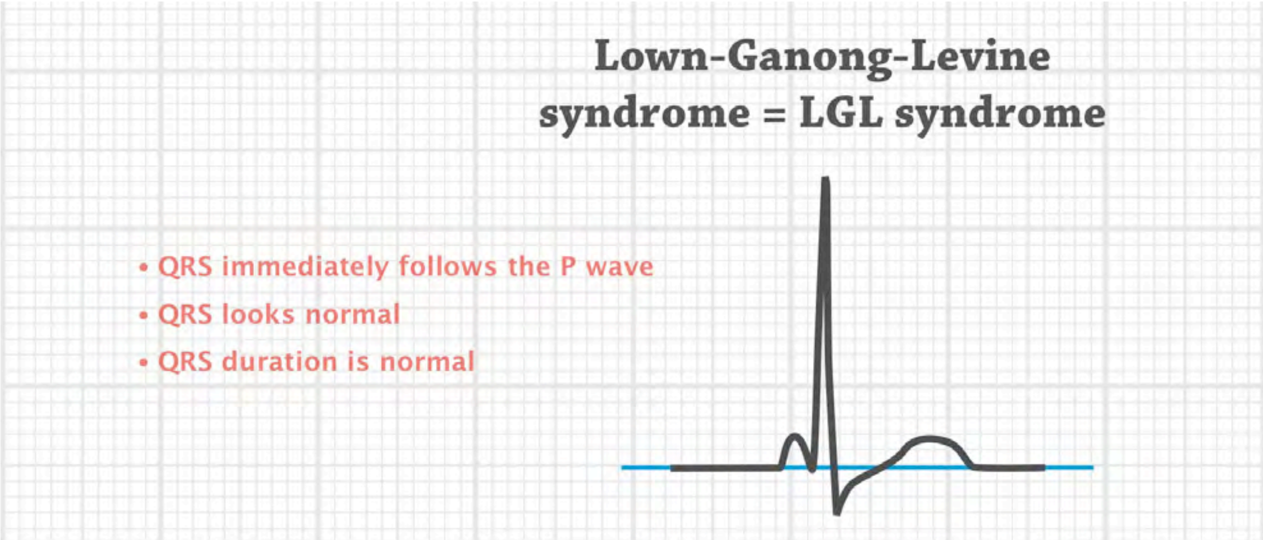


Example of a first degree AV block (AV block I). In this case, the PR interval is 0.32s and there is a QRS complex after each P wave.

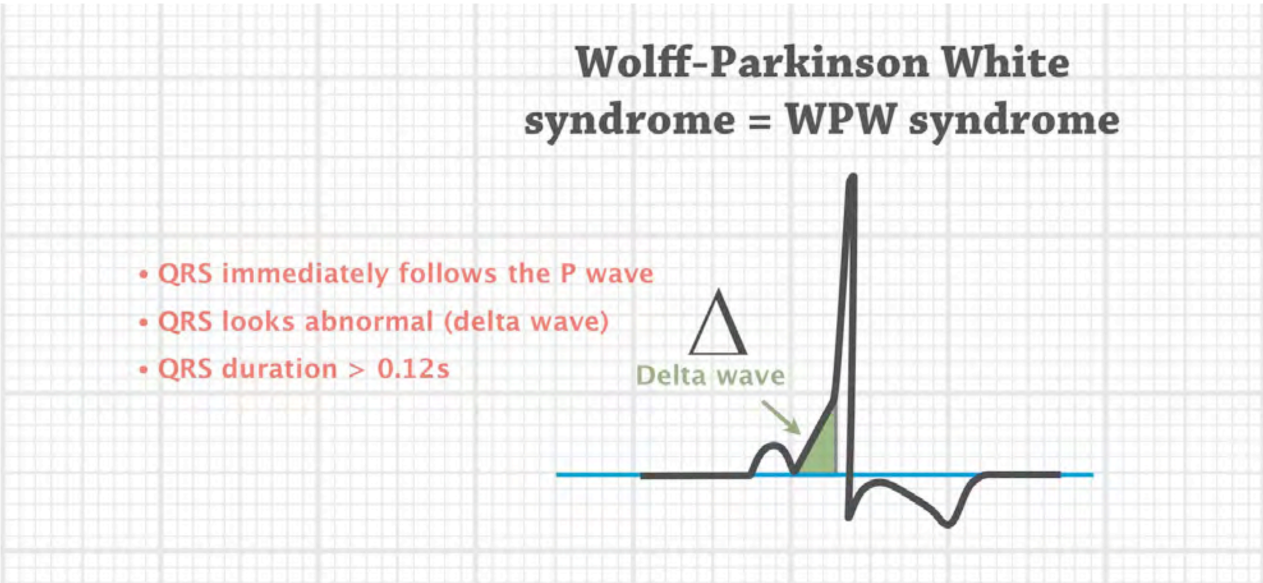
When the PR interval is < 0.12 seconds:

When the PR interval is shorter than 0.12 seconds, depolarization of the ventricles occurs earlier than normal. This situation is called **preexcitation** (or **preexcitation syndrome**). In these syndromes, an additional bundle conducts the impulse down from the atria to the ventricles. The conduction speed in the additional bundle is faster than in the AV node—so the impulse reaches the ventricles earlier than normal and the PR interval is shortened.

There are two important preexcitation syndromes that you should remember. The **Lown-Ganong-Levine syndrome (LGL syndrome)** is characterized by a QRS complex that immediately follows the P wave. The appearance and duration of the QRS complexes are normal.

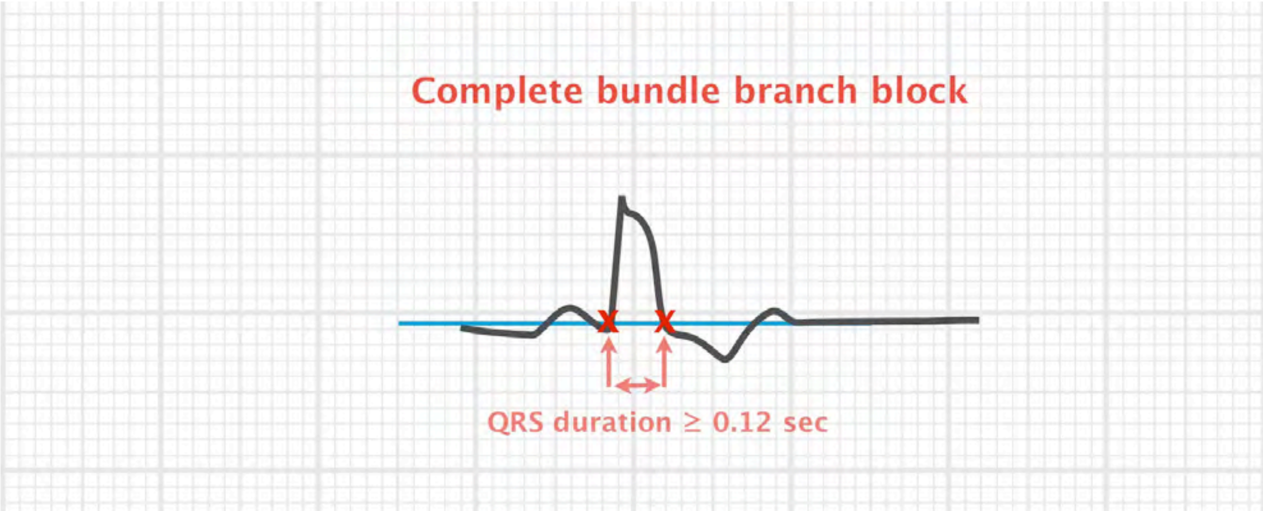


The other form of preexcitation is called **Wolff-Parkinson-White syndrome (WPW syndrome)**. A slurred upstroke of the QRS complex immediately follows the P wave; it is also known as a "delta wave," as it resembles the Greek letter delta. The duration of the QRS is usually lengthened to > 0.12s.



QRS duration

Under normal circumstances, depolarization of the ventricles takes up to 0.10 seconds. Dilatation of the ventricles may cause a slight lengthening of the QRS (> 0.1 to < 0.12 s). A significantly prolonged **QRS duration of ≥ 0.12s**, however, indicates that either the right or left bundle branch is blocked. This situation is called a **complete bundle branch block**. We'll hear more about it in Level 5.

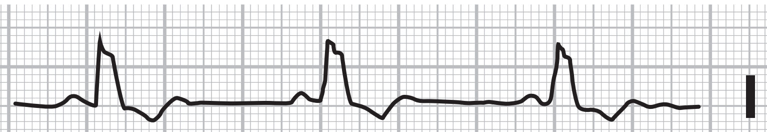


There are also other reasons for broad QRS complexes. As we have just learned, one such example is the WPW syndrome, in which a delta wave is added at the beginning of the QRS complex. Other reasons will be introduced in later chapters.

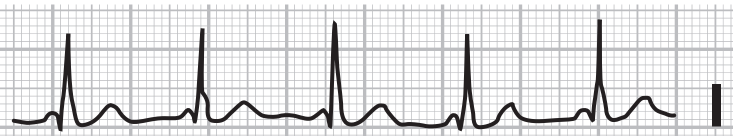
Level 3

QUIZ SECTION

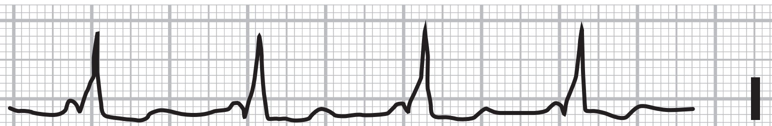
The following examples may seem familiar to you, but at this time not only the measurements but also the correct diagnoses are required. Note that there may be more than only one abnormality in a single example!



ECG 1

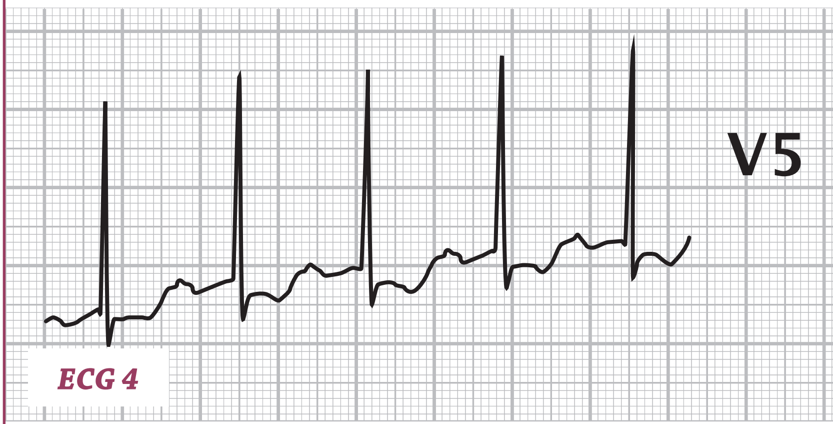


ECG 2

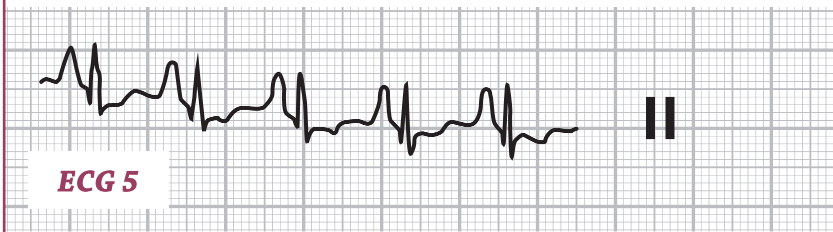


ECG 3

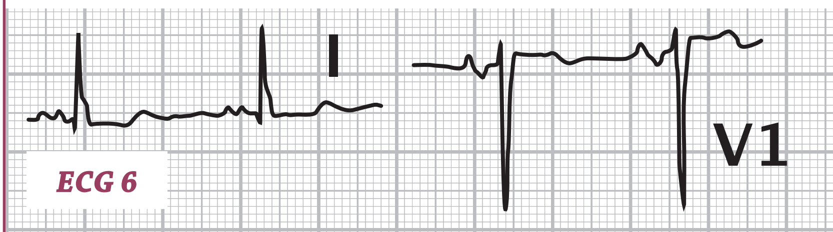
	P mitrale	I° AV block	LGL syndrome	WPW syndrome	Complete bundle branch block	None of the answers provided
ECG 1						
ECG 2						
ECG 3						



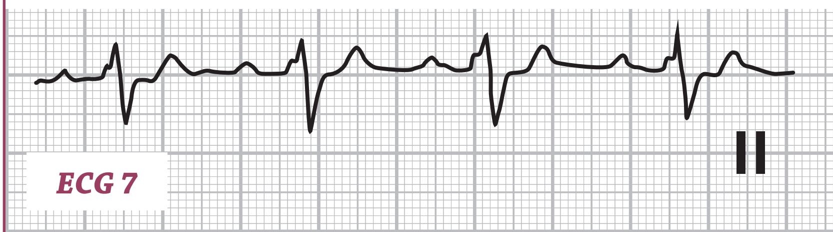
ECG 4



ECG 5



ECG 6



ECG 7

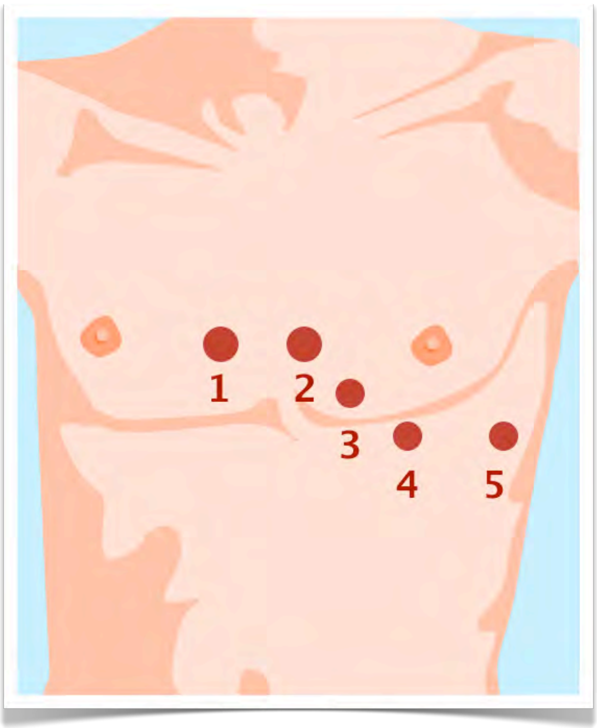
ECG	P mitrale	I° AV block	LGL syndrome	WPW syndrome	Complete bundle branch block	None of the answers provided
ECG 4						
ECG 5						
ECG 6						
ECG 7						

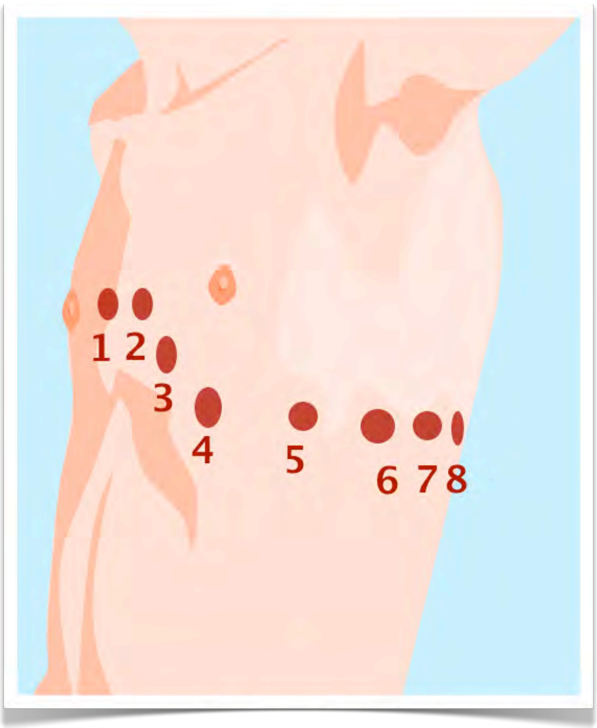
Level 4: The precordial leads—what nobody ever tells you

In this chapter you will learn where to put the precordial leads and what they tell you about the heart.

The precordial leads show the electrical activity of the heart in the **horizontal plane**. Most commonly, six precordial leads are recorded. The precordial leads are registered in combination with the limb leads. You are going to learn more about the limb leads in Level 9 of this training.

How to place the precordial leads





Proper placement of the precordial leads V1 through V6.

The precordial leads are placed at predefined positions on the chest. Here's how to go about it:

Step 1: You have to find the second rib and the second intercostal space first. Then count down to the fourth intercostal space. Attach **V1 in the fourth intercostal space on the right side of the sternum** and **attach V2 in the fourth intercostal space on the left side of the sternum**.

Step 2: After you've attached V1 and V2, attach V4 at the intersection of the midclavicular line and the fifth intercostal space.

Step 3: Attach V3 exactly half way in between V2 and V4. From V4 on, we don't need to worry about the intercostal spaces anymore; the subsequent leads are attached at the same horizontal level as V4.

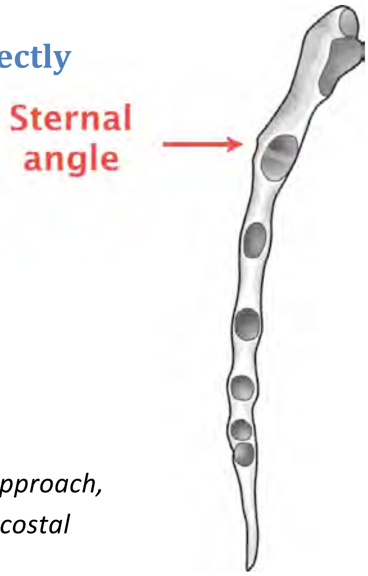
Step 4: V5 is placed in the anterior axillary line (same level as V4).

Step 5: V6 is placed in the mid-axillary line (same level as V4).

Occasionally, two additional leads (V7 & V8) are also attached. V7 is located at the posterior axillary line (same level as V4), and V8 is attached at the scapular line (same level as V4).

How to find and count the intercostal spaces correctly

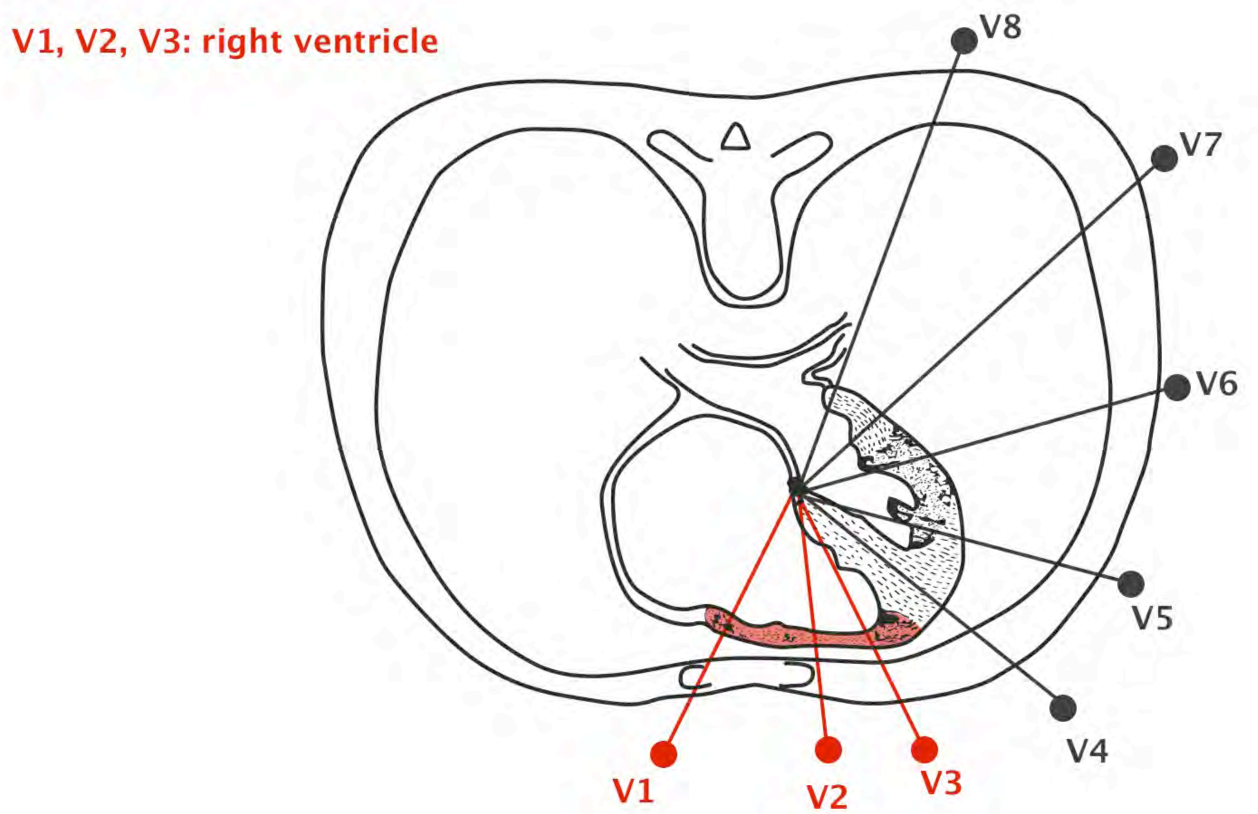
The easiest way to find the fourth intercostal space is to look for the sternal angle. The **sternal angle** is a little edge in the upper third of the sternum (see image), which can be found in almost any patient. The second rib inserts right next to the sternal angle. Below the second rib is the second intercostal space. Then you just count down to the fourth and fifth intercostal spaces, respectively.



Try to find the second rib on yourself using this approach, and you'll see that it's easy. Then count the intercostal spaces!

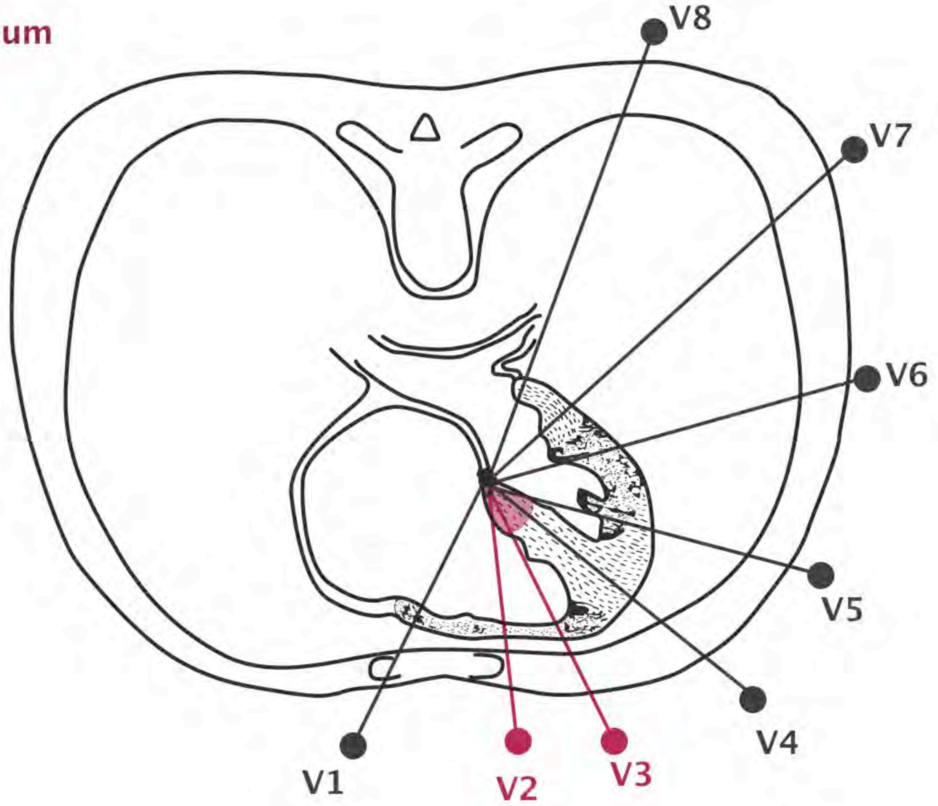
What anatomical regions are depicted by what leads?

Each precordial lead depicts a certain region of the heart. Some leads even depict more than one region. Let's say you see ST elevations on the ECG—a sign of myocardial infarction. Just by looking at the affected leads, you'll be able to tell where the infarction is located.



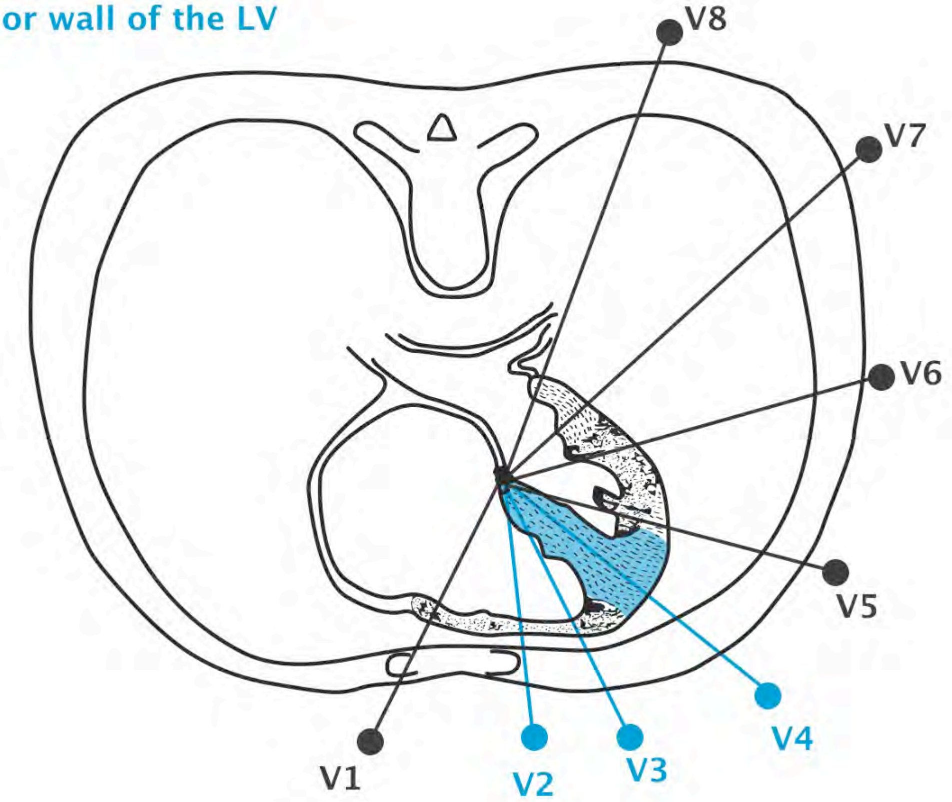
If changes are seen in leads V1, V2 and V3, the right ventricle is affected.

V2, V3: basal septum



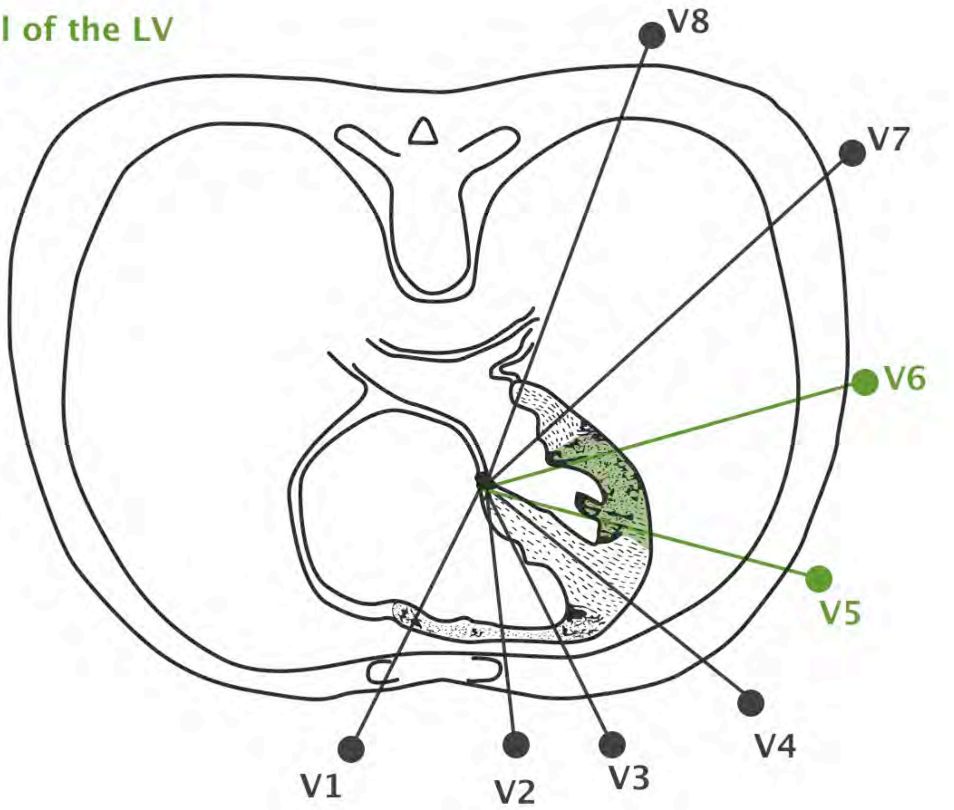
If only V2 and V3 show changes, it's the basal septum that has the problem.

V2, V3, V4: anterior wall of the LV



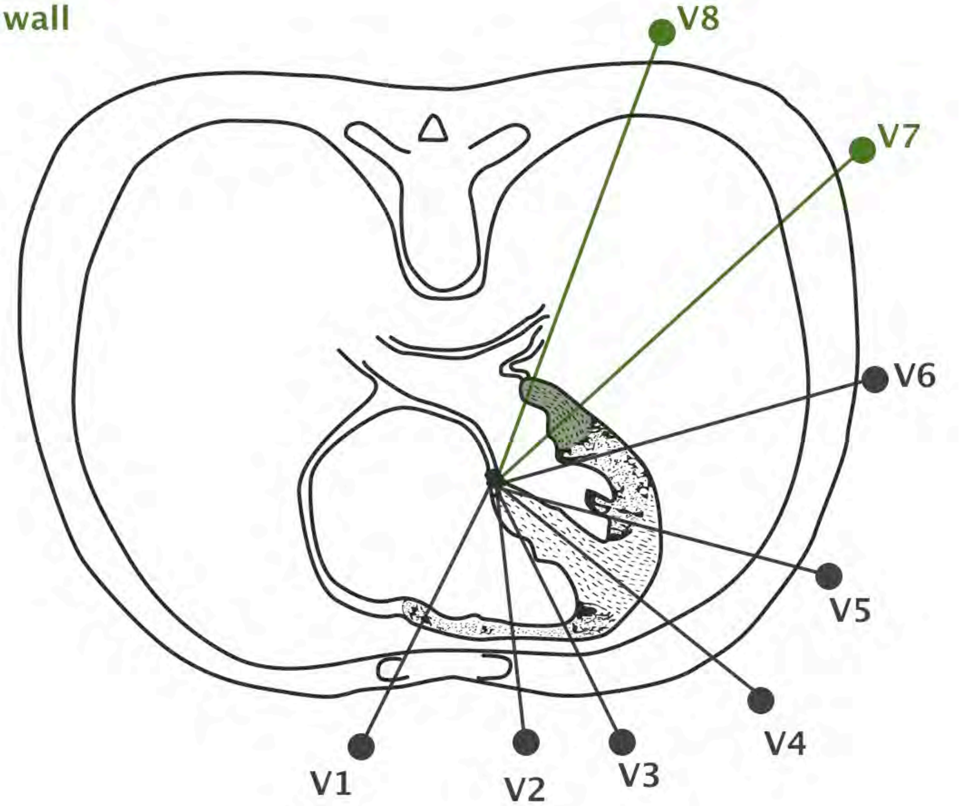
If changes can be seen in V2, V3 and V4, then the anterior wall of the left ventricle (and the septum) are affected.

V5, V6: lateral wall of the LV



V5 and V6 show the lateral wall of the left ventricle.

V7, V8: posterior wall

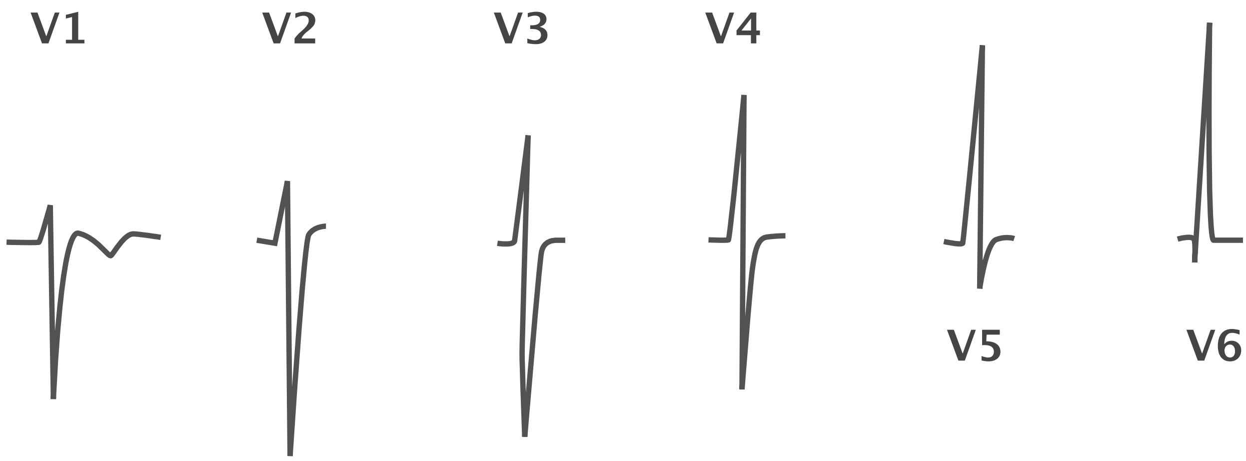


Whereas V7 and V8 depict the posterior wall of the left ventricle.

*Changes that are seen in the anterior AND the lateral walls are called **Anterolateral**.*
*Changes that are seen in the lateral and posterior walls are called **Posterolateral**.*
*Changes that are seen in the anterior wall and the septum are called **Anteroseptal.***

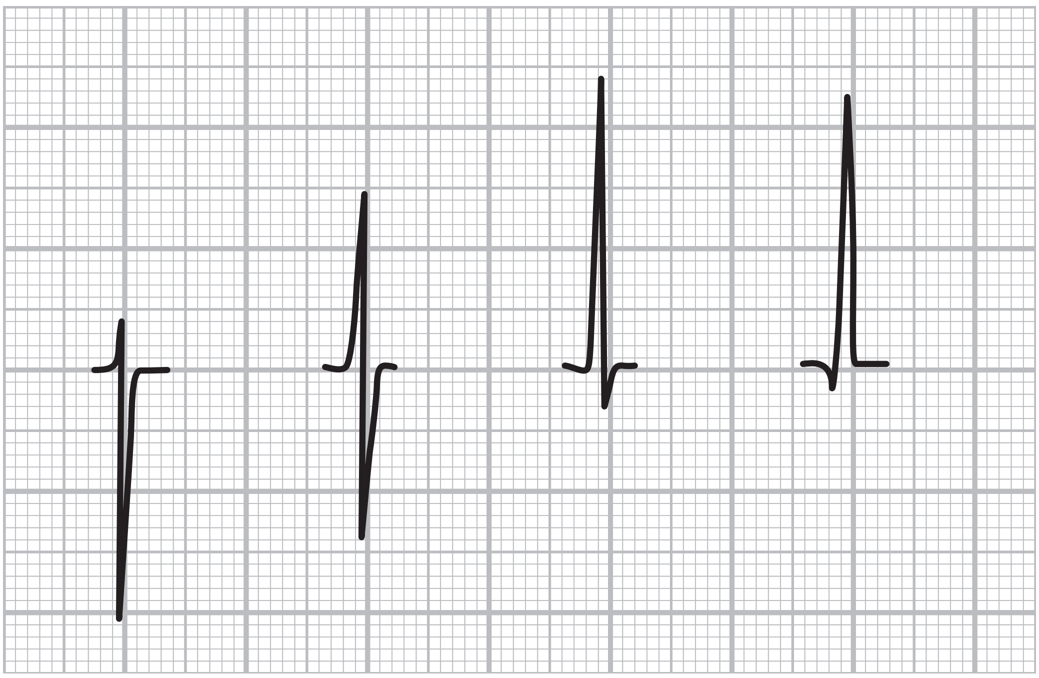
The normal pattern

Each precordial lead has a typical ECG pattern. Try to remember this picture of normal chest leads:



The R/S ratio ("R to S ratio")

As the name implies, the R/S ratio compares the size of the R wave to the size of the S wave in each lead. Let's look at four examples. Please complete the calculations for examples 3 and 4.

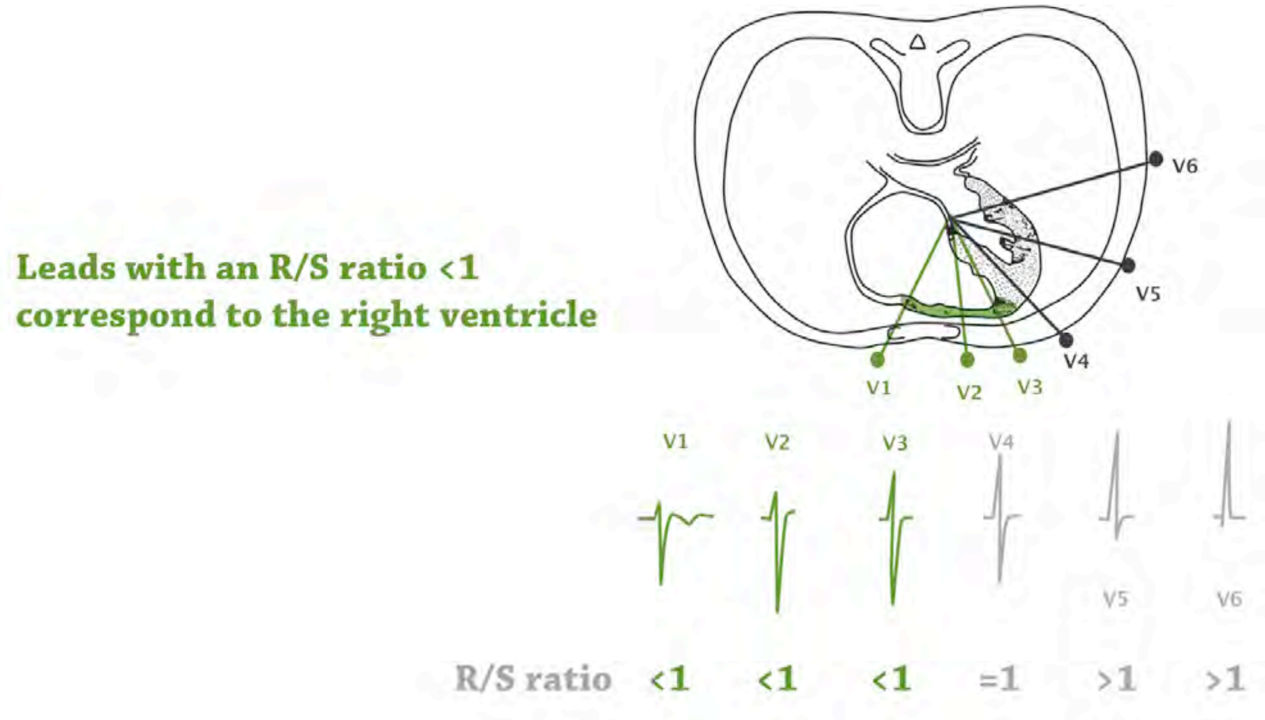


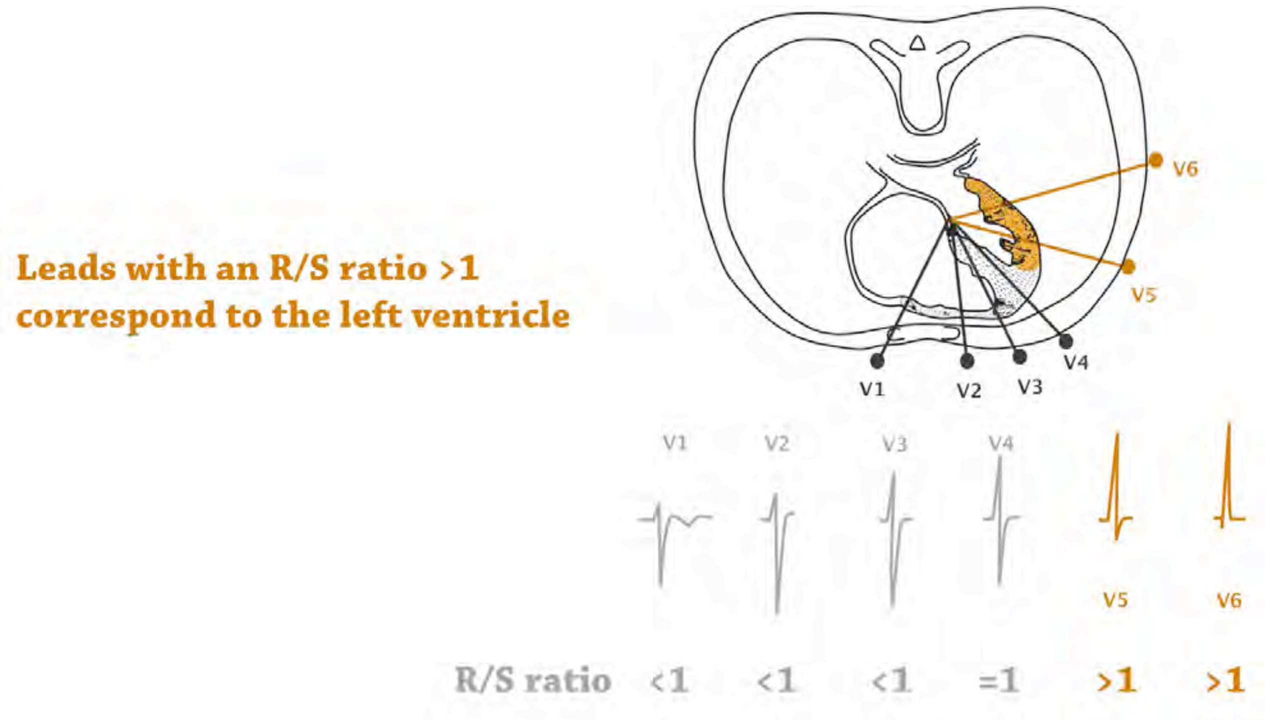
	Example 1	*Example 2*	*Example 3*	*Example 4*
R (mV)	*0.4*	*1.4*		
S (mV)	*2.0*	*1.4*		
R/S	*0.4/2.0 = 1/5 = 0.2*	*1.4 / 1.4 = 1*		

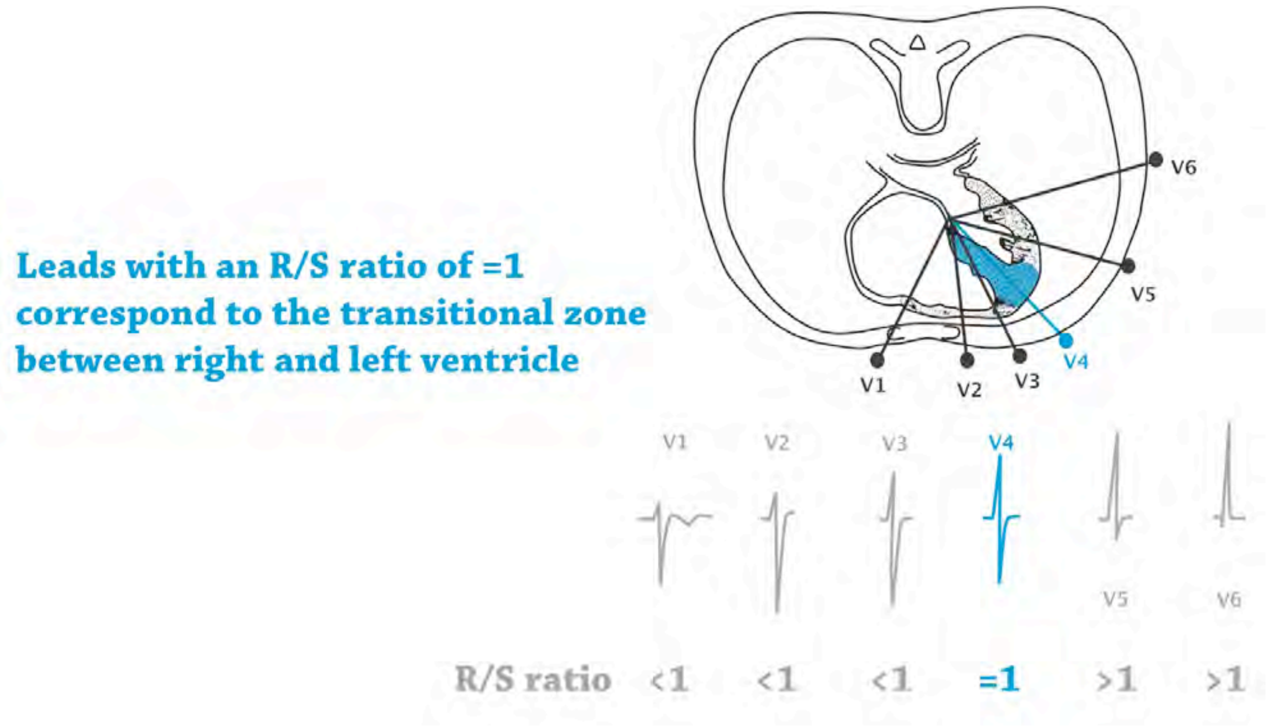
A lot of folks neglect the R to S ratio. But you shouldn't!

So why is the R/S ratio important?

There are two very important laws that apply under normal circumstances (i.e., when the muscle mass of the left ventricle exceeds that of the right ventricle). Law number 1 says:

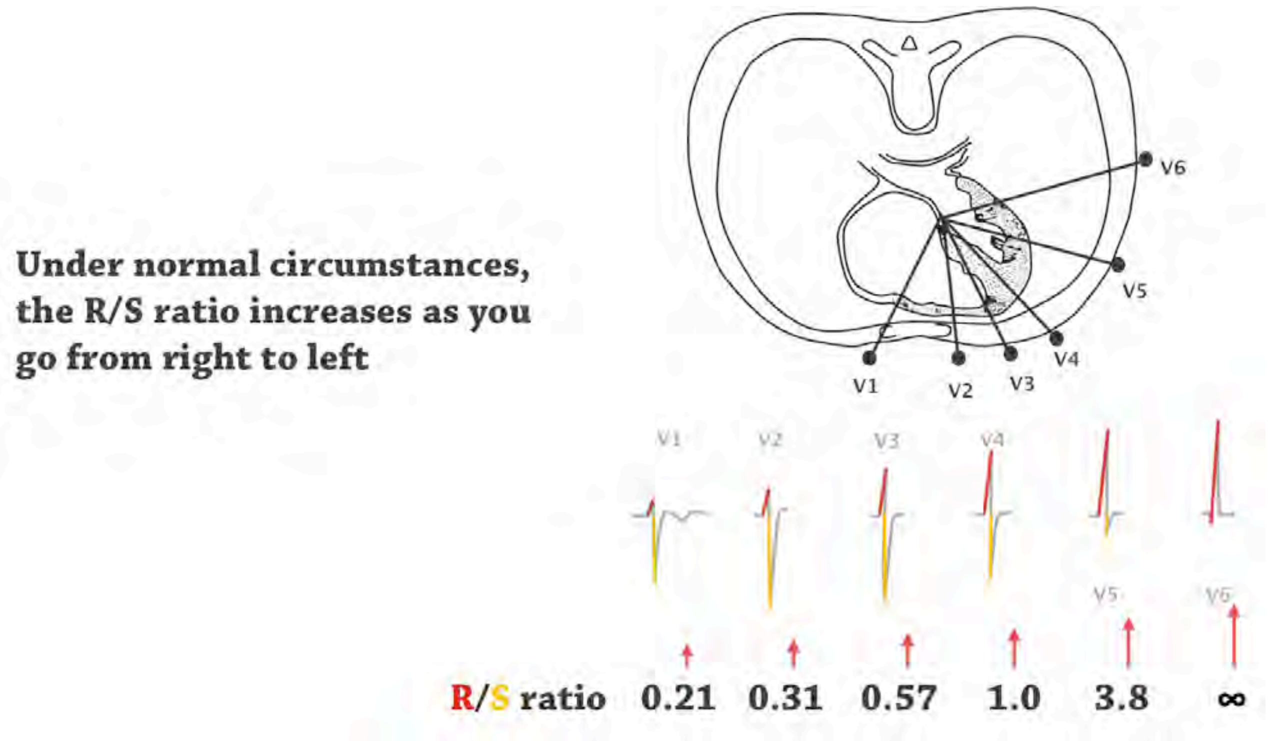






The transitional zone usually occurs at leads V3 or V4.

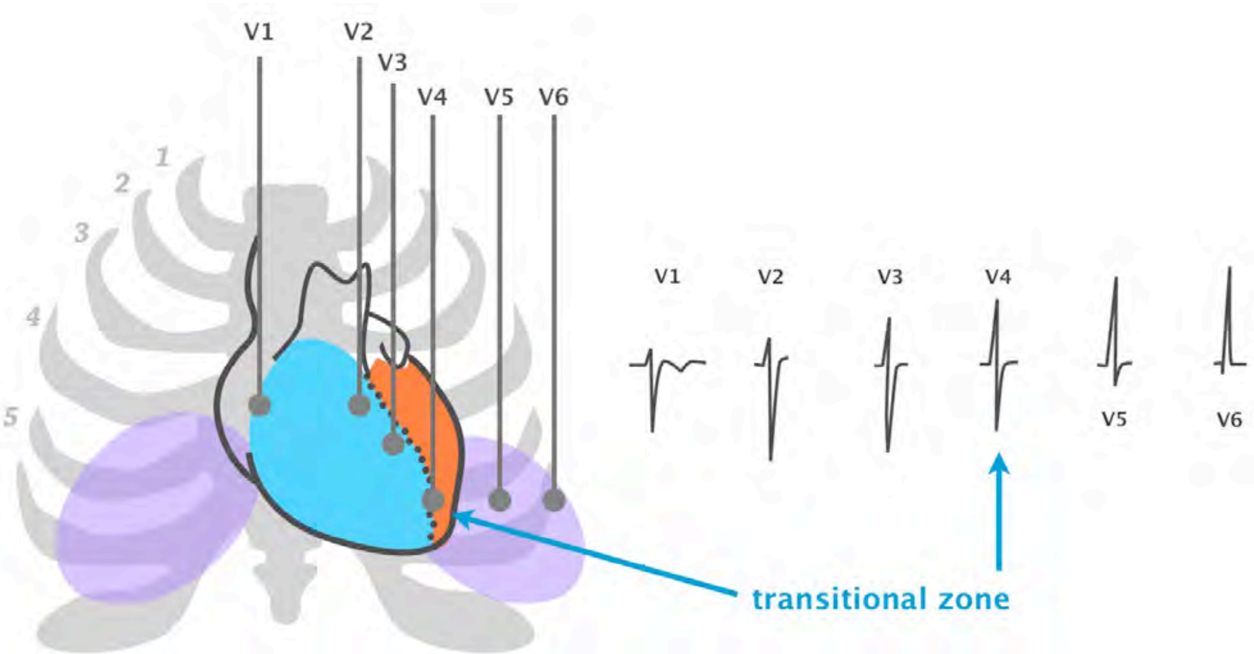
And law number 2 says:



Law 2 will be really important when we learn about myocardial infarction! This information might come in handy during your next night on call.

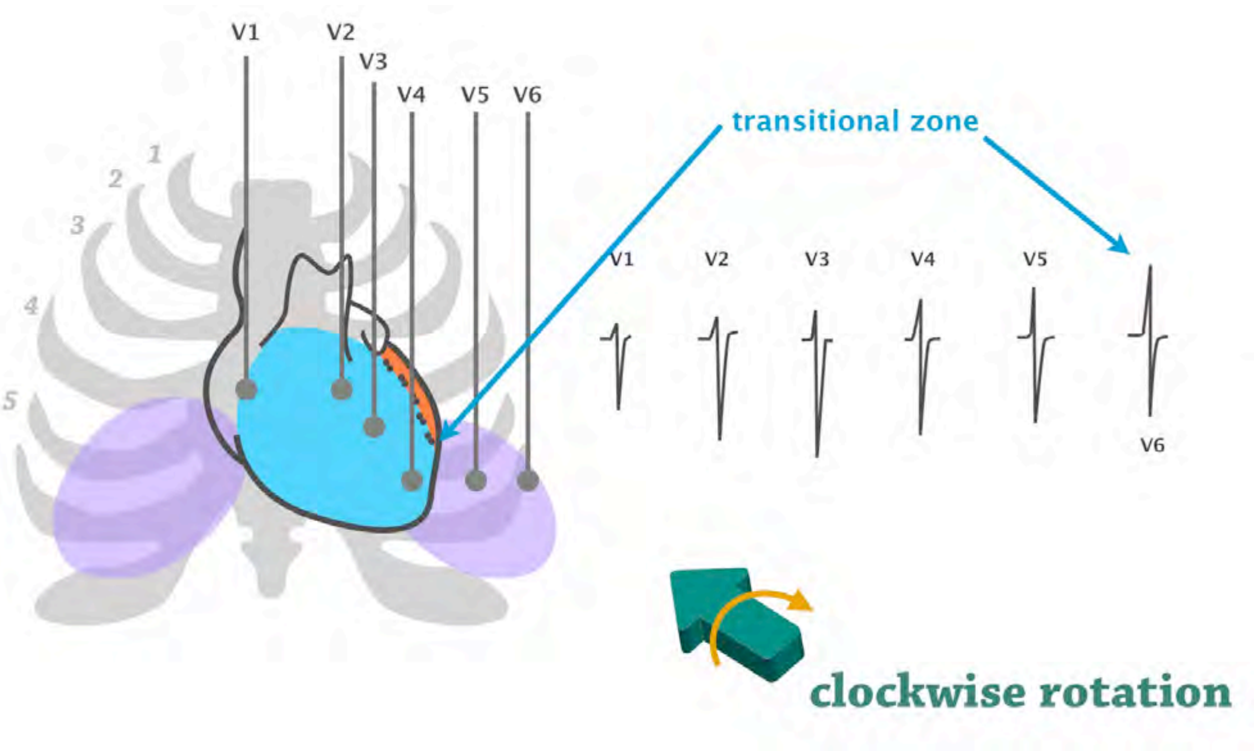
When the transitional zone is off

As we learned above, the transitional zone (the dotted line separating right from left ventricle) usually occurs at V3 or V4, as depicted in this image:

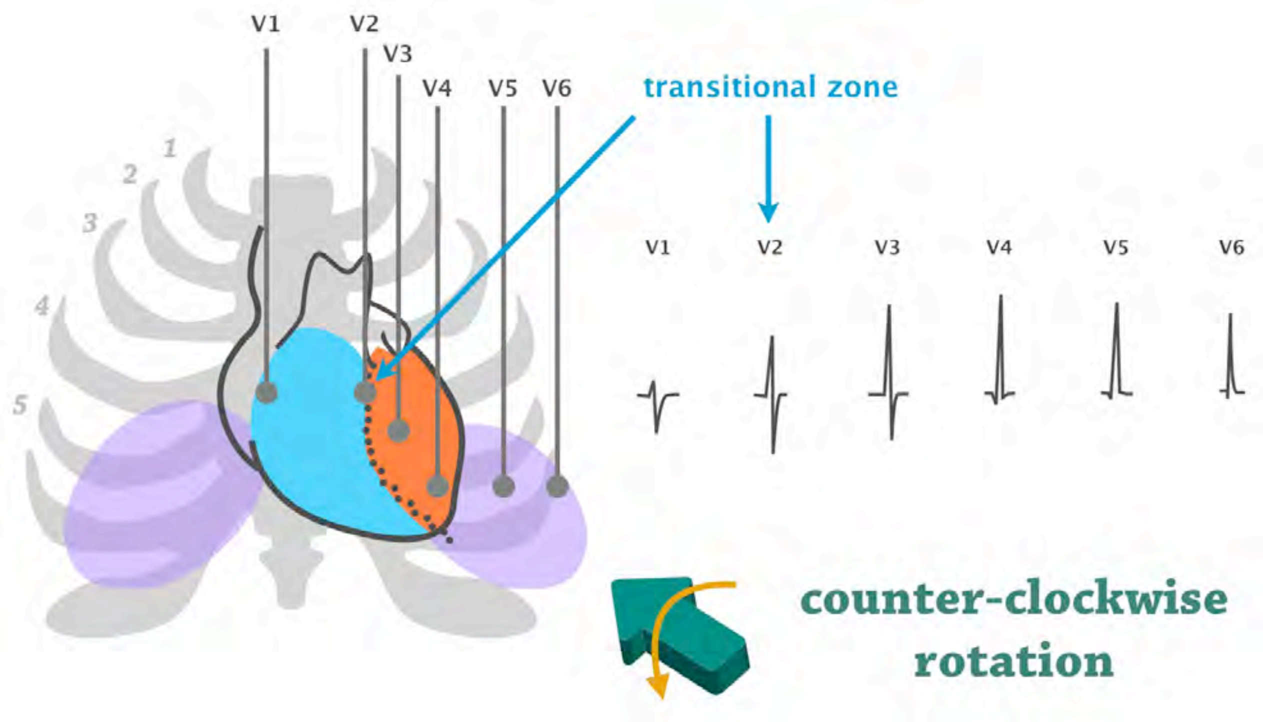


But not every heart is the same. Sometimes, the heart is "rotated" in a clockwise or counter-clockwise fashion along its longitudinal axis (going from the apex to the base of the heart).

When the heart is rotated in a clockwise fashion, the transitional zone shifts towards V5 or V6:



And when the heart is rotated in a counter-clockwise fashion, the transitional zone occurs at V1 or V2:



You'll need to be able to tell if a precordial lead depicts the right or the left ventricle. Knowledge about rotation is therefore critical.

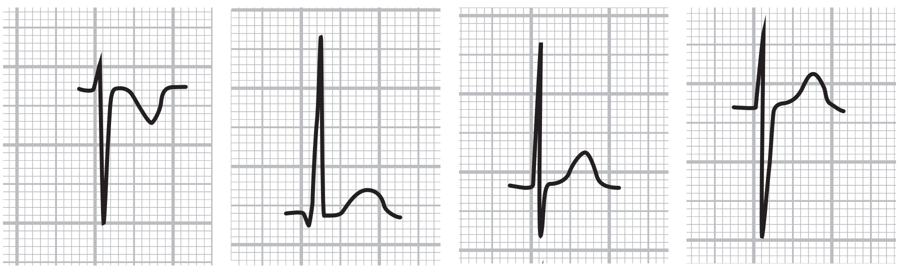
Level 4

QUIZ SECTION

Now it's time for some exercises. They will help you to repeat and remember the most important information covered in this level.

Which leads provide information on the...	V1	V2	V3	V4	V5	V6	V7	V8
Right ventricle								
Upper part of the septum								
Left ventricle								
Anterior wall of the LV								
Lateral wall of the LV								
Posterior wall of the LV								

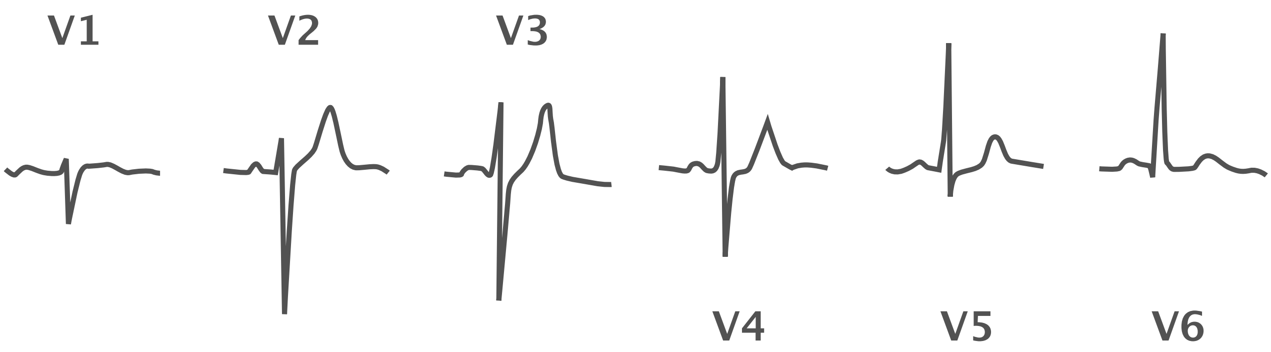
Which ventricle is represented by these leads under normal circumstances?



Right ventricle				
Left ventricle				

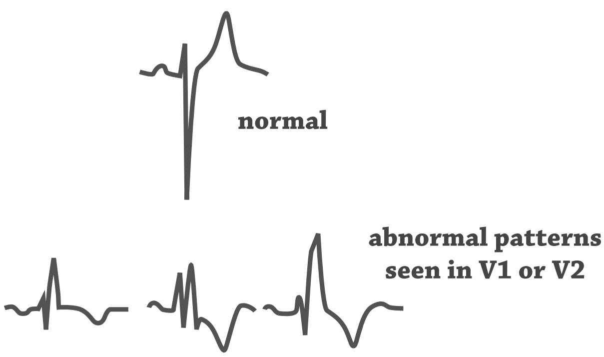
Level 5: The chest leads—100% confidence

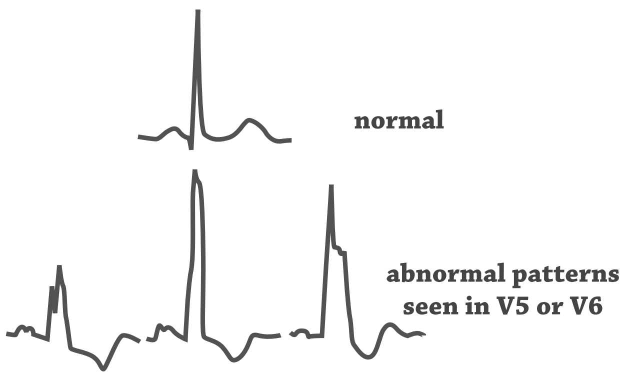
It's so important that you remember the normal appearance of the precordial (chest) leads. So take a look at this example of a normal ECG again, and then see how the abnormal patterns differ:



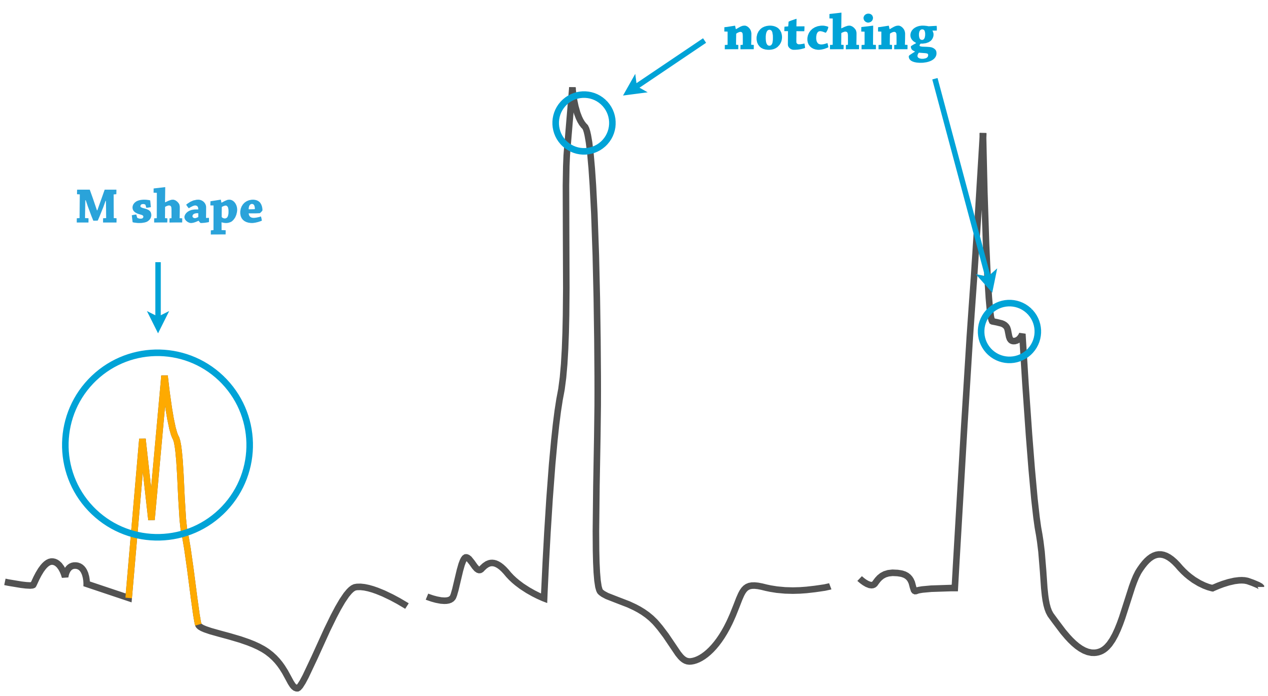
Right ventricle (V1 & V2): we can usually see small R waves and large S waves in normal individuals.

Left ventricle (V5 & V6): small Q waves and narrow and tall R waves are usually seen in normal individuals.





The pattern seen in the six abnormal QRS complexes is often referred to as notching, slurring, an M shape, or an RSR pattern

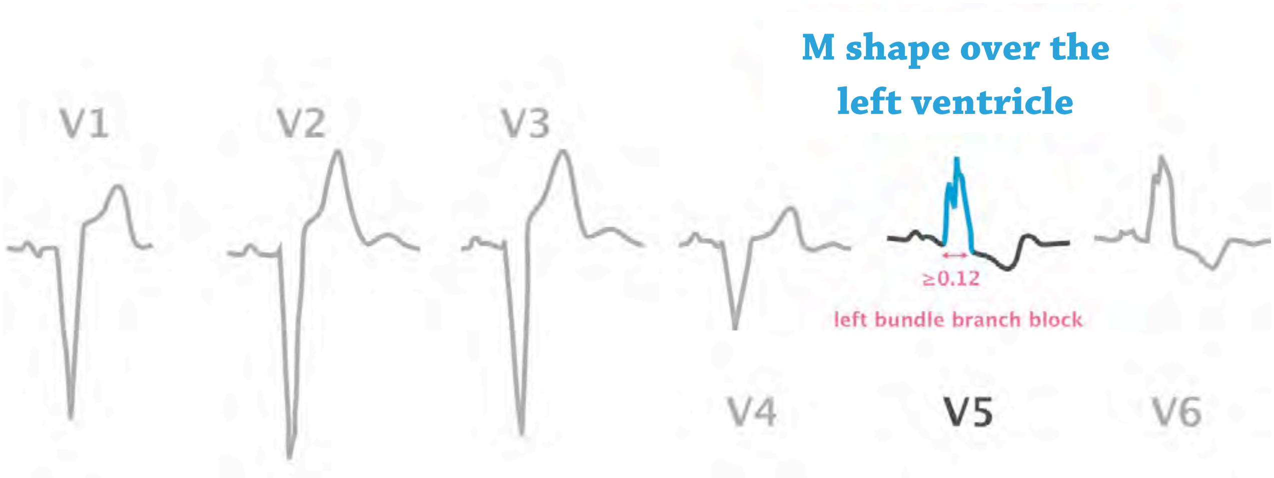


*The **M pattern** is usually quite easy to see (yellow). When the delay in depolarization of the ventricles is less obvious, then that's called **notching**.*

These changes in R wave morphology indicate that depolarization of the ventricles is delayed. This delay may be caused by **ventricular hypertrophy, ventricular dilatation,** or **bundle branch block**.

In bundle branch block, conduction through the left or right bundle branch is completely blocked. Depolarization of the ventricles therefore takes longer than normal and the QRS complex is lengthened to 0.12 seconds or longer.

In order to find out if the left or the right bundle branch is affected, we need to look at the chest leads:



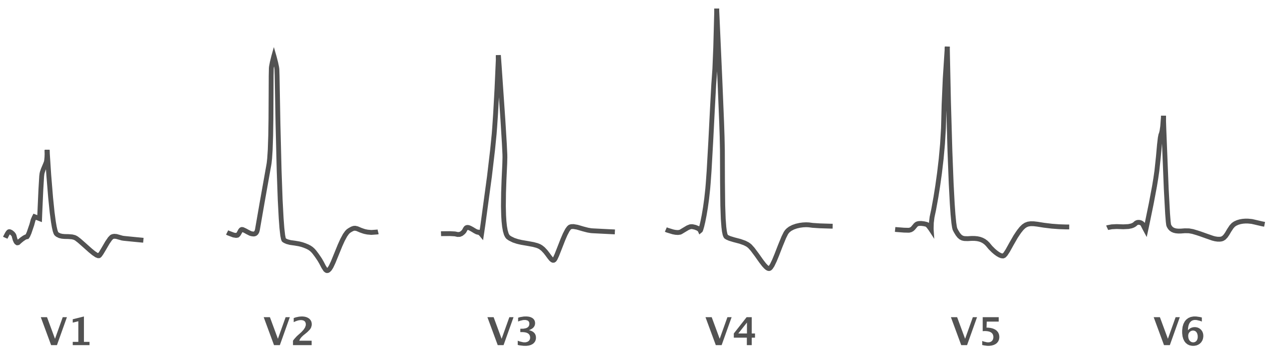
In complete left bundle branch block (LBBB), the QRS duration is ≥ 0.12 seconds and an M-pattern (notching) is seen over the left ventricle (V5 or V6).

When the QRS duration is between 0.10 and 0.12 seconds, then that's called **incomplete bundle branch block**, which also causes notching of the QRS complex. Incomplete bundle branch block may be caused by dilation or hypertrophy of the ventricles.

In complete right bundle branch block (RBBB), the QRS duration is ≥ 0.12 seconds and an M-pattern (or notching) is seen over the right ventricle (V1 or V2).

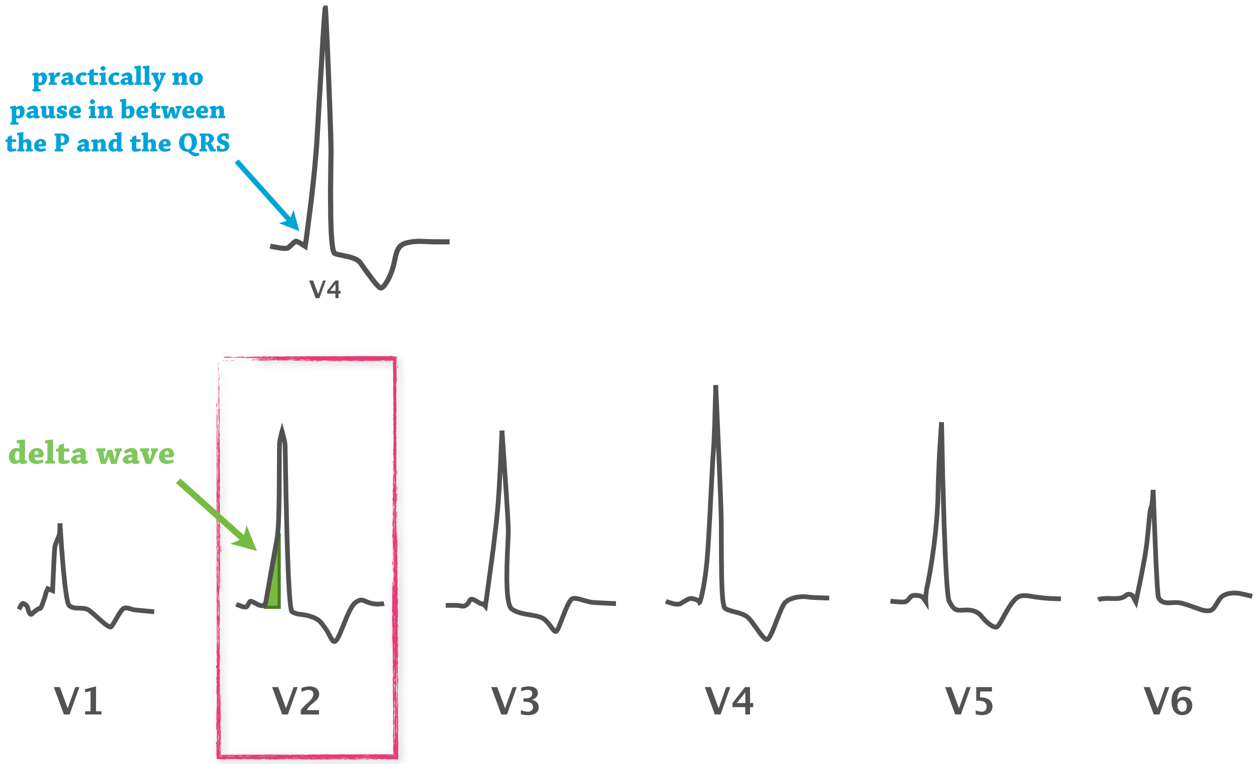
At this point we need to take a quick side-step…

There's one important pathology that could be confused with bundle branch block because QRS duration is also lengthened. We have already learned about this disease in level 3. Here's an example. Can you spot the problem?



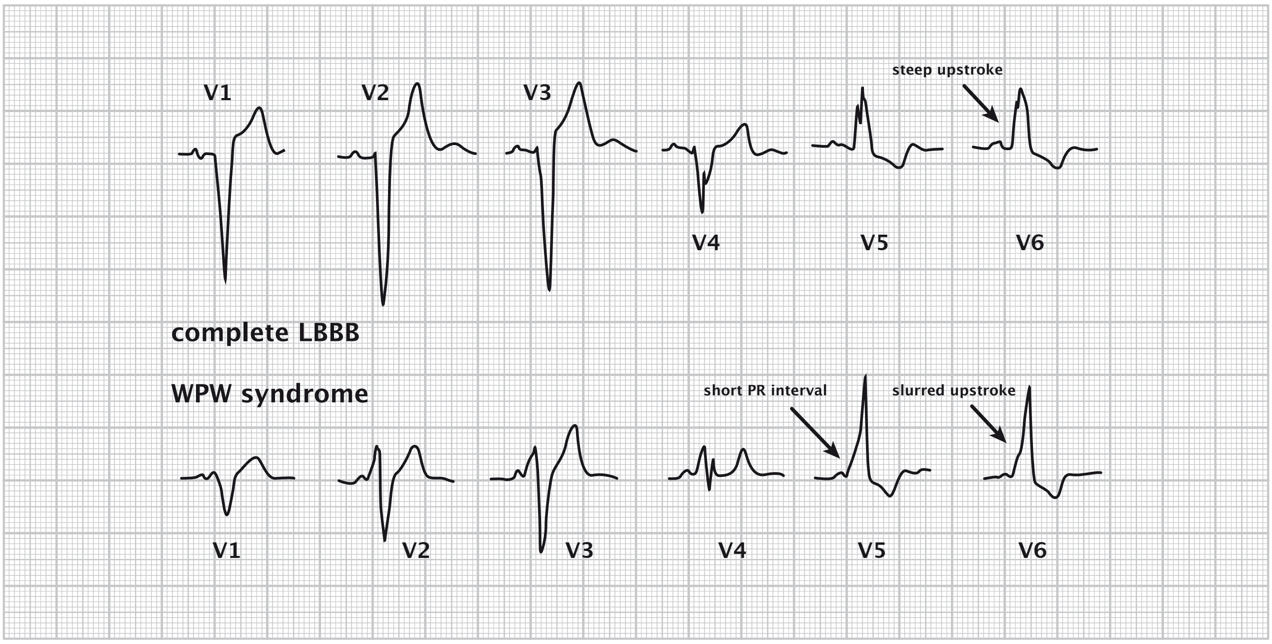
In this example, the QRS duration is lengthened to ≥ 0.12 seconds and there's notching in lead V1. Is this a case of right bundle branch block?

You might have already realized what's wrong with this ECG. There are a few problems: the QRS is lengthened, the PR interval is too short, AND the beginning of the QRS looks kind of funny.



This is a clear case of a **WPW syndrome**: the QRS is lengthened, the PR interval is shortened, and a delta wave is present. You'll get the chance to see a lot more examples of this disease in the exercises and on our course platform (ecgmastery.com).

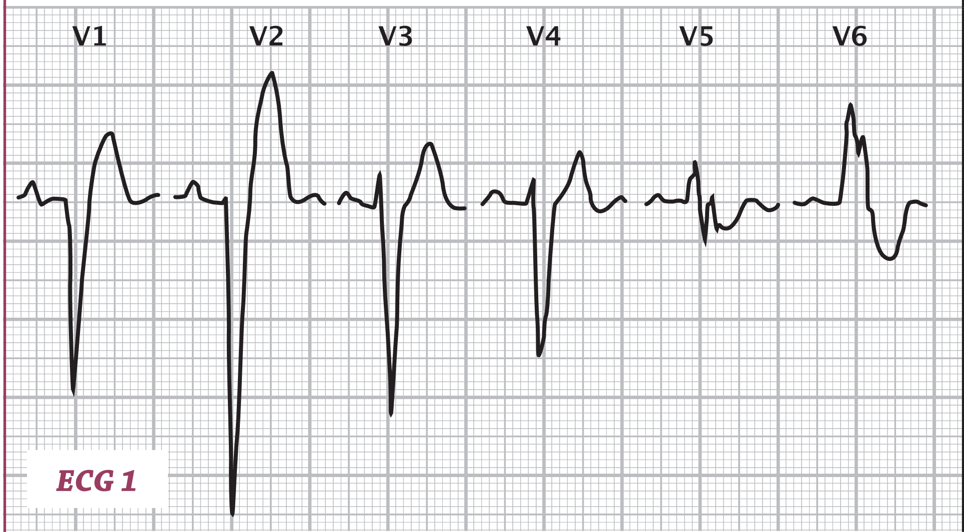
Sometimes WPW Syndrome may look like LBBB with predominant R waves over the left ventricle and predominant S waves over the right ventricle:



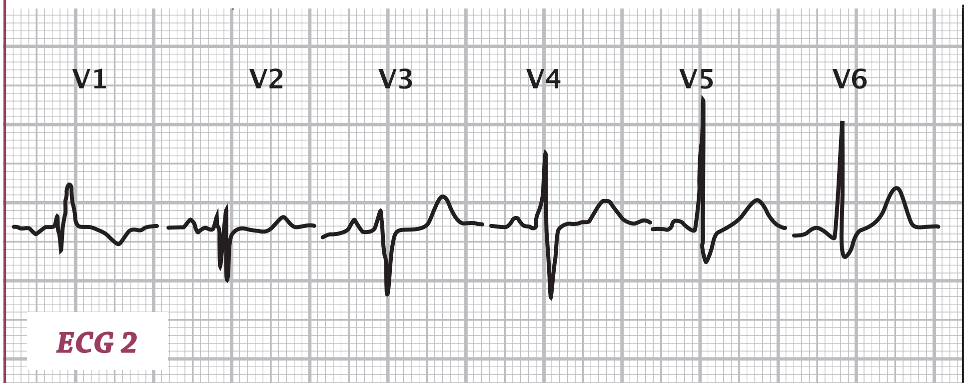
Level 5

QUIZ SECTION

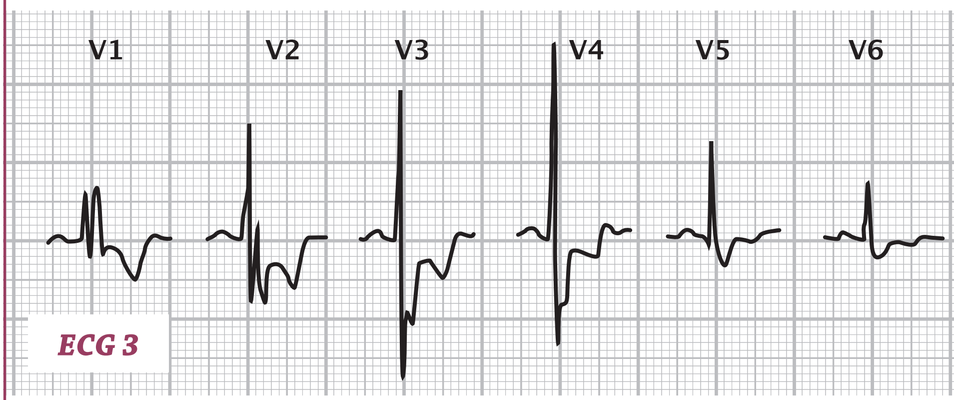
And now it's time for some exercises ...



ECG 1

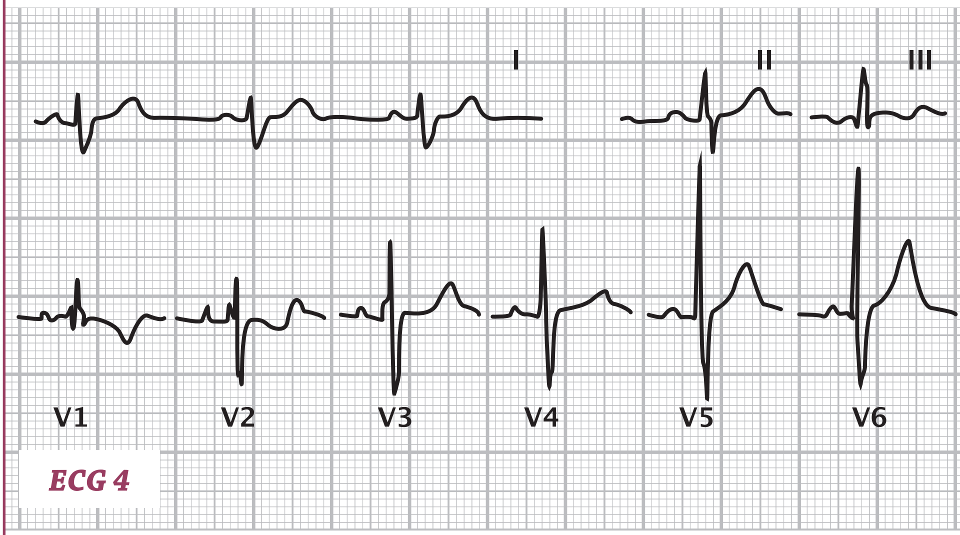


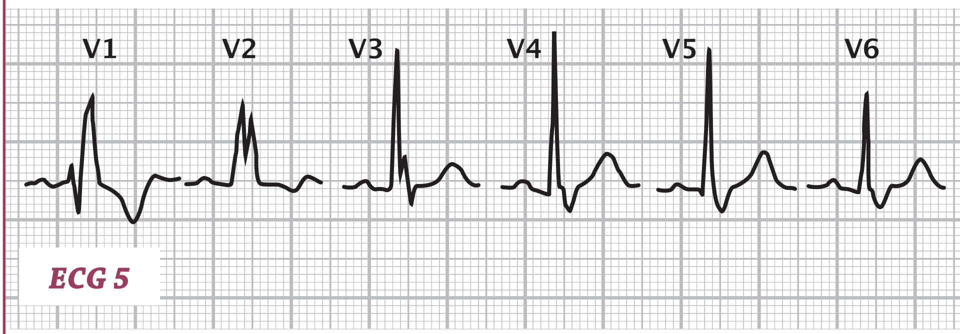
ECG 2

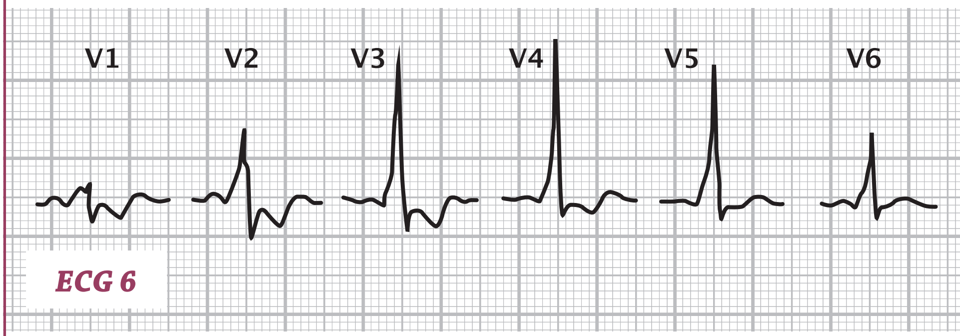


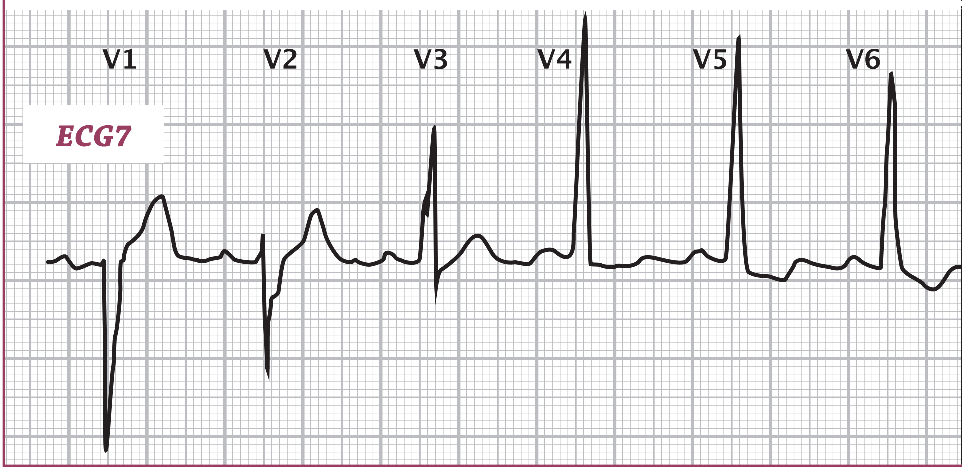
ECG 3

	Diagnosis					Diagnostic criteria				
	Complete right bundle branch block	Complete left bundle branch block	Volume overload right ventricle	Volume overload left ventricle	WPW syndrome	Duration of the QRS complex	(V1) QRS shape	(V6) QRS shape	Duration of the PR interval	Delta wave in leads:
ECG 1										
ECG 2										
ECG 3										









Diagnosis					Diagnostic criteria				
Complete right bundle branch block	Complete left bundle branch block	Volume overload right ventricle	Volume overload left ventricle	WPW syndrome	Duration of the QRS complex	(V1) QRS shape	(V6) QRS shape	Duration of the PR interval	Delta wave in leads:

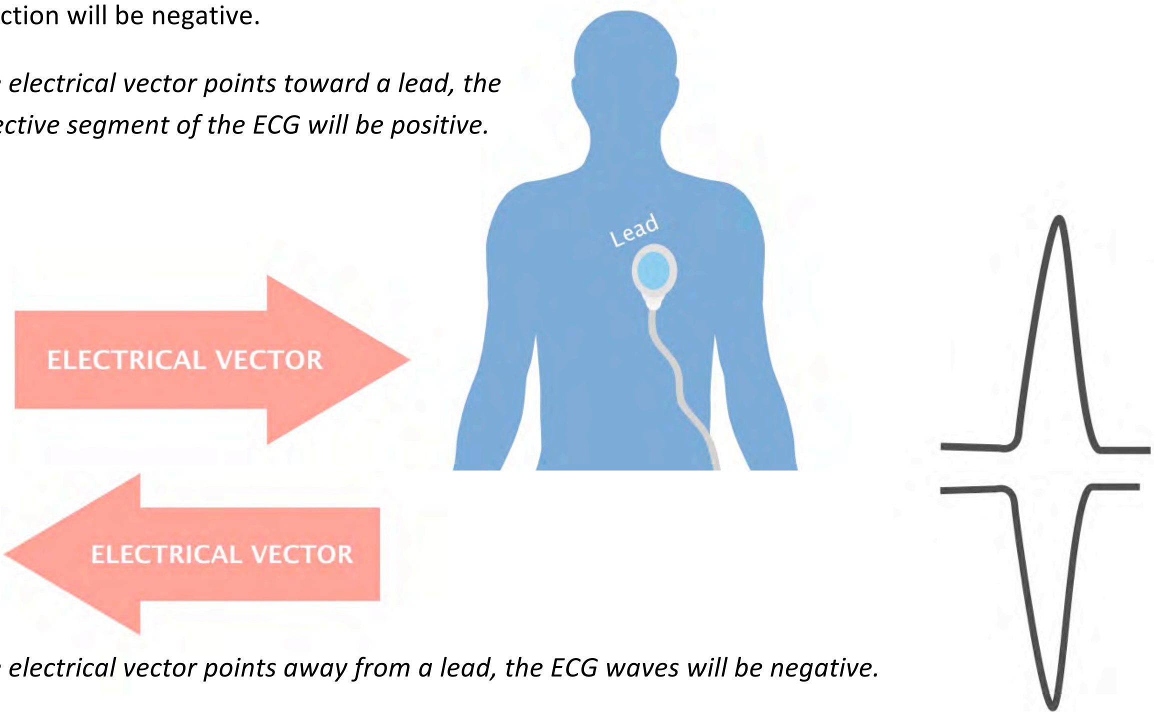
Level 6: What you really need to know about ventricular hypertrophy

The ECG is an important tool for the identification of left ventricular hypertrophy. In this chapter, you'll learn what to look for.

We learned in Level 4 that R waves increase as we go from right (V1) to left (V6). The size of the R wave is a reflection of the myocardial mass underneath the lead. That's why the R waves over the thin-walled right ventricle (V1 and V2) are smaller than the R waves over the muscular left ventricle (V5 and V6).

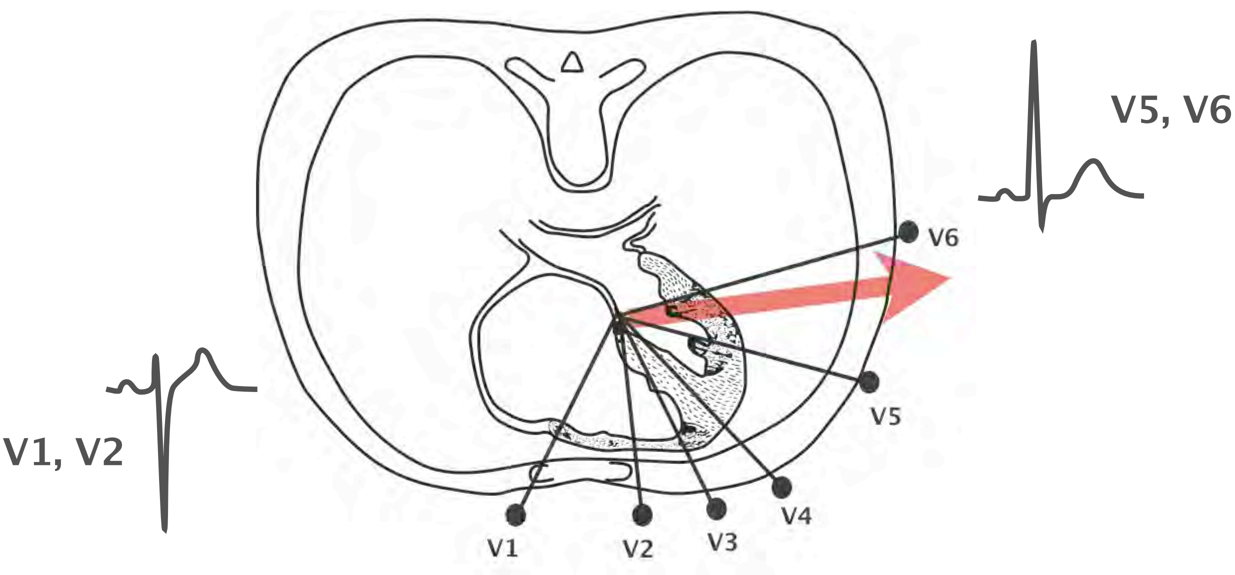
The waves of the ECG are a product of electrical depolarization. If depolarization moves toward a lead, the respective segment of the ECG wave will be positive. If depolarization moves away from the lead, the deflection will be negative.

If the electrical vector points toward a lead, the respective segment of the ECG will be positive.



If the electrical vector points away from a lead, the ECG waves will be negative.

It follows that a strong electrical vector that points in the direction of V5 and V6 produces a large R wave in V5 or V6 and a deep S wave in the opposite leads V1 and V2. In other words, the S wave in V1 and V2 is more or less a mirror image of the R wave in V5 and V6.



So remember:

The higher the R wave over the left ventricle, the larger the muscular mass of the left ventricle (a direct sign of left ventricular hypertrophy).

The deeper the S wave over the right ventricle, the larger the muscular mass of the left ventricle (an indirect sign of left ventricular hypertrophy).

The Sokolow index

Under normal circumstances the left ventricle has a higher muscular mass than the right ventricle. In order to assess whether (abnormal) left ventricular hypertrophy is present, the **Sokolow index** can be used. It basically takes the preceding two statements and turns them into numbers. Here's how it's done:

1. Take the R (mV) in V5 or V6 (whichever one is taller).
2. Add the S (mV) in V1 or V2 (whichever one is deeper).
3. If the resulting number is over 3.5mV, left ventricular hypertrophy is probably present.

Sometimes the R wave in a left ventricular lead alone exceeds 2.5 mV; this can also be interpreted as a sign of LVH.

The following example illustrates how to use the Sokolow index:

We'll use the R in V5 because it's taller than the R in V6. The amplitude of that R wave is 2.2mV. Then we'll measure the S in V2 because it's deeper than the S in V1. That S wave is 3.1mV. Then we add up those numbers: 2.2 + 3.1 = 5.3mV. Since 5.3 is larger than 3.5, left ventricular hypertrophy is probably present.

However, this technique should be used with caution. False positive and false negative results may occur. Also, this method is not suitable for patients under the age of 35 years. A lot of people in this age group will exceed the threshold of 3.5mV without having left ventricular hypertrophy (which means high rates of false positives!).

Now, let's turn to right ventricular hypertrophy…

The ECG can also be used to assess right ventricular hypertrophy. However, all too often, clinicians forget about it—probably because it's just a little bit trickier than the assessment of left ventricular hypertrophy.

There are a couple of ECG findings that can be used for the assessment of right ventricular hypertrophy. Here are the ones that we find most useful—we call them our **RSS criteria**:

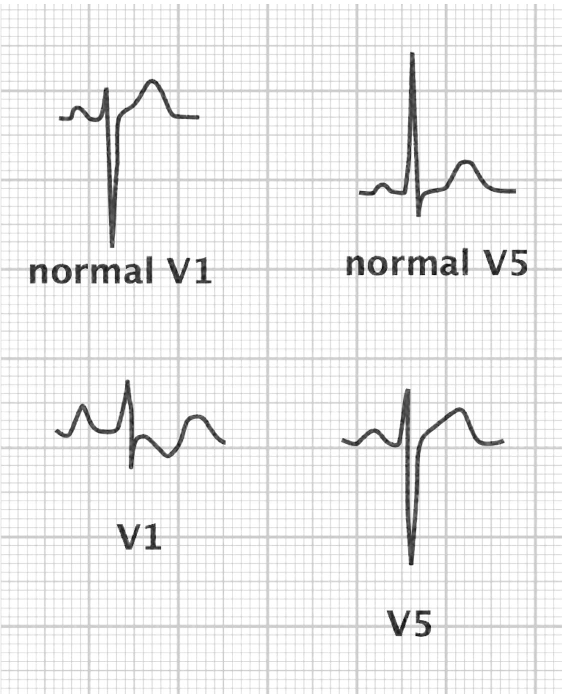
Criteria #1: Look at the **R** in V1; positive if it's ≥ 0.5mV

Criteria #2: Look at the **S** in relation to the R in V1**;** positive if the R/S ratio in V1 ≥ 1

Criteria #3: Look at the **S** in V5: positive if ≥ 0.5mV

If two of the three criteria are positive, right ventricular hypertrophy is probably present. If right axis deviation (taught in Level 11) or an incomplete right bundle branch block are also present, the likelihood of right ventricular hypertrophy increases even further.

Here's an example:



normal patient

RSS **right ventricular hypertrophy**

#1: **R (V1) = 0.7mv → positive**
#2: **R/S (V1) = 0.7/0.3 = 2.3 → positive**
#3: **R (V5) = 1.2mV → positive**

In this example, all RSS criteria are positive. So right ventricular hypertrophy is probably present.

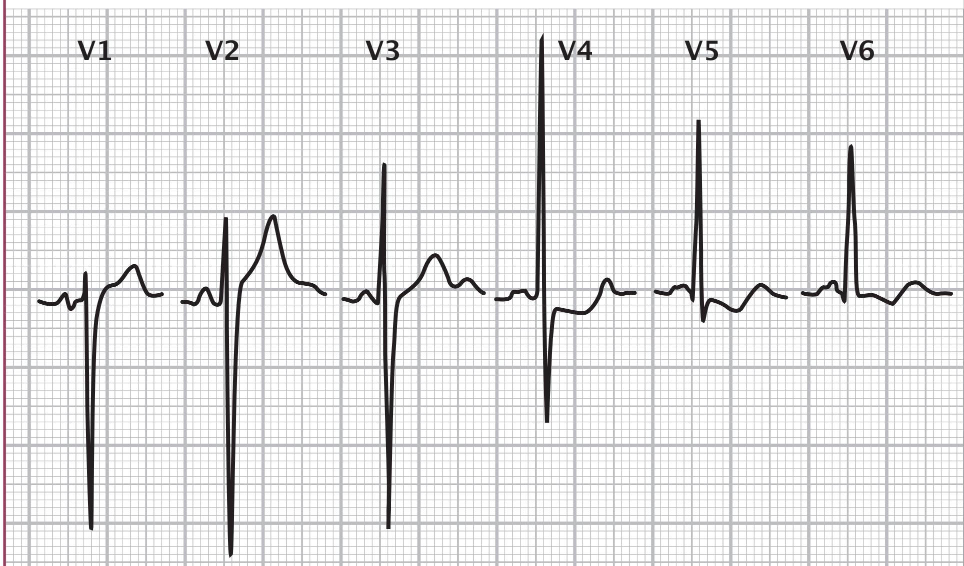
Note that this suspicion always has to be confirmed with echo.

Level 6

QUIZ SECTION

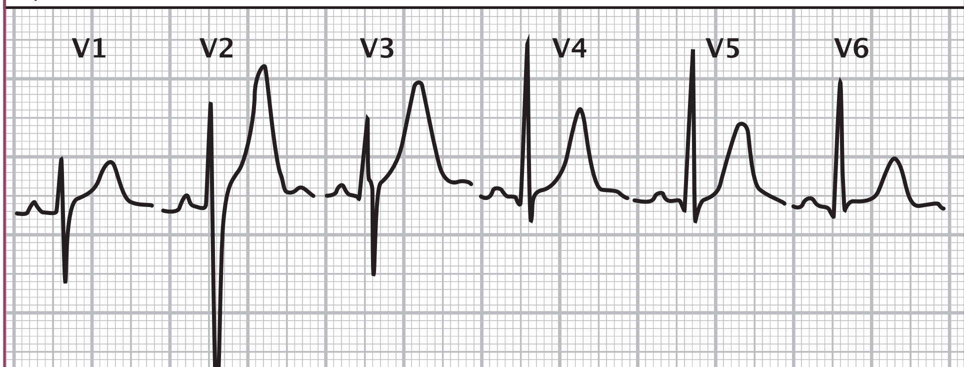
Use the above method to complete the following examples. Fill in your measurements (R waves, S waves and R/S ratios) on the lines below the leads. You don't need to mark the measurements below every lead – just the ones that are relevant. It should be quite obvious from what we've discussed in this level what the relevant leads are. After you've performed the measurements, choose from the four possible diagnoses given on the right side of each example. Use the method taught in Level 4 for the assessment of rotation.

	Left ventricular hypertrophy	Right ventricular hypertrophy	Left ventricular volume overload	Right ventricular volume overload	Rotation		
					Counter clockwise	Clockwise	Normal transition zone
ECG 1							
ECG 2							



ECG 1

R (mV)	
S (mV)	
R/S ratio	

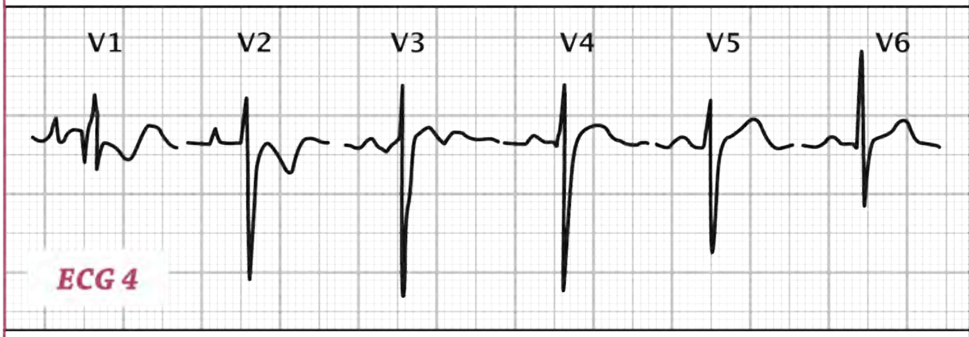


ECG 2

R (mV)	
S (mV)	
R/S	

Left ventricular hypertrophy	Right ventricular hypertrophy	Left ventricular volume overload	Right ventricular volume overload	Rotation: Counter clockwise	Rotation: Clockwise	Rotation: Normal transition zone

R (mV)	
S (mV)	
R/S	

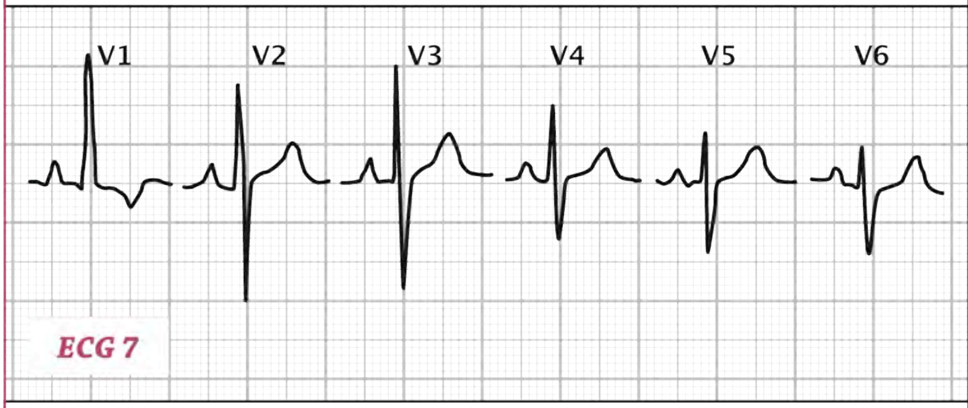


R (mV)	
S (mV)	
R/S	

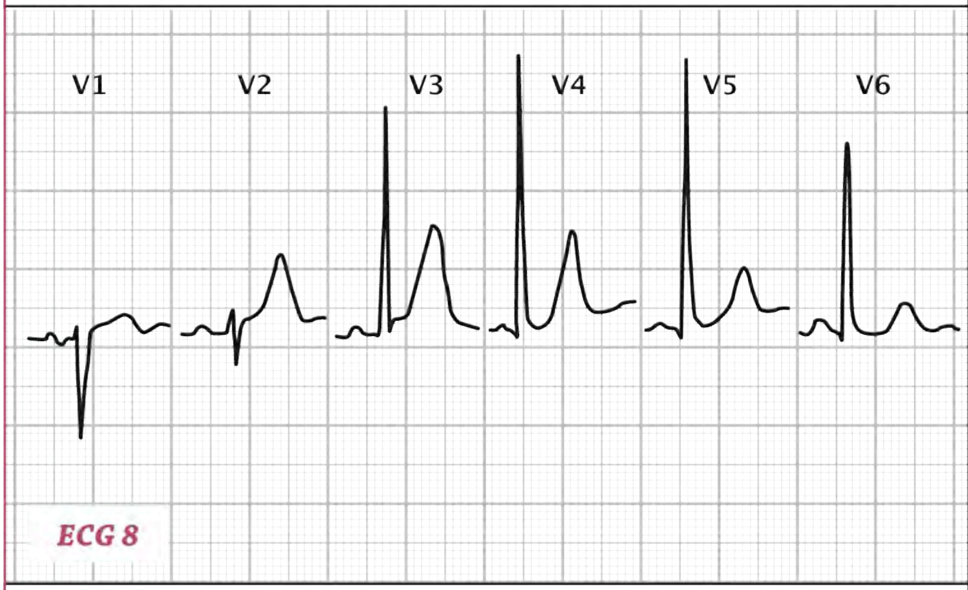
R (mV)	
S (mV)	
R/S	

Left ventricular hypertrophy	Right ventricular hypertrophy	Left ventricular volume overload	Right ventricular volume overload	Rotation: Counter clockwise	Rotation: Clockwise	Rotation: Normal transition zone

R (mV)						
S (mV)						
R/S						



R (mV)						
S (mV)						
R/S						

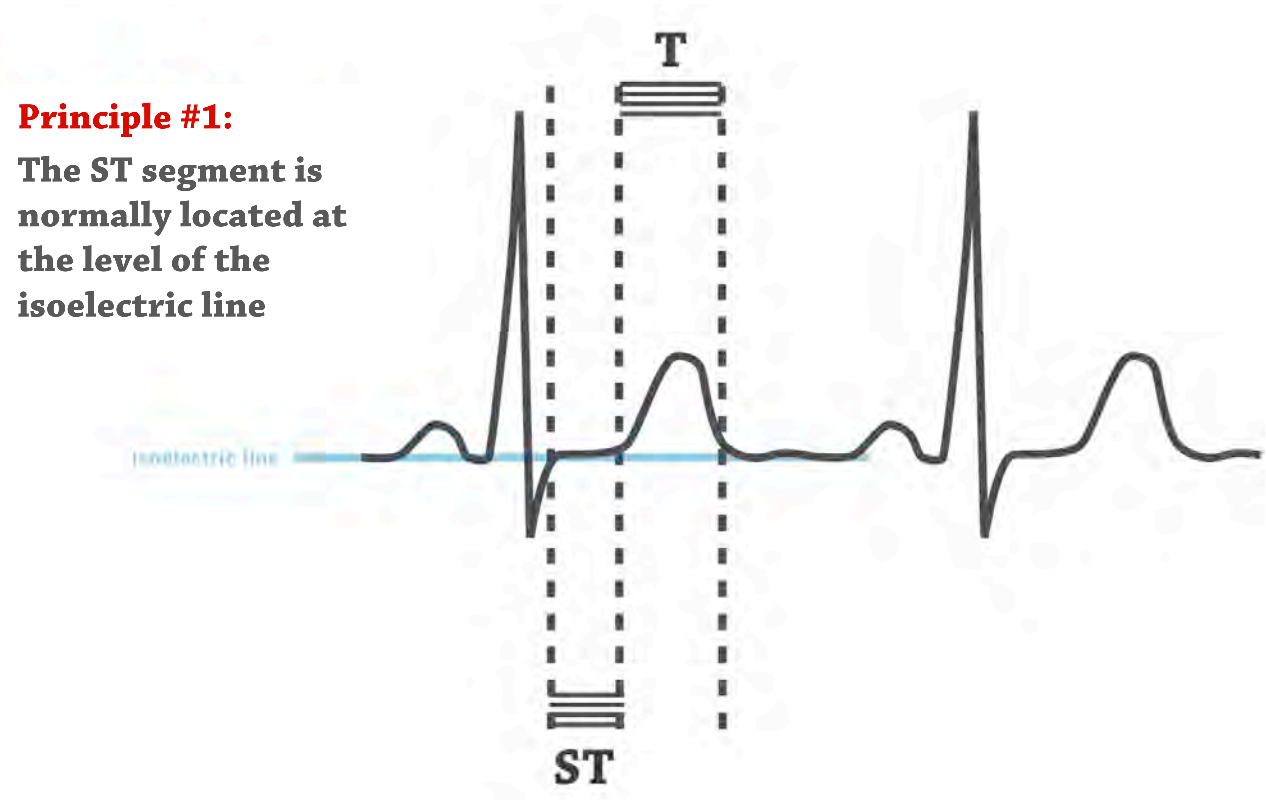


R (mV)						
S (mV)						
R/S						

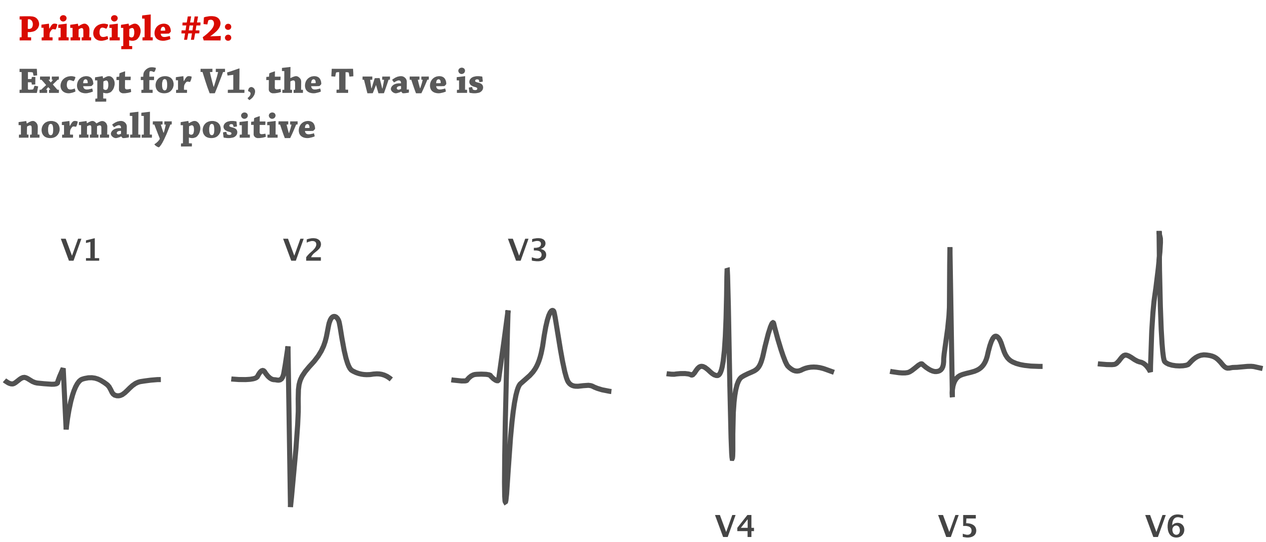
Level 7: ST depression and T negativity—a simple approach

ST depression and T wave negativity are commonly associated with debilitating and potentially life-threatening diseases. Every ECG student should be able to recognize and interpret them. So pay close attention.

Let's start off with two simple principles:



By definition, the isoelectric line is located at the level of the ECG curve that comes after the T wave, before the next P wave.



Once you recognize the presence of ST depressions or T wave inversions, you should look at two things:

1. Their location (which leads are affected).
2. Their shape.

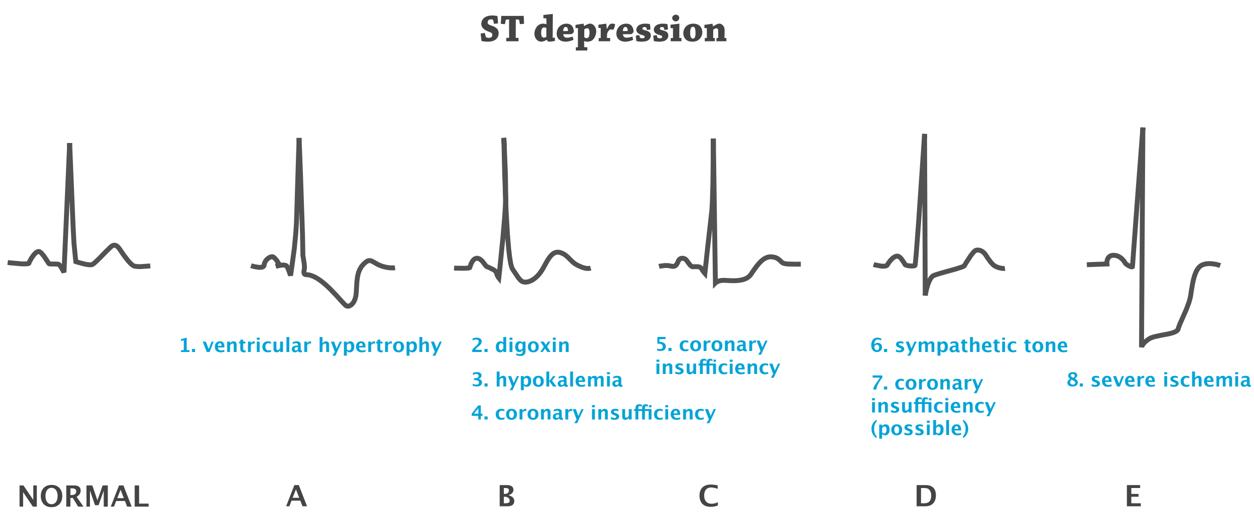
Talking about location…

In level 4, you learned what leads depict which parts of the ventricle. So if ST depression is present in V5 and V6 for example, you know that it's the lateral wall that has a problem.

Talking about shape…

The different forms of ST depressions

In our experience, you can tell a lot about the underlying pathologies if you know how they change the morphology of the ST segment. Here are some examples:



Example A: A descending ST depression is usually associated with ventricular hypertrophy.

Examples B, C and D: These are only relevant over the left ventricle (One exception to this rule are mirror images of a posterior wall ST elevation myocardial infarction, which will also produce similar ST depressions in V1, V2, and V3. More about that in level 9.)

Example B: ST depression with a sagging morphology—this may be caused by coronary insufficiency (angina), digoxin, or hypokalemia.

Example C: Horizontal ST depression, typically seen in patients with coronary insufficiency (i.e., symptomatic coronary heart disease).

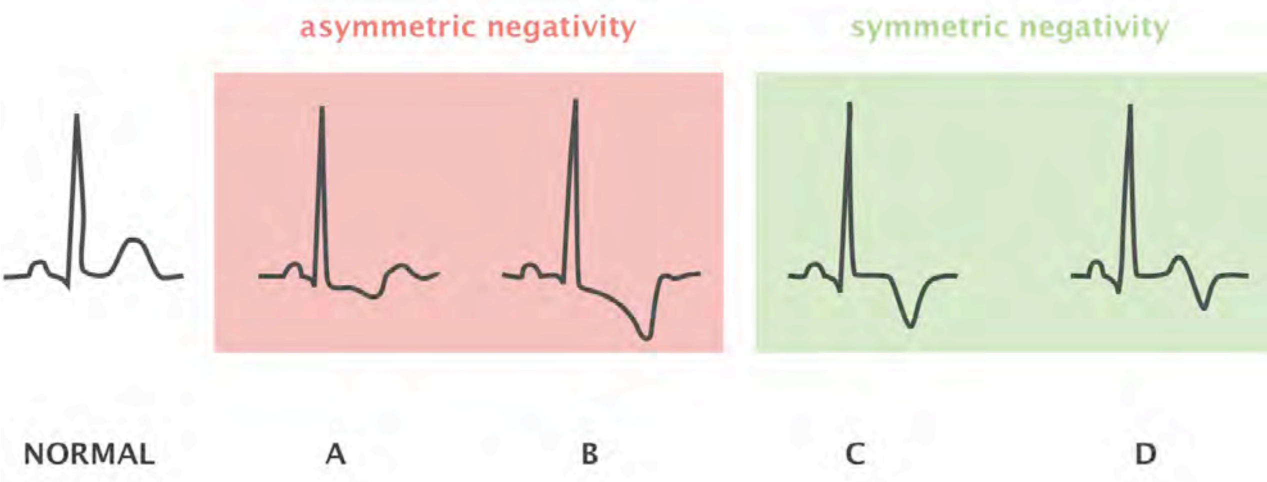
Examples B and C: Commonly seen in patients with exercise-induced angina undergoing stress test.

Example D: Ascending ST depression may be caused by high sympathetic tone, but also by physical activity. During physical activity, ascending ST depressions do not necessarily mean that ischemia is present.

Example E: Deep horizontal ST depressions are often seen in several corresponding leads in the setting of severe ischemia.

Patterns of negative T waves (also known as T wave inversions)

Here are the most important patterns of inverted T waves:



Different patterns of T wave inversions.

On the far left side, you can see a normal T wave for comparison. The other four patterns are negative and—therefore—abnormal. There's an important distinction that you need to make here:

- The T waves in examples A and B are **asymmetric**. They are slowly downward-sloping with an abrupt return to the isoelectric line.
- The negative T waves in examples C and D, on the other hand, are **symmetric**.

This distinction is important because these changes occur in two distinct settings with hugely different implications:

- **Asymmetric T wave inversion** usually occurs in the setting of ventricular hypertrophy. When the left ventricle is hypertrophic, the inversions are located somewhere between V4 and V6. When the right ventricle is affected, they can be seen somewhere between V1 and V3.
- **Symmetric T wave inversion** occurs in a setting where myocardial cells are dying off—usually in the setting of myocardial ischemia or myocarditis.

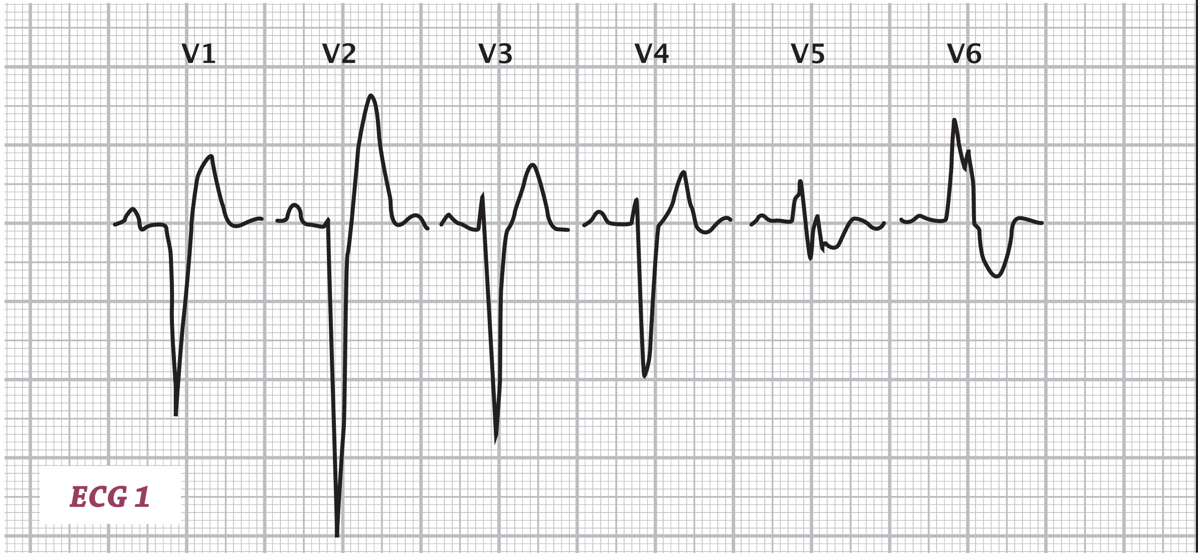
T wave inversion can also be **biphasic**, as in example A, in which we see a negative-positive pattern; whereas in example D we see a positive-negative pattern (terminally negative). Terminal negativity of the T wave has a high specificity for coronary artery disease, especially when the terminal part is symmetric.

T waves are also abnormal if they are not positive "enough." With predominant R waves, T waves should be at least 1/8 the size of the R wave. T waves may also be abnormal if they are "flat" or even horizontal.

*In right and left **bundle branch block**, repolarization is also impaired. Therefore, we can see negative T waves and ST depressions in leads V1 to V3 in right bundle branch block and in V4 to V6 in left bundle branch block. Two other common problems associated with negative T waves and ST depressions are **premature ventricular beats** and **Wolff-Parkinson-White syndrome**.*

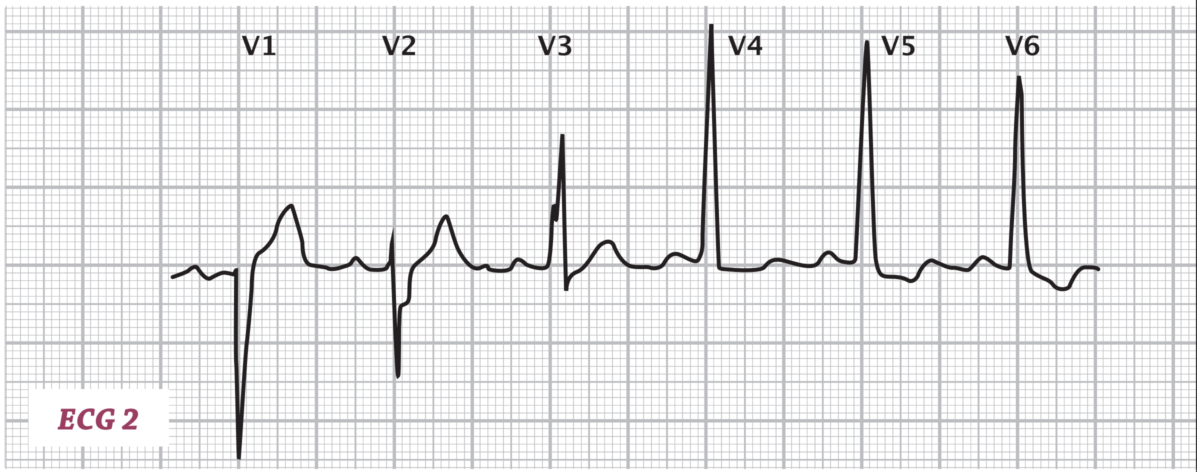
Level 7
QUIZ SECTION

In the following exercises, please describe the pattern of ST segment changes (e.g., horizontal, descending, etc.) as well as T wave changes (e.g., symmetric, asymmetric, biphasic, etc.) and decide what the underlying diagnosis could be.

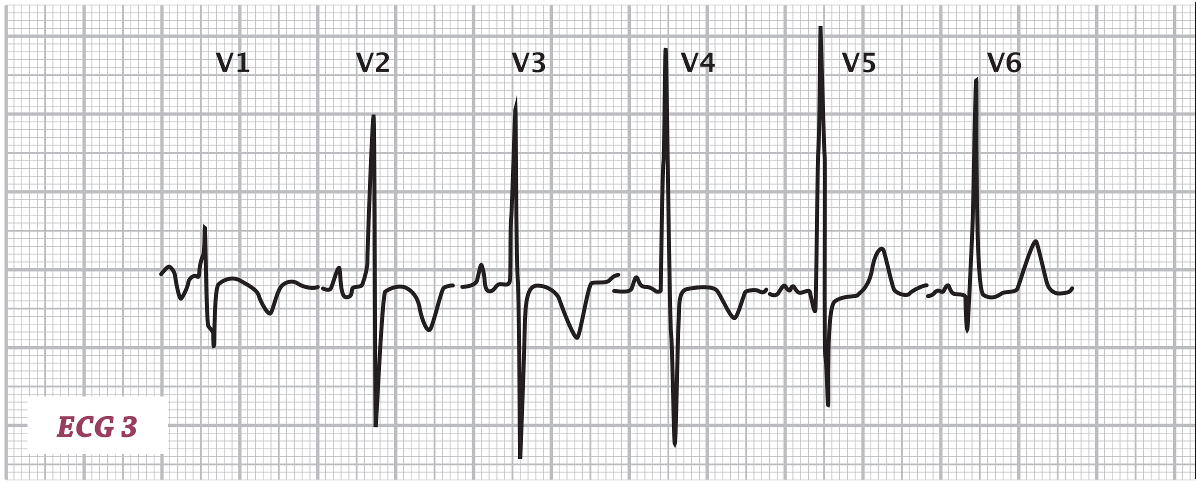


ECG 1

ST depression					T negativity						Diagnosis						
Descending	Sagging OR U–shaped	Horizontal	Ascending	None	Flat	Neg. / pos. biphasic	Asymmetrically negative	Symmetrically negative	Pos. / neg. biphasic	None	Left ventricular hypertrophy	Right ventricular hypertrophy	Complete left bundle branch	Complete right bundle branch	WPW syndrome	Coronary ST depression	Coronary T wave inversion

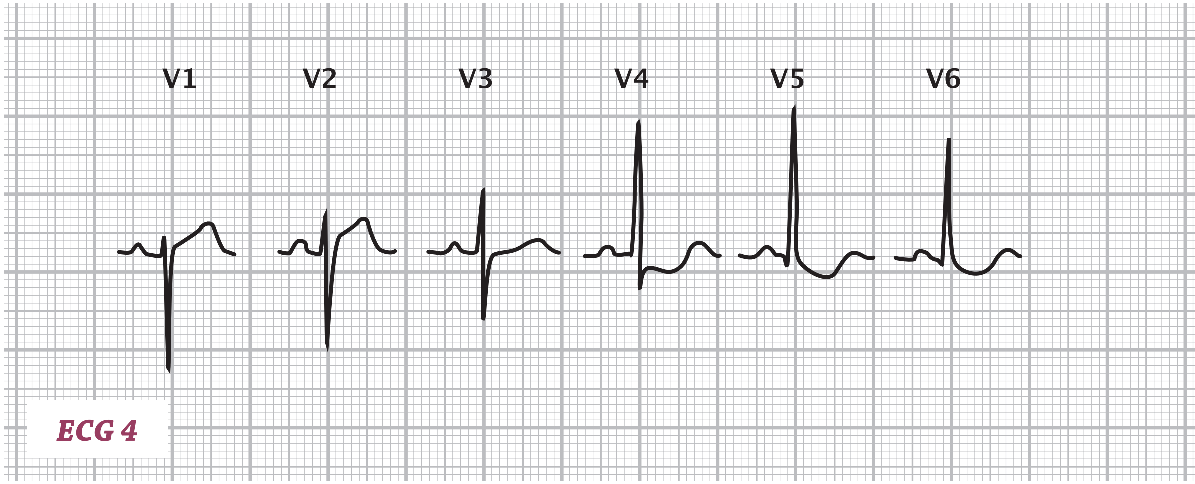


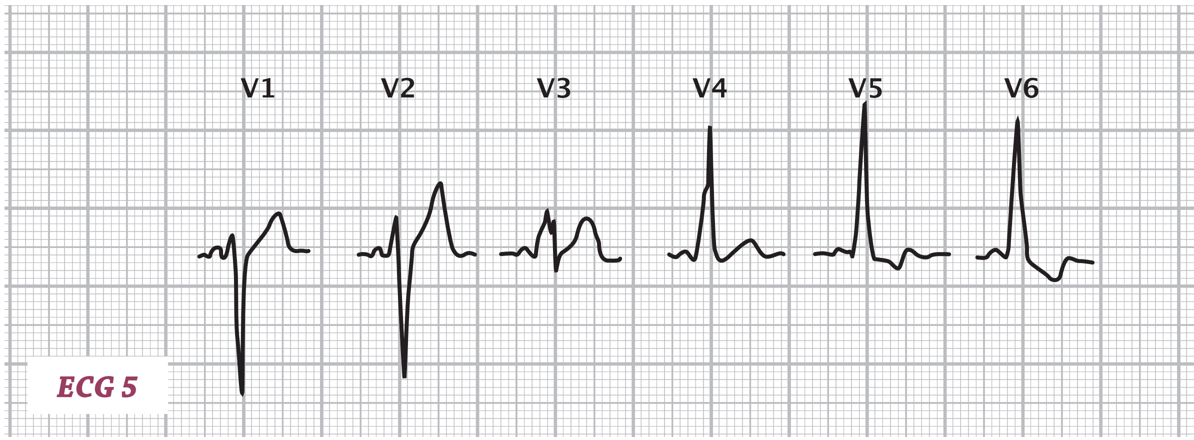
ECG 2



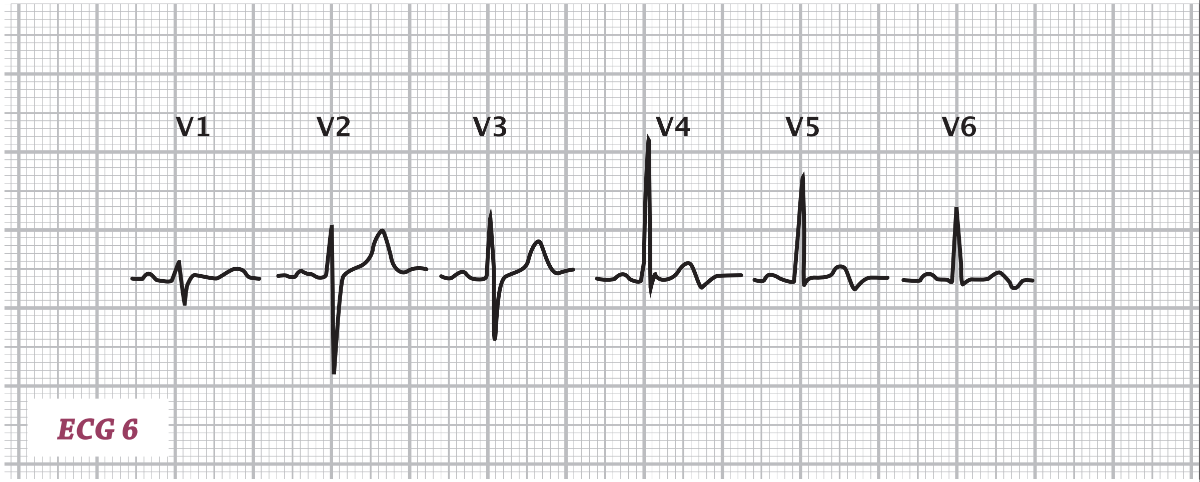
ECG 3

	ST depression					T negativity						Diagnosis						
	Descending	Sagging OR U-shaped	Horizontal	Ascending	None	Flat	Neg. / pos. biphasic	Asymmetrically negative	Symmetrically negative	Pos. / neg. biphasic	None	Left ventricular hypertrophy	Right ventricular hypertrophy	Complete left bundle branch	Complete right bundle branch	WPW syndrome	Coronary ST depression	Coronary T wave inversion
ECG 2																		
ECG 3																		

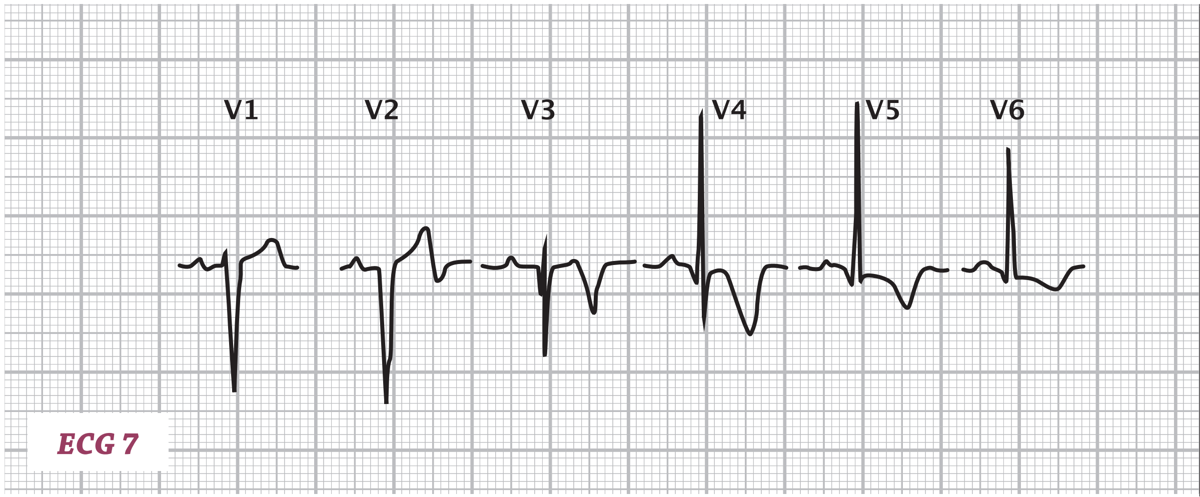




ST depression					T negativity						Diagnosis						
Descending	Sagging OR U-shaped	Horizontal	Ascending	None	Flat	Neg. / pos. biphasic	Asymmetrically negative	Symmetrically negative	Pos. / neg. biphasic	None	Left ventricular hypertrophy	Right ventricular hypertrophy	Complete left bundle branch	Complete right bundle branch	WPW syndrome	Coronary ST depression	Coronary T wave inversion



ECG 6



ECG 7

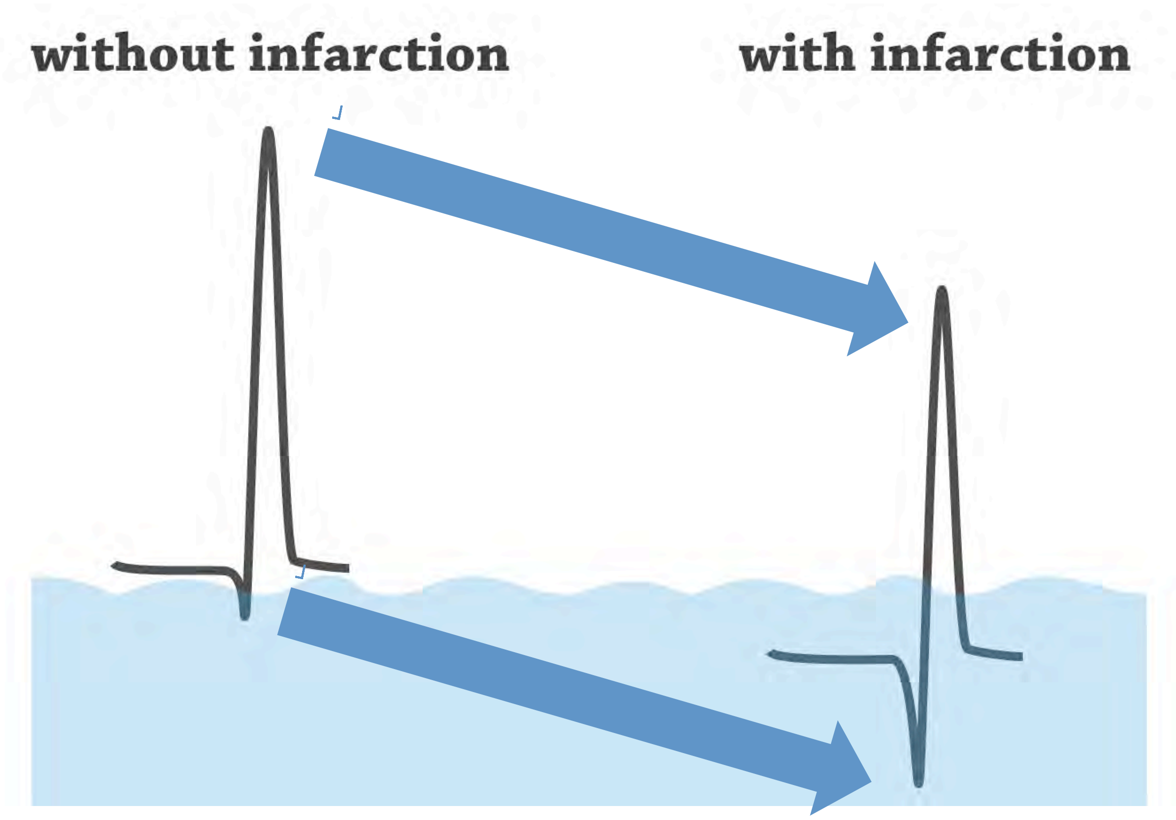
	ST depression					T negativity						Diagnosis						
	Downshaping	Sagging OR U-shaped	Horizontal	Upshaping	None	Flat	Neg. / pos. biphasic	Asymmetrically negative	Symmetrically negative	Pos. / neg. biphasic	None	Left ventricular hypertrophy	Right ventricular hypertrophy	Complete left bundle branch	Complete right bundle branch	WPW syndrome	Coronary ST depression	Coronary T wave inversion
ECG 6																		
ECG 7																		

Level 8: What everybody ought to know about myocardial infarction and the QRS complex

In this level, you are going to learn how myocardial infarction affects the appearance of the QRS.

Drowning in negativity

There's one big idea that you have to keep in mind in order to remember what myocardial infarction does to the QRS complex. And this big idea is: **drowning in negativity.**

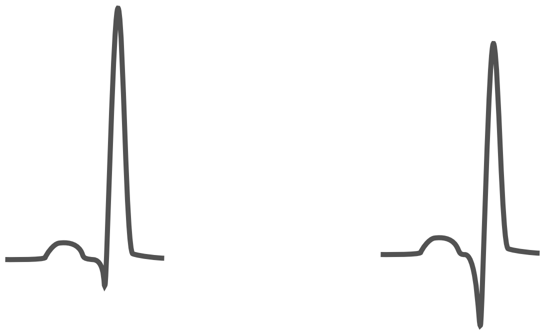


Drowning means that certain parts of the QRS become negative (Q waves) while other parts will decrease in size (R waves). In other words, one or more of the following things can happen:

- A preexisting **R wave** decreases in size
- A preexisting **Q wave** gets deeper
- A new **Q wave** develops

The resulting pattern is highly dependent on the initial form of the QRS complex. As we've said before, if you know what the QRS complex in each lead looks like, you'll also know when something's wrong.

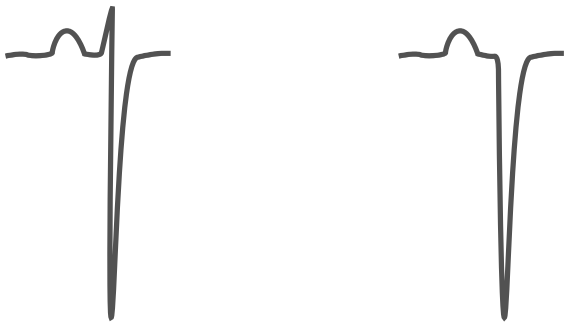
Let’s have a look at some examples:



without infarction **with infarction**

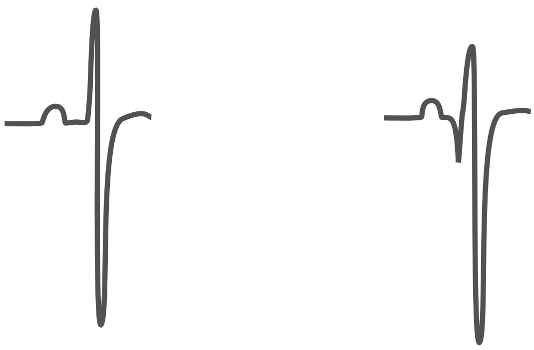
Example A: In this example, there’s an initial Q wave even without myocardial infarction. This could be V5 or V6 where we would typically see a small Q even in normal patients. When myocardial infarction develops, the Q gets much deeper than before—here it’s 1/3 the size of the R wave.

Small Q waves can be present in leads V5, V6, I, aVL, II, and III of healthy patients.



without infarction **with infarction**

Example B: Here we have a small initial R wave. This is the typical appearance of leads V1 or V2. When myocardial infarction develops, the R gets lost and we end up with one deep QS complex.



without infarction **with infarction**

Example C: In this example, the R wave is already pretty tall (left side, without infarction), while the S is still fairly deep (R/S ratio < 1). So this must be an area under leads V2 to V4. In these leads we usually don’t see any Q waves. But when myocardial infarction develops, there’s a new Q wave at the beginning of the QRS—the initial R wave is lost.

These changes appear over the parts of the ventricle that are affected by myocardial infarction, which makes localization of the affected area fairly easy.

Good to know: These changes to the QRS complex can be seen in acute AND old myocardial infarctions. When you observe them in a patient who does not have any symptoms of acute myocardial infarction, this probably means that you are dealing with an old infarct.

Pathologic or not pathologic—that is the question

It can sometimes be tricky to differentiate between normal Q waves and pathologic Q waves. Pathologic Q waves in the setting of myocardial infarction are usually deeper and wider than normal Q waves. The **criteria for pathologic Q waves** are:

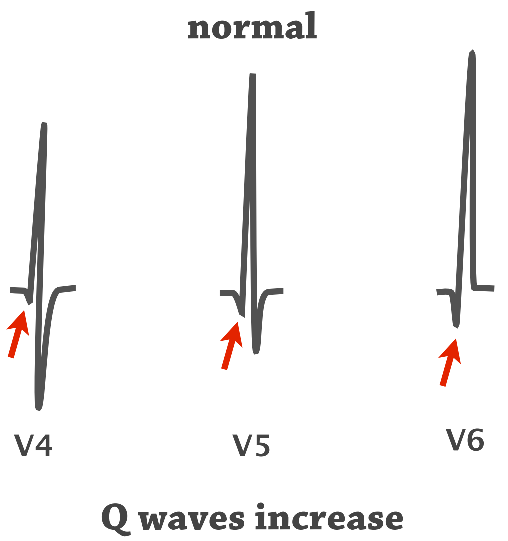
- The depth of the Q wave is ≥ 1/4 the size of the R wave in the same lead.

or

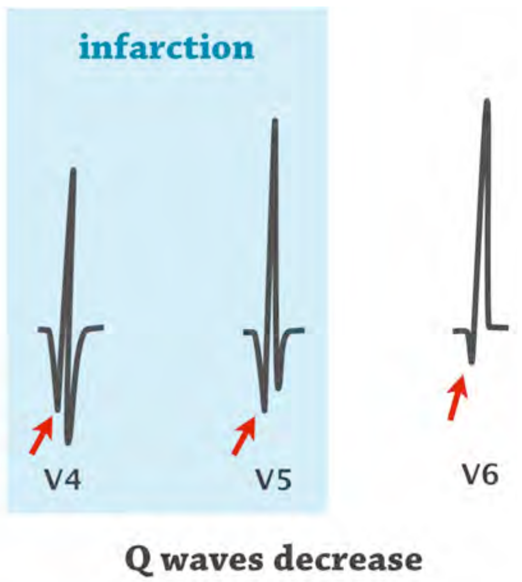
- The Q wave duration is > 0.04 seconds (1 small box on the ECG paper).

There are a couple of additional criteria but these are the ones you should remember for now.

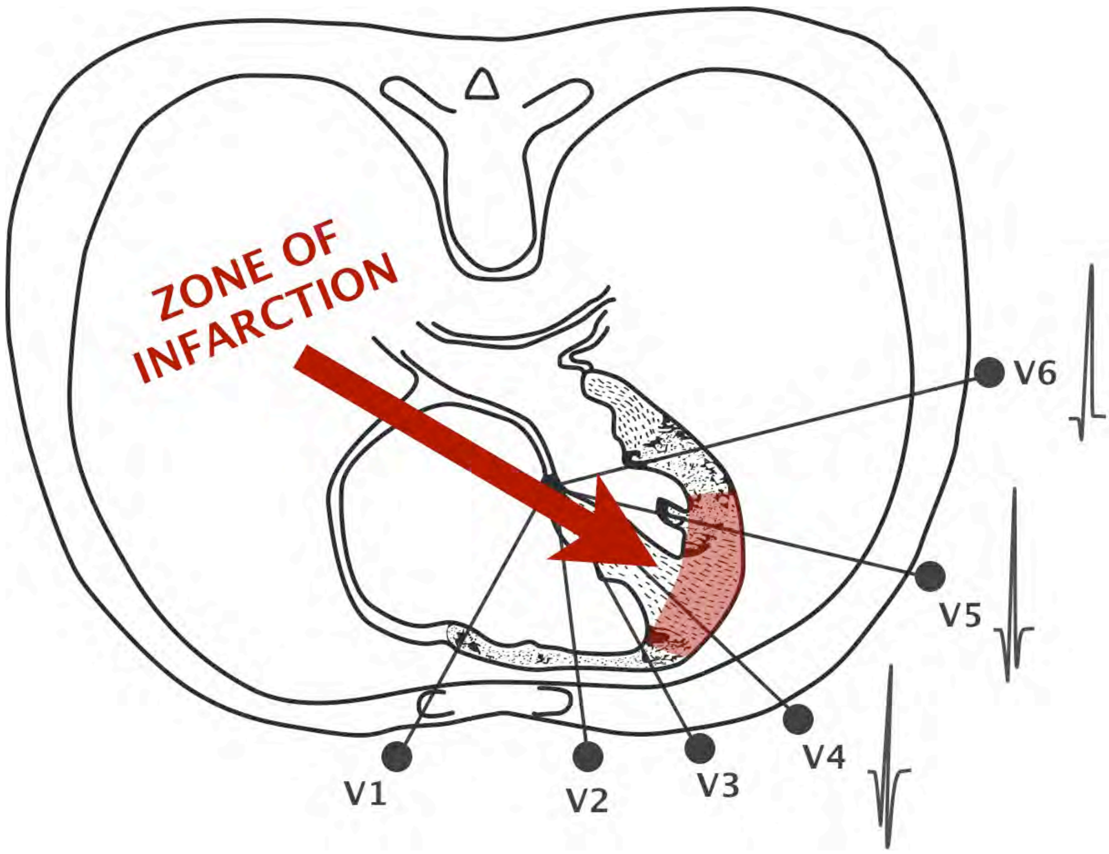
One other trick that you can use in the precordial leads is to look at the Q wave progression in leads V4 to V6. Under normal conditions, the depth of the Q wave increases as we go from V4 to V6, as seen on the following example:



However, when there's an infarct in the area of V4 and V5, Q waves will decrease in size as we go from V4 to V6, as seen in the following example:



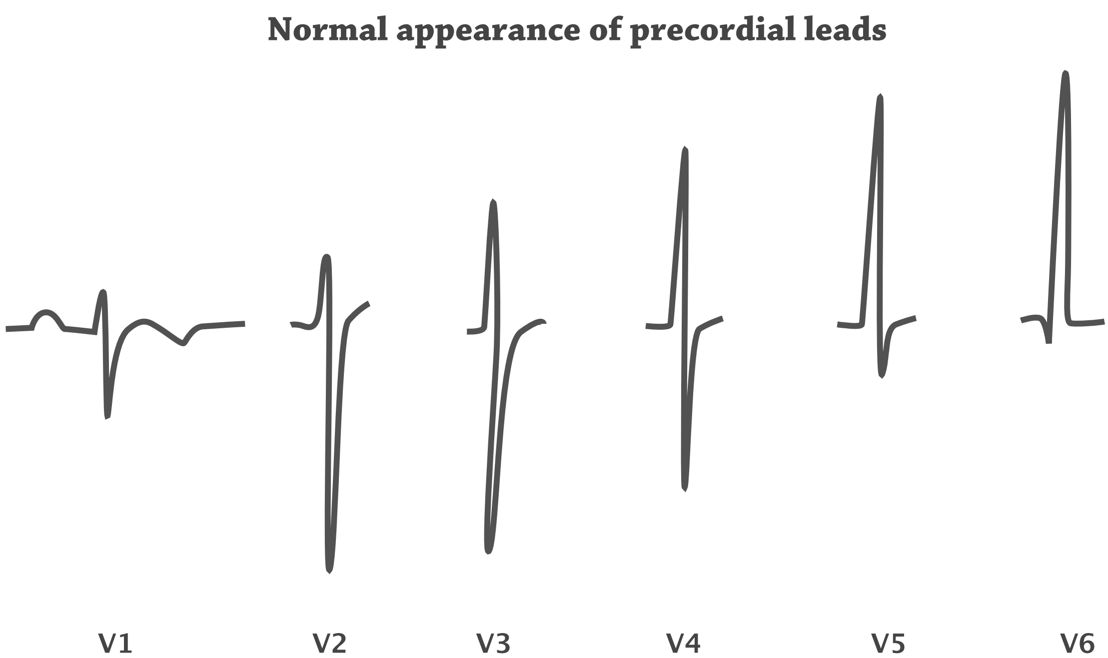
The following image shows an infarct at the anterolateral region. In this example, there will be pathologic Q waves in V4 and V5 that will be bigger and more pronounced than the small Q wave in lead V6.



So remember:

When Q waves get smaller from V4 to V6, myocardial infarction is probably present.

Now let's have a look at the normal appearance of the precordial leads again:

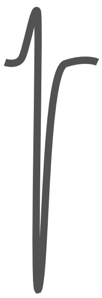


Two important tricks for your toolbox

We'll have to learn two important facts that are important for ECG mastery:

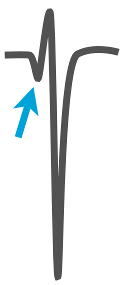
Fact #1 says: **Leads V1, V2, and V3 usually start with an initial R wave.**

V1 can sometimes come without an initial R wave but from V2 onward we almost always see it. In V3 the R is usually already pretty big.



small initial R seen in V1 and V2

Now take a look at this example:



Small initial Q wave.

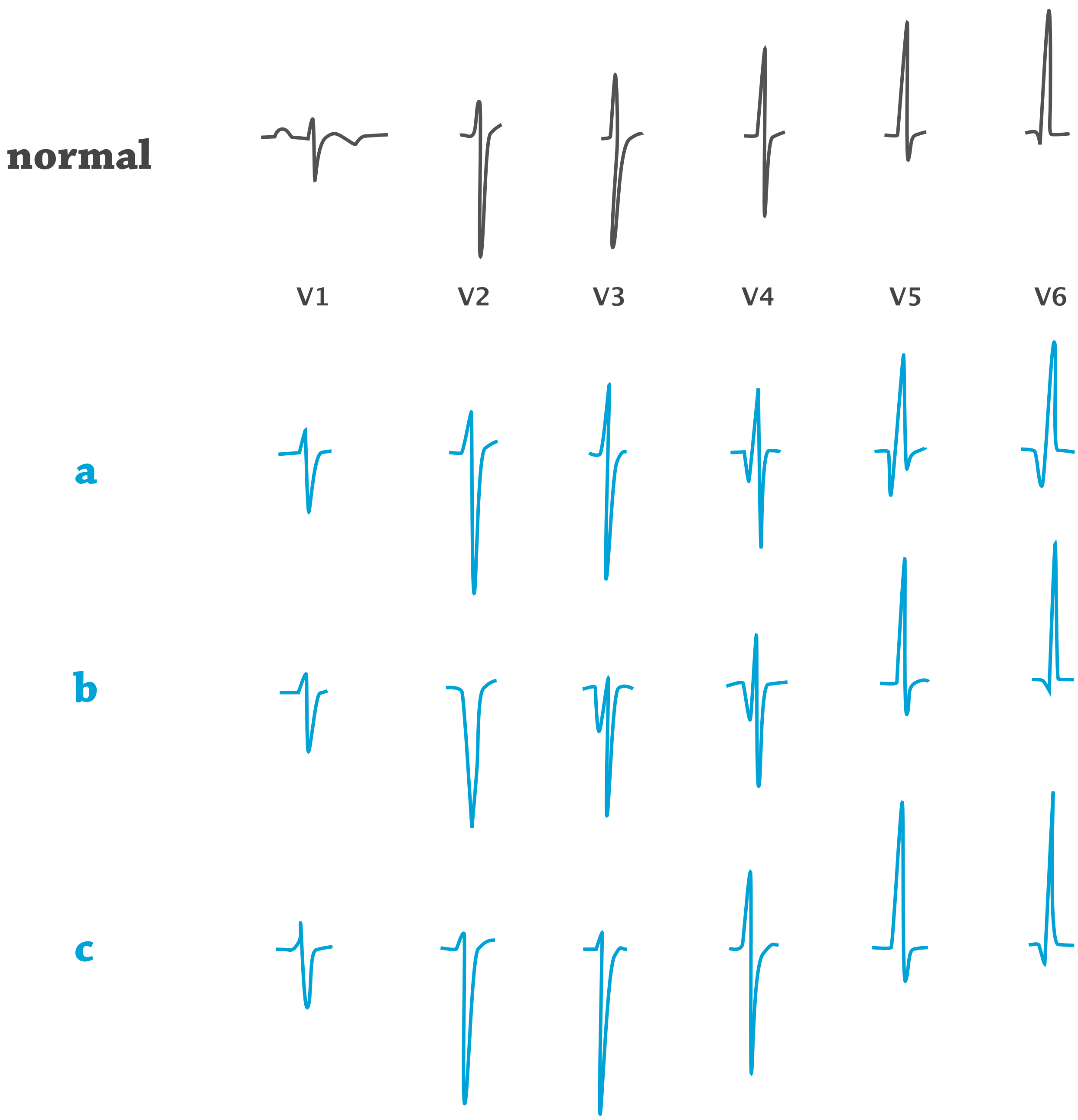
Beware of anything that looks like this in leads V1, V2 or V3!

This QRS also has a small R wave, but there's a small Q wave preceding it. If you see something like this in leads V1, V2, or V3, you should always remember Fact #1. Myocardial infarction is very likely in these cases.

Fact #2 says: **Normally R wave amplitudes increase as we go from V1 to V6.**

If R wave amplitude does NOT increase from V1 to V3 OR if R wave amplitude even decreases, we also have to think about the possibility of myocardial infarction in the anterior wall.

Now we'll look at some examples:



Example a: There are abnormal Q waves in leads V4 to V6. Also, R wave amplitude decreases from V3 to V4. These are clear signs of myocardial infarction of the anterolateral region (V4 = anterior wall, V5 and V6 = lateral wall).

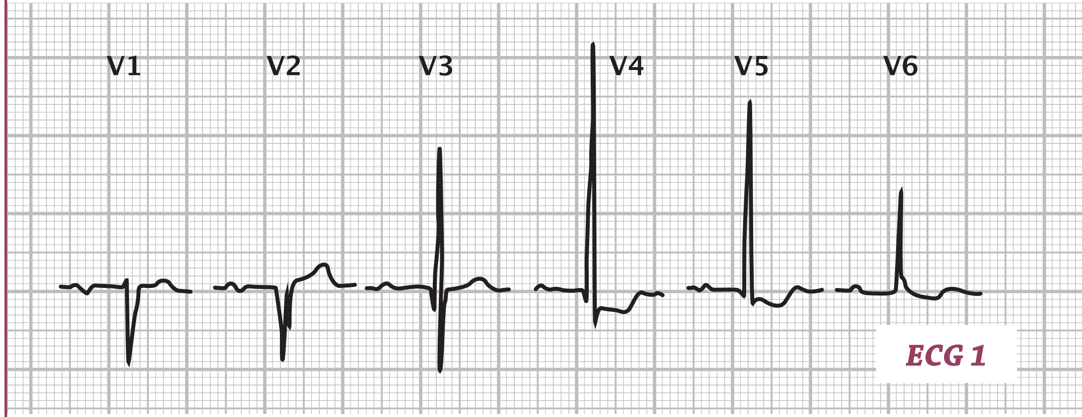
Example b: The R wave seen in V1 gets completely lost in V2 where we see a large QS complex. Furthermore, pathologic Q waves can be seen in V3 and V4. This is a clear case of an anterior wall myocardial infarction (V2 to V4 = anterior wall).

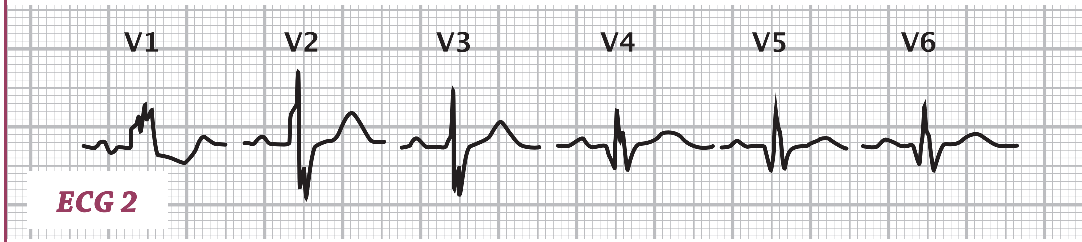
Example c: Here the signs of myocardial infarction are more subtle than in the previous examples. R wave amplitude decreases as we go from V1 to V2 and stays the same from V2 to V3. R wave progression in V4 is normal again. This is probably a case of myocardial infarction of the basal septum (V2 and V3 = basal septum).

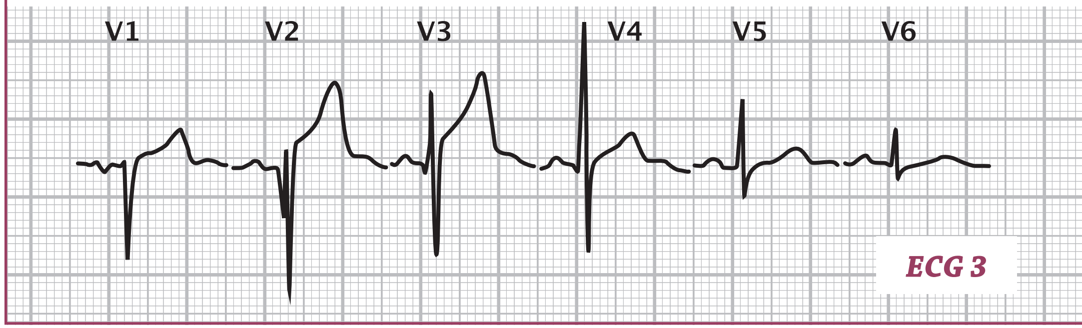
Level 8

QUIZ SECTION

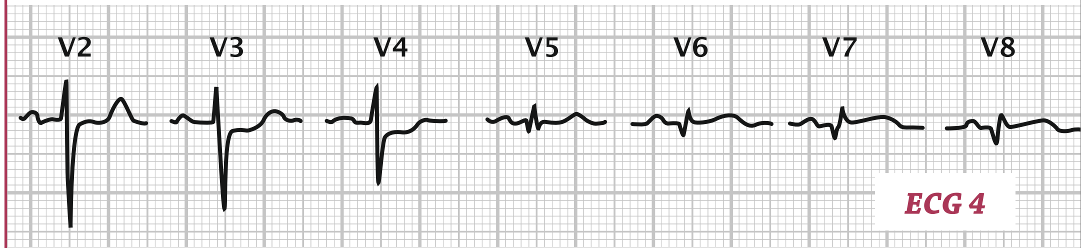
Now it's time for some exercises again!

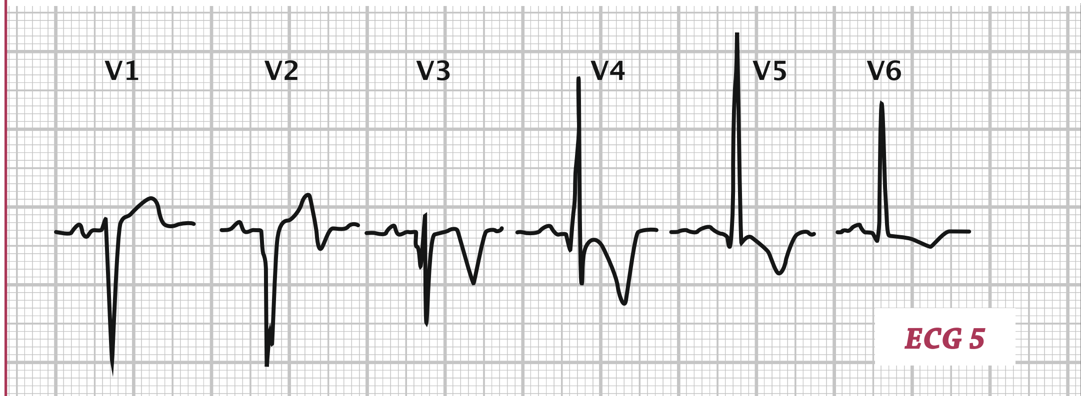






	Changes in QRS morphology related to myocardial infarction (pathologic Q wave, QS pattern, reduced initial R wave) can be found in leads								Infarction Localization						Which additional ECG changes can be found? (write them down)
	V1	V2	V3	V4	V5	V6	V7	V8	Anteroseptal	Anterior wall	Lateral wall	Anterolateral region	Posterior wall	Posterolateral region	
ECG 1															
ECG 2															
ECG 3															





Changes in QRS morphology related to myocardial infarction (pathologic Q wave, QS pattern, reduced initial R wave) can be found in leads								Infarction Localization						Which additional ECG changes can be found? (write them down)
V1	V2	V3	V4	V5	V6	V7	V8	Anteroseptal	Anterior wall	Lateral wall	Anterolateral region	Posterior wall	Posterolateral region	

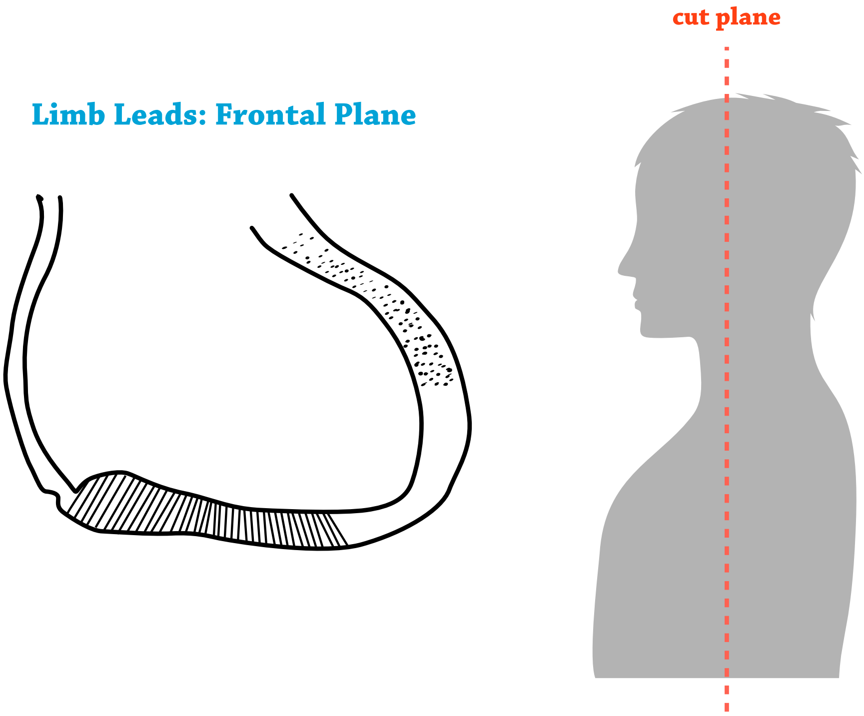
Level 9: Inferior wall myocardial infarction—pearls and pitfalls

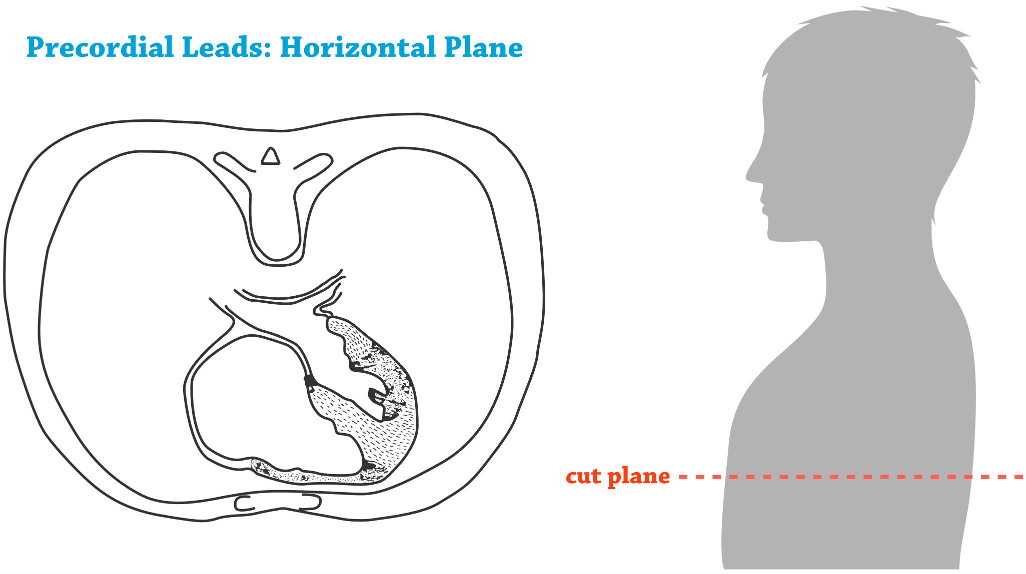
In the previous chapters, we focused on the precordial leads (chest leads). Learning the ECG works best if you have a thorough understanding of the precordial leads *before* learning about the limb leads. But now it's time to move on.

The limb leads

The limb leads and the precordial leads "look" at the heart from two different perspectives.

The precordial leads more or less show the horizontal plane, whereas the **limb leads** show the **frontal plane**.





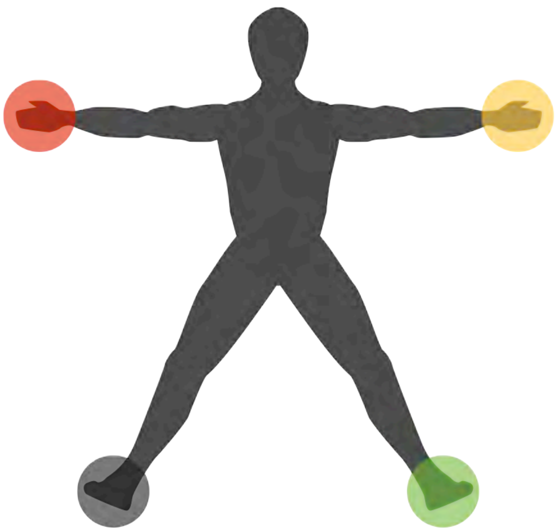
The limb leads consist of:

- Three standard leads called **I**, **II**, and **III**
- Three augmented leads called **aVR** (right arm), **aVL** (left arm), and **aVF** (foot)

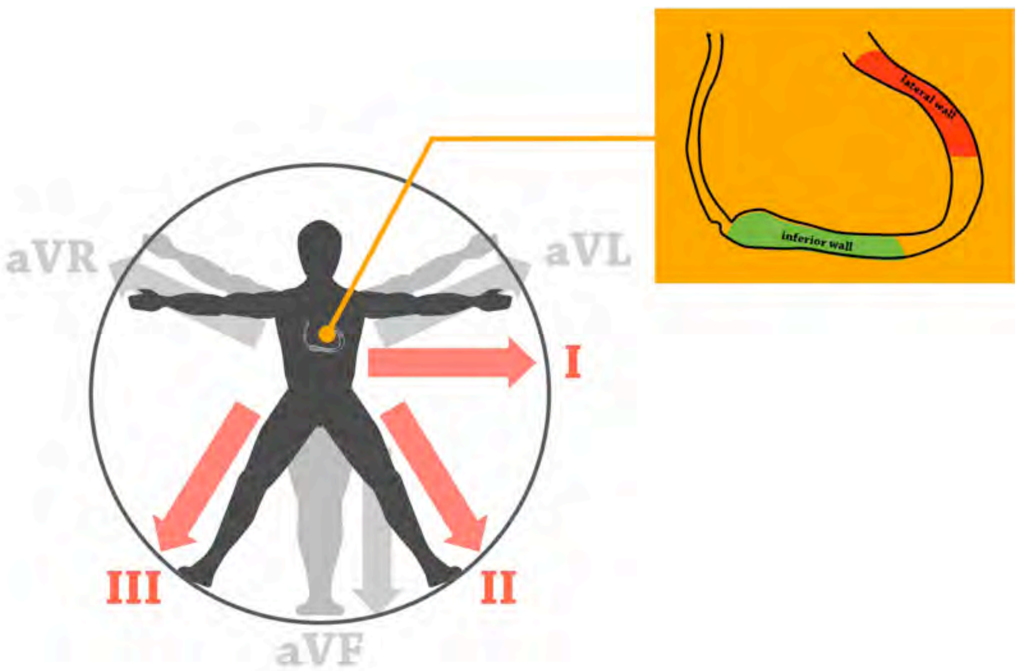
Four wires are needed in order to record these leads:

- The **red wire** goes onto the **right arm.**
- The **yellow wire** goes onto the **left arm.**
- The **green wire** goes onto the **left foot**.
- The **black wire** goes onto the **right foot.**

You can remember this sequence by picturing a traffic light with a red light on top, a yellow light in the middle, and a green light on the bottom:



Using these wires, you can now record the limb leads. As we said, these leads "look at" the electrical activity of the heart in a frontal plane:



The figure shows that changes of the lateral wall (red area), like myocardial infarction, are depicted by leads I and aVL. Changes in the inferior wall (green area) are depicted by leads II, III, and aVF.

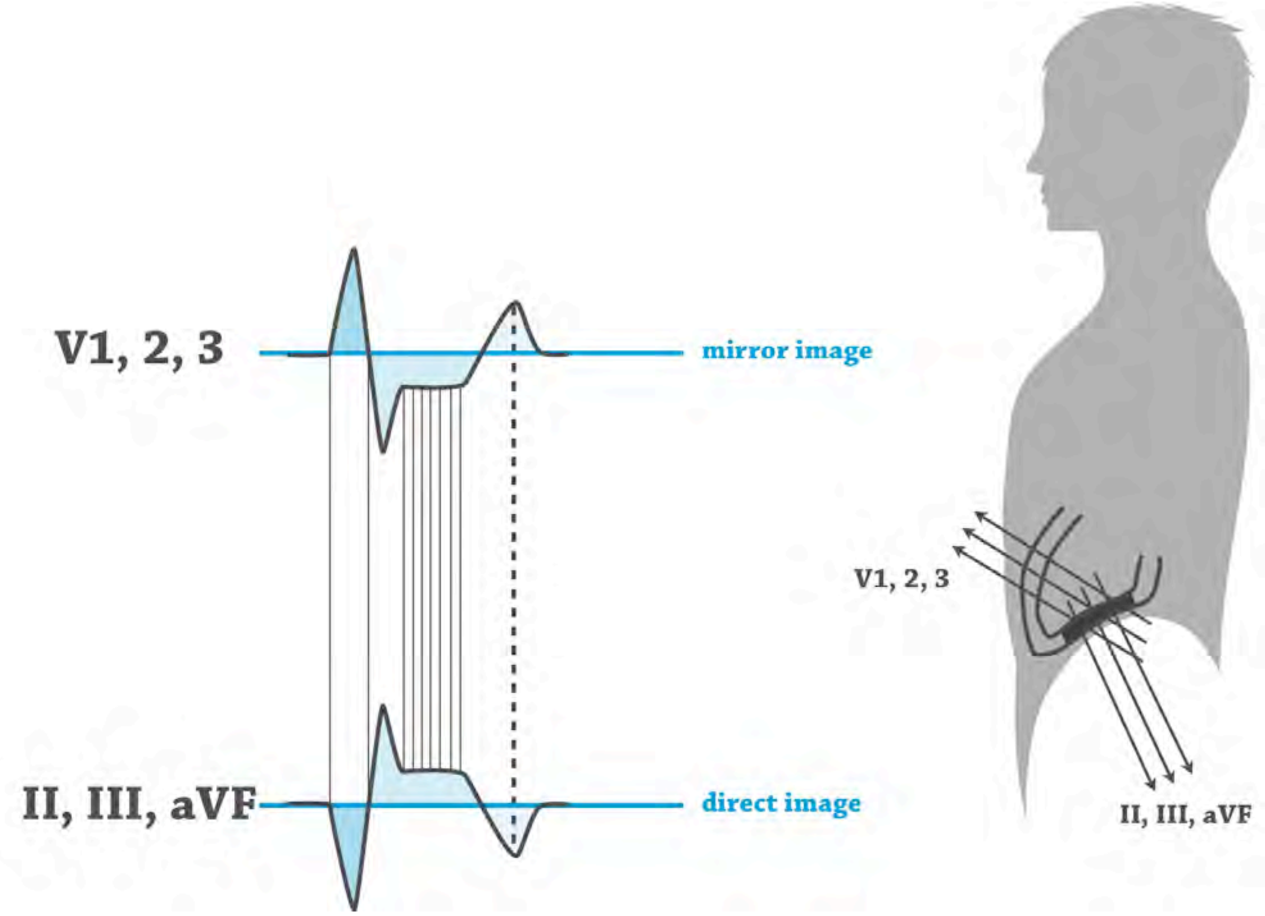
As we already learned, precordial leads V5 and V6 also depict the lateral wall. So we don't absolutely need leads I and aVL to make the diagnosis of problems of the lateral wall like myocardial infarction.

Conversely, the precordial leads don't show the inferior wall—at least not directly. So we need leads II, III, and aVF to evaluate the inferior wall.

Occasionally, leads II, III, and aVF will not detect inferior wall infarction, especially when it's small. That's when a little trick comes in handy.

Looking at mirror images

The direct electrical "image" of an inferior wall myocardial infarction is visualized in II, III, and aVF. Leads V1, V2, and V3 "look at" the heart from the opposite side and can therefore produce so-called mirror images:



Example of an inferior wall myocardial infarction. Direct changes can be seen in leads II, III, and aVF: deep and broad Q wave, ST elevation, and negative T wave. A mirror image can be seen in leads V1, V2, and V3: broad R wave, ST depression, and positive T wave.

So we have to update our knowledge about the precordial leads. V1, V2, and V3 not only give you information about the right ventricle and the basal septum but also about the inferior wall…in the form of mirror images. A lot of people don't know about this!

Updating our knowledge about the Q wave criteria

Let’s quickly recap the criteria for pathologic Q waves from chapter 8. We said that Q waves are pathologic if:

- The depth of the Q wave is ≥ 1/4 the size of the R wave in the same lead.

or

- The Q wave is > 0.04 seconds (1 small box on the ECG paper).

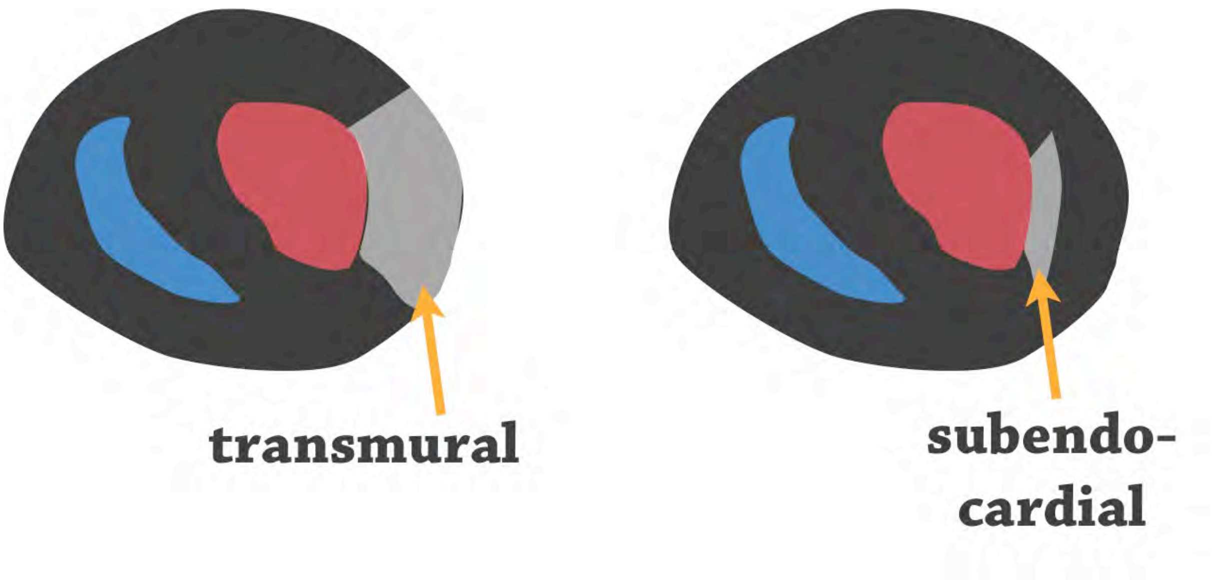
Now there are **two more criteria** for pathologic Q waves:

- Any Q waves in leads V1 to V3 (even if ≤ 0.04 sec) are abnormal.
- In all cases, Q waves have to be present in two contiguous (neighboring) leads. Contiguous leads are: I and aVL; II, III, and aVF; V1 to V6 (e.g., V1 and V2 are contiguous, V3 and V4 are contiguous, etc.).

Q wave and non–Q wave infarctions

Not every patient with myocardial infarction develops Q waves. There are Q wave and non–Q wave infarctions. The presence and size of Q waves correlates with the extent of myocardial scarring; however, this correlation is far from perfect.

In the olden days, people thought that Q wave infarctions were transmural *(involving the entire thickness of the ventricle) and that non-Q wave infarctions were only* subendocardial. *However, pathologic studies have found that this reasoning is flawed and that there were transmural infarctions that did not develop Q waves and subendocardial infarctions that did.*



In the next chapter, you will learn how to diagnose myocardial infarction if Q waves are absent.

Please welcome ... the ECG cookbook!

Now, it's time to introduce you to our **ECG cookbook**. The cookbook will provide you with a step-by-step approach for evaluating an actual ECG without missing anything. There are a total of 11 steps in the cookbook. You should be able to complete 5 of them with the knowledge you've acquired so far. We'll add more steps to the cookbook as we progress. We recommend that you make it a habit to go through all the steps of the cookbook when evaluating an ECG. That way you'll make sure not to miss anything, you'll improve the odds of coming up with the right diagnosis, AND you'll develop a habit, which will become second nature within a short period of time.

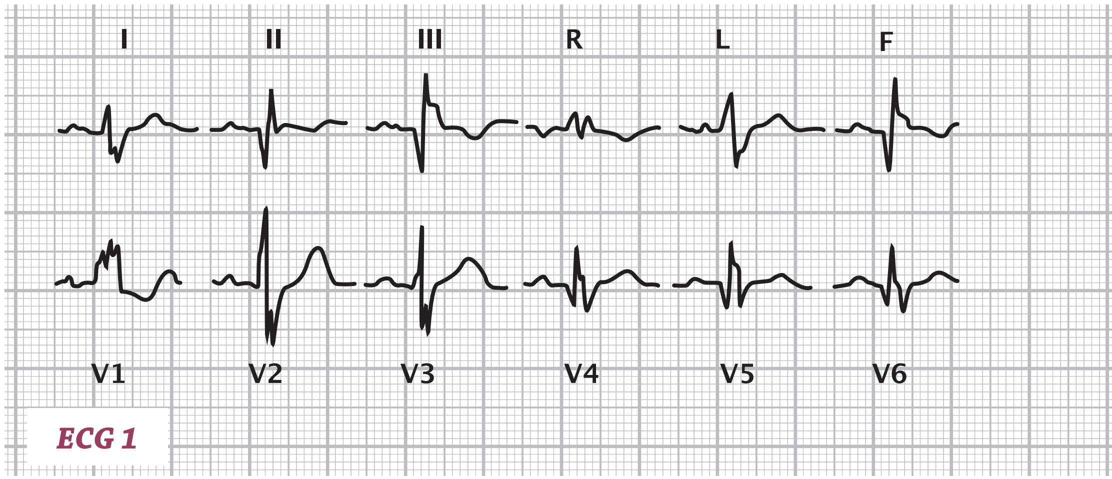
So without further ado, here's the cookbook....

Question	Answer	Diagnosis
1. Rhythm		
2. Heart rate		
3. P waves		
4. PR interval	a) > 0.2 sec (if PR interval constant for all beats & each P wave is followed by a QRS complex)	I° AV block
	b) < 0.12 sec & QRS complex normal	LGL syndrome
	c) < 0.12 sec & visible delta wave	WPW syndrome
5. QRS axis		
6. QRS duration	a) ≥ 0.12 sec (always think of the WPW syndrome as a differential)	complete bundle branch block
	b) > 0.1 and < 0.12 sec with typical bundle branch block appearance (notching)	incomplete bundle branch block
7. Rotation	Rotation is defined according to the heart's transition zone. Normally the transition zone is located at V4, which means that right ventricular myocardium is located at V1-V3 and left ventricular myocardium is at V5-V6.	transition zone at V5-V6: clockwise rotation transition zone at V1-V3: counter-clockwise rotation CAVE: don't evaluate rotation in the setting of myocardial infarction, WPW syndrome or bundle branch block
8. QRS amplitude	a) QRS amplitude <0.5 mV in all standard leads	low voltage
	b) Positive criteria for left ventricular hypertrophy	left ventricular hypertrophy
	c) Positive criteria for right ventricular hypertrophy	right ventricular hypertrophy
9. QRS infarction signs	abnormal Q waves, QS waves, missing R wave progression	myocardial infarction – localization according to affected leads
10. ST-T segment		
11. QT duration, T-U waves		

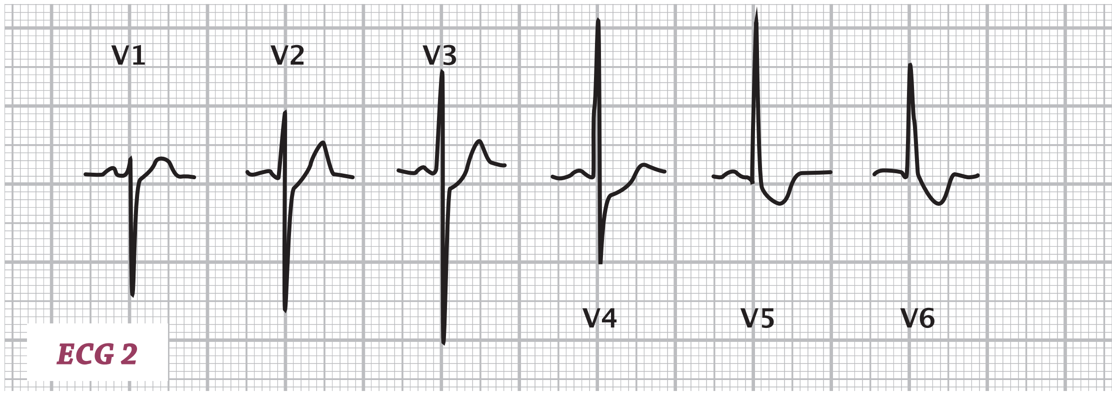
Level 9

QUIZ SECTION

And now it's time for some exercises using our cookbook.

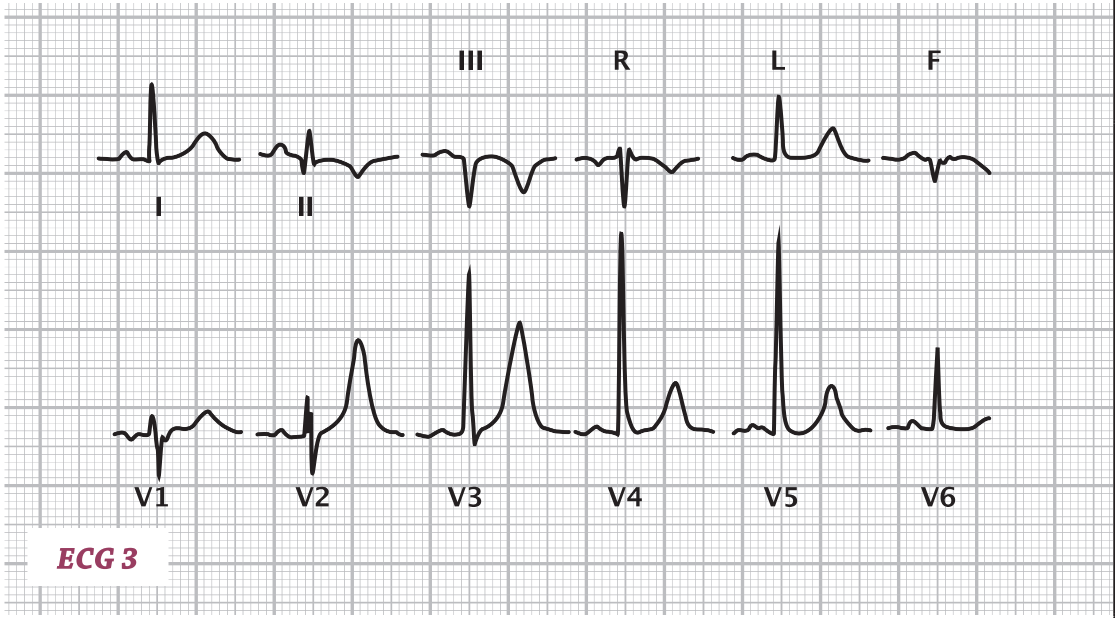


ECG 1

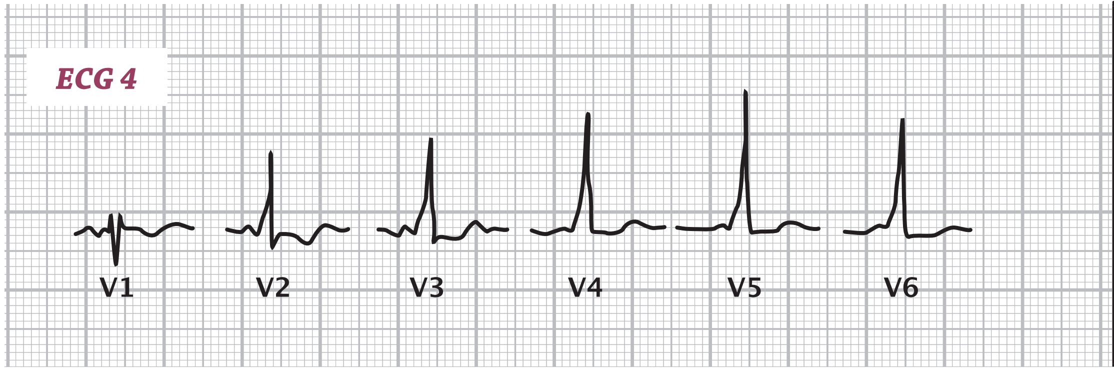


ECG 2

	PR			QRS duration				Rotation			Hyper-trophy		Infarction						
	I° AV block	WPW-syndrome	LGL-syndrome	Complete RBBB	Complete LBBB	Dilated right ventricle	Dilated left ventricle	Normal transition zone	Clockwise rotation	Counterclockwise rotation	Right ventricular hypertrophy	Left ventricular hypertrophy	Anteroseptal region	Anterior wall	Anterolateral region	Lateral region	Posterolateral region	Posterior wall	Inferior wall
ECG 1																			
ECG 2																			

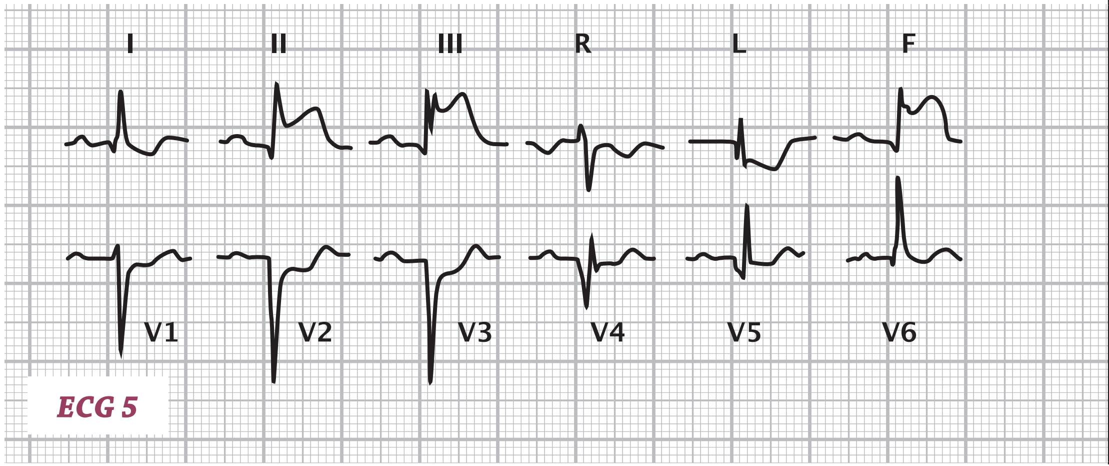


ECG 3



ECG 4

PR			QRS duration				Rotation			Hyper-trophy		Infarction						
I° AV block	WPW-syndrome	LGL-syndrome	Complete RBBB	Complete LBBB	Dilated right ventricle	Dilated left ventricle	Normal transition zone	Clockwise rotation	Counterclockwise rotation	Right ventricular hypertrophy	Left ventricular hypertrophy	Anteroseptal region	Anterior wall	Anterolateral region	Lateral region	Posterolateral region	Posterior wall	Inferior wall



PR	I° AV block	
	WPW syndrome	
	LGL syndrome	
QRS duration	Complete RBBB	
	Complete LBBB	
	Dilated right ventricle	
	Dilated left ventricle	
Rotation	Normal transition zone	
	Clockwise rotation	
	Counterclockwise rotation	
Hyper-trophy	Right ventricular hypertrophy	
	Left ventricular hypertrophy	
Infarction	Anteroseptal region	
	Anterior wall	
	Anterolateral region	
	Lateral region	
	Posterolateral region	
	Posterior wall	
	Inferior wall	

Level 10: Acute coronary syndromes—mastering the ST segment

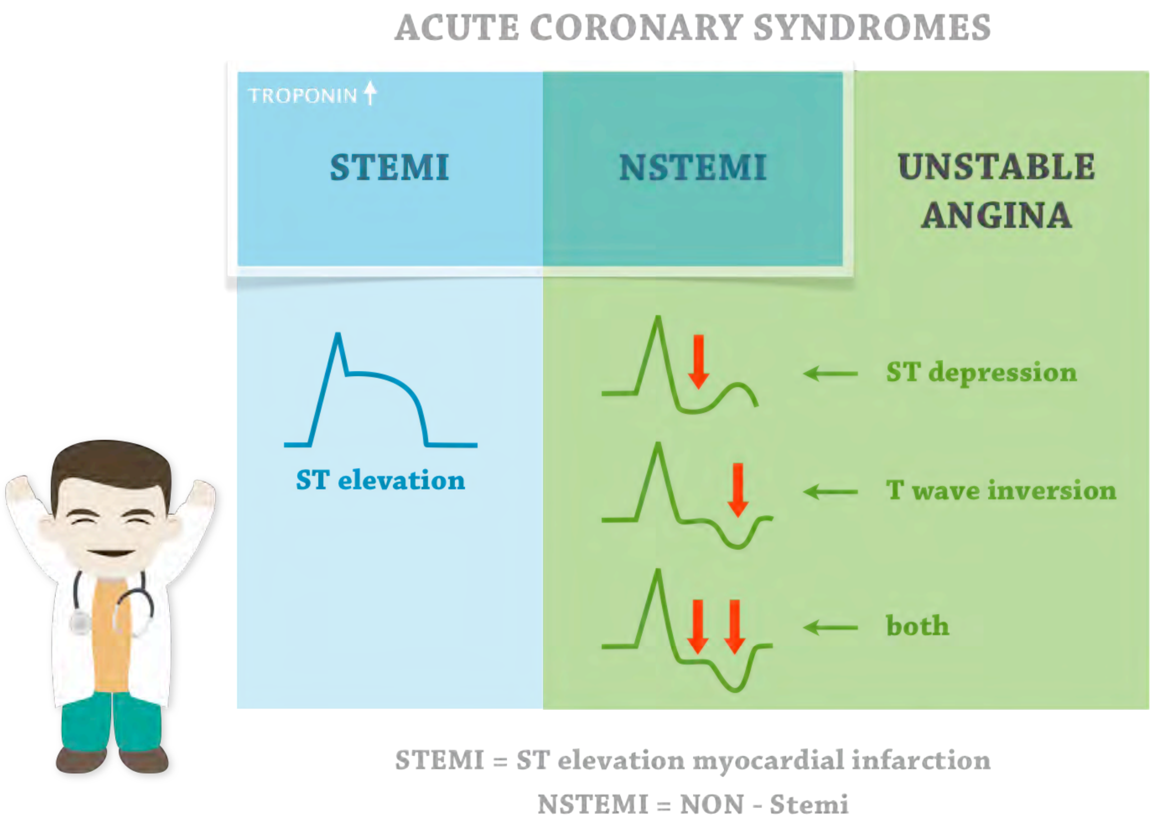
In the previous chapters we discussed what happens to the QRS complex in the setting of myocardial infarction. You learned that the QRS "drowns in negativity" when myocardial infarction occurs, which means that R wave amplitudes decrease and Q waves emerge.

These QRS changes are signs of myocardial necrosis and/or scarring. Scars are usually irreversible. So these changes to the QRS complex are also **irreversible**.

But myocardial infarction not only affects the QRS complex but also the ST segment, and these changes are usually **transient**.

Acute myocardial infarction is part of the so-called **Acute Coronary Syndromes** (ACS). Acute Coronary Syndromes result from (partly) occluded coronary arteries either by a thrombus or ruptured plaque.

If you want to become a true master of the ST segment, you'll need a thorough understanding of the different Acute Coronary Syndromes. So here they are.

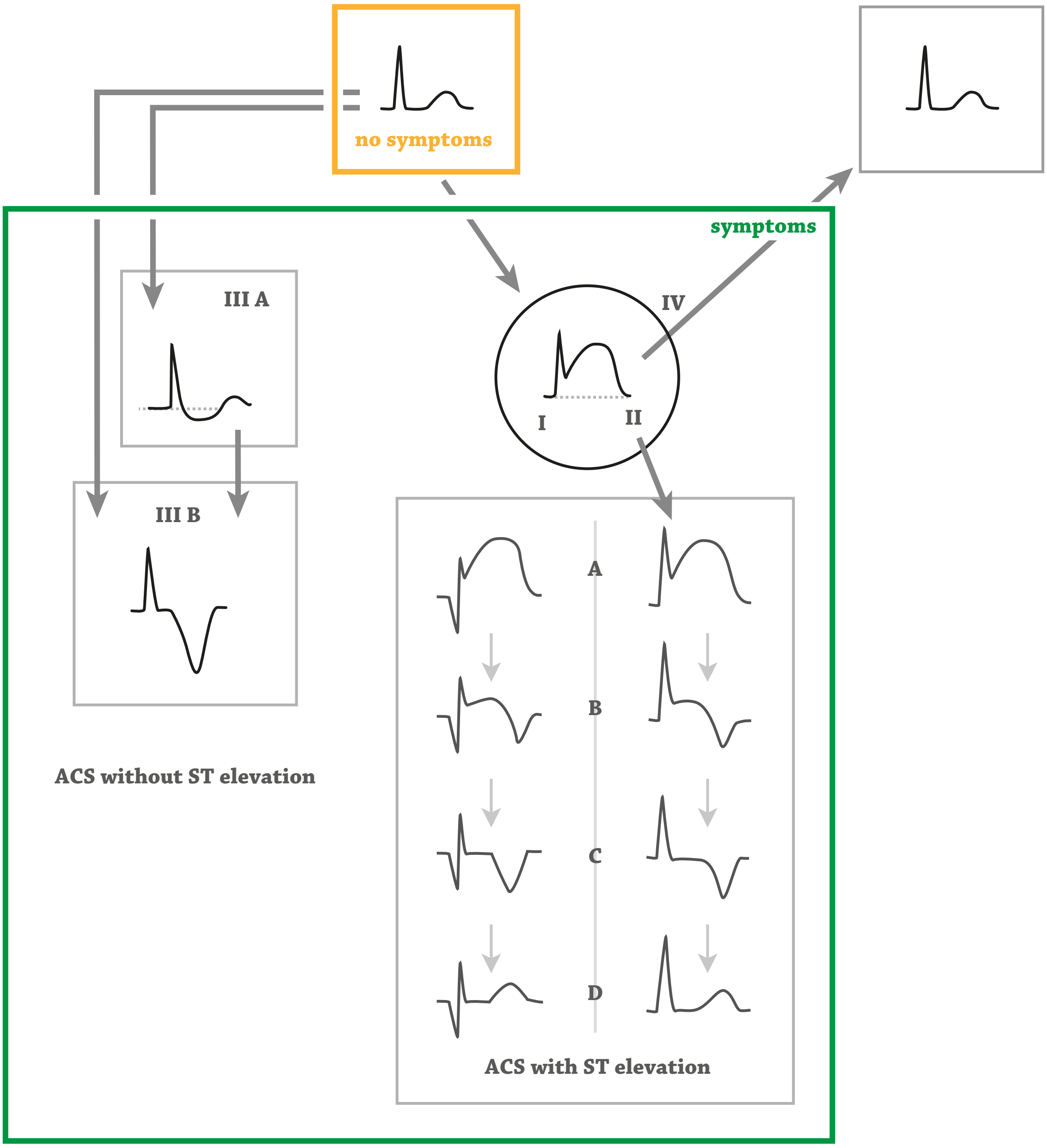


A few things to remember:

1. Both **STEMIs and NSTEMIs** are characterized by an **elevation of troponin** in the blood. Troponin is elevated because myocardial cells are dying off.
2. As the name implies, **STEMI** comes with an **elevation of the ST segment** (duh!), which discriminates it from NSTEMI and unstable angina.
3. In **NSTEMI and unstable angina**, changes to the ST segment can be subtle; there can be **ST depression, T wave inversion,** or both.
4. ST changes are very similar in unstable angina and NSTEMI. However, in **unstable angina, troponin** (and other cardiac enzymes) are **NOT elevated**.

The figure below shows the different stages of acute coronary syndromes.

The terms “STEMI,” “acute myocardial infarction,” and “ACS with ST elevation” are sometimes used interchangeably. However, ACS doesn’t necessarily lead to myocardial infarction (i.e., necrosis). Therefore, you should think of ST elevation as a sign of acute ischemia rather than infarction.



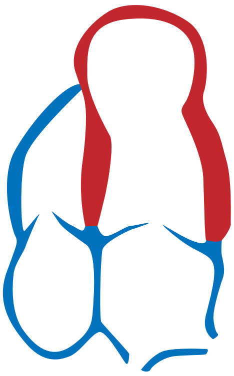
Situations I and II—ACS with ST elevation

ST elevation can occur with or without Q waves.

Let’s first take a look at ST elevations with Q waves (situation I in the previous illustration):

- As symptoms develop, **ST segment elevation appears** (ischemia).
- A few hours after the beginning of myocardial ischemia, pathologic **Q waves appear** as a sign of necrosis (IA in the illustration).

- As mentioned above, ST elevation is a transient phenomenon. The process from ST elevation to its resolution is called **ST segment resolution**. It starts with the ST segment going down and the T wave becoming negative (IB).
- In the subacute phase of myocardial infarction (IC), the **ST segment returns to the isoelectric line,** and **the T wave becomes negative**. In some patients, this pattern persists forever.
- In the chronic phase of myocardial infarction (ID), the T wave becomes positive again. There is no residual sign of infarction in the ST segment or T wave. The myocardial scar is only visible as a Q wave or QS complex.
- Time until complete ST segment resolution is variable. It strongly depends upon time to revascularization. Usually, the ST segment starts to go down immediately after complete revascularization. In other cases ST elevation disappears only after several days. Persistence of ST-segment elevations over weeks after myocardial infarction is alarming as it is often caused by a left ventricular aneurysm.



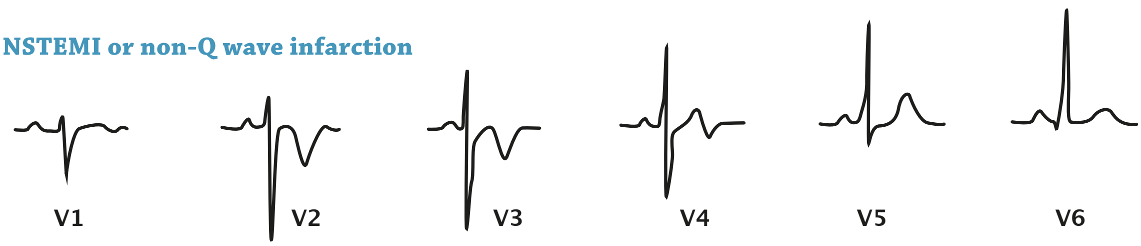
myocardial aneurysm

The time dependent pattern of changes seen in the ST segment and T wave can also be observed in non–Q wave infarction (and in patients with perimyocarditis)—this is situation II in the illustration.

Situation III—ACS without ST elevation

In NSTEMI and unstable angina, symptoms are associated with ST depression (III A in the illustration) or T wave inversion (III B). In order to differentiate between NSTEMI and unstable angina, you'll have to look whether cardiac enzymes are elevated.

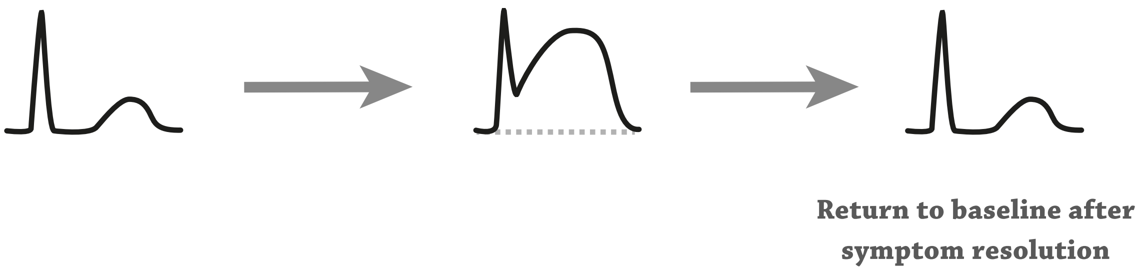
Since some patients with coronary artery disease have negative T waves even when they are asymptomatic, it's very important to look for changes in ST-T wave morphology during symptoms.



NSTEMI in the territory of the left anterior descending artery (LAD). Leads V2, V3, and V4 are affected.

Situation IV—Prinzmetal angina: a special case

There is a form of myocardial ischemia that's commonly associated with ST elevation. This disease is called **Variant angina** or **Prinzmetal angina**. Chest pain is typically of short duration (15 to 20 minutes) and appears at rest or even during sleep. Unlike other forms of angina, ST elevation returns to baseline immediately after symptoms disappear. Coronary occlusion is thought to be caused by coronary spasm in these cases.

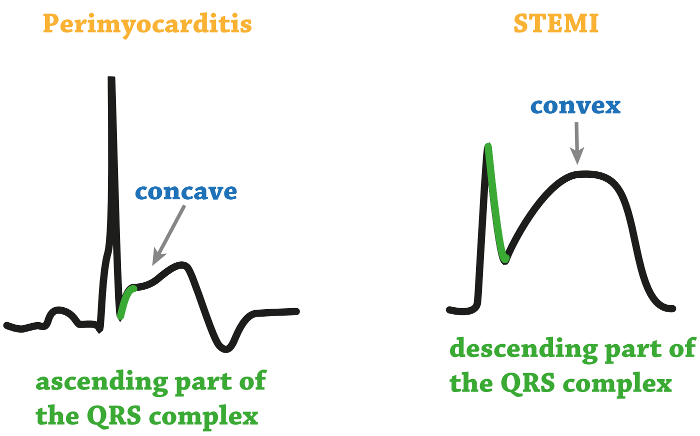


Perimyocarditis

In perimyocarditis, the ST segment is usually also elevated. Perimyocarditis is a diffuse disease and, unlike infarction, it's not limited to the perfusion territory of one coronary artery.

Whenever you see ST elevations in areas that are not supplied by one single artery, you should think of Perimyocarditis.

Typically, the ST elevation is not convex, as in myocardial infarction but rather concave (as seen on the following image). Furthermore, the ST segment usually originates from the ascending part of the QRS complex in perimyocarditis, whereas in STEMI, it usually originates from the descending part of the QRS.



In Perimyocarditis you can also see the time-dependent changes seen in ACS with ST elevation, ST resolution, T wave inversion, etc.

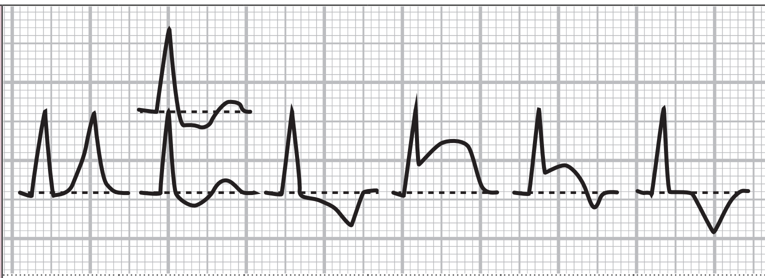
Vagotonia

And finally, there's one more form of ST segment elevation that's rather innocent compared to the previous ones. This type of ST elevation can be seen in the setting of **vagotonia** (i.e., an increase in vagal tone). The elevation is up to 0.2 mV in amplitude, and it's usually accompanied by a tall and peaked T wave, as well as a low heart rate of < 60 beats per minute.

Case of vagotonia with ST elevation and a tall, peaked T wave.

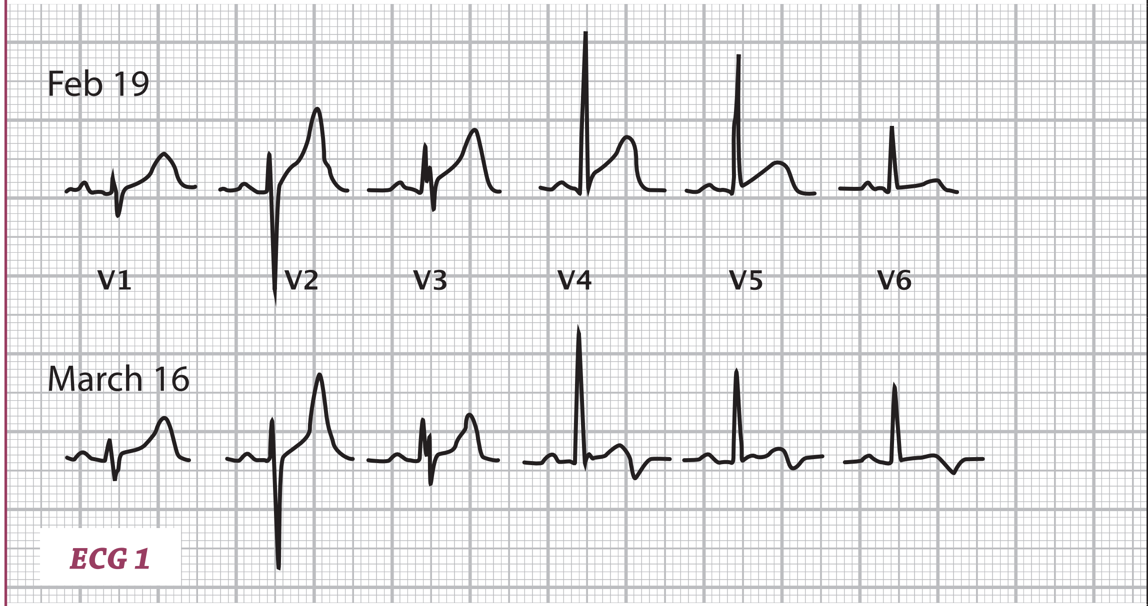
With this knowledge in mind, we can now add the evaluation of the ST segment to the steps of our cookbook. Note that the ST segment should always be evaluated in combination with the QRS complex.

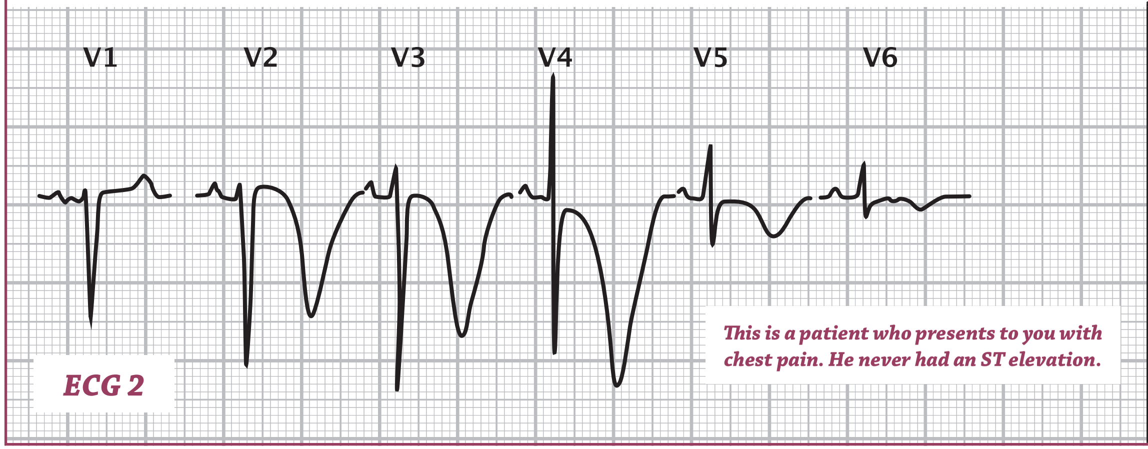
Question	Answer	Diagnosis
1. Rhythm		
2. Heart rate		
3. P waves		
4. PR interval	a) > 0.2 sec (if PR interval constant for all beats & each P wave is followed by a QRS complex)	I° AV block
	b) < 0.12 sec & QRS complex normal	LGL syndrome
	c) < 0.12 sec & visible delta wave	WPW syndrome
5. QRS axis		
6. QRS duration	a) ≥ 0.12 sec (always think of the WPW syndrome as a differential)	complete bundle branch block
	b) > 0.1 and < 0.12 sec with typical bundle branch block appearance (notching)	incomplete bundle branch block
7. Rotation	Rotation is defined according to the heart's transition zone. Normally the transition zone is located at V4, which means that right ventricular myocardium is located at V1–V3 and left ventricular myocardium is at V5–V6.	transition zone at V5–V6: clockwise rotation transition zone at V1–V3: counter-clockwise rotation CAVE: don't evaluate rotation in the setting of myocardial infarction, WPW syndrome or bundle branch block
8. QRS amplitude	a) QRS amplitude <0.5 mV in all standard leads	low voltage
	b) Positive criteria for left ventricular hypertrophy	left ventricular hypertrophy
	c) Positive criteria for right ventricular hypertrophy	right ventricular hypertrophy
9. QRS infarction signs	abnormal Q waves, QS waves, missing R wave progression	myocardial infarction – localization according to affected leads

10. ST-T segment							
	tall T wave	ST depression	ST depression	ST elevation		negative T	
QRS normal	→						hyperkalemia, vagotonia
QRS normal		→					probably ischemia (DD: Digitalis)
QRS normal			→				non-specific repolarization abnormality
QRS normal				→			acute ischemia, perimyocarditis Variant angina
QRS normal					→		STEMI in resolution
QRS normal						→	STEMI in resolution NSTEMI, perimyocarditis
QRS with Q wave				→	→	→	STEMI acute and in resolution
QRS: left ventricular hypertrophy			→				left ventricular hypertrophy with abnormal repolarization
QRS: right ventricular hypertrophy, bundle branch block or WPW syndrome			→				In these situations an ST segment deviation is almost always present and cannot be interpreted in and of itself. It has to be left out in the ECG report
11. QT duration, T-U waves							

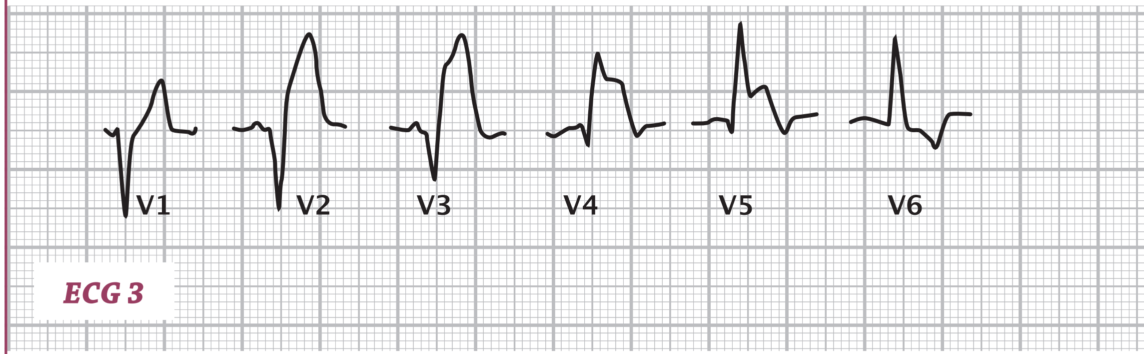
Level 10
QUIZ SECTION

For the following exercises use our cookbook including the evaluation of the ST segment.

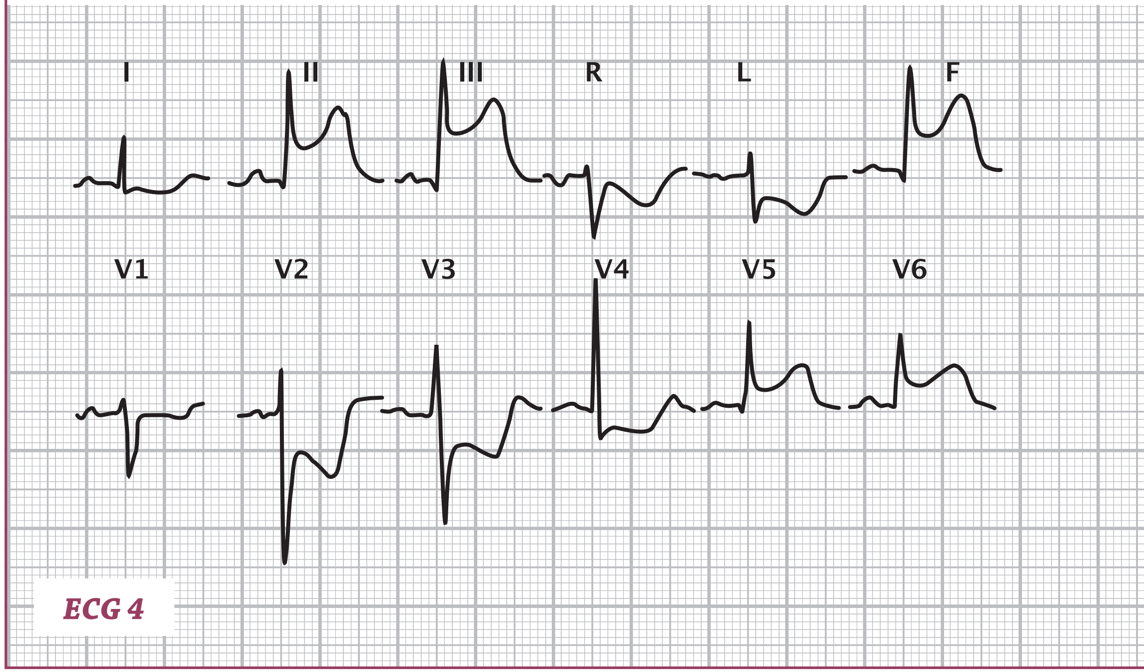




	Pathology					Phase				
	Q wave STEMI	Non-Q wave STEMI	Acute coronary syndrome / NSTEMI	Perimyocarditis	None of the pathologies mentioned	Acute	In resolution	Chronic (only applies to STEMI)	Nomenclature cannot be applied	Which additional pathologies can be found? (use our cookbook)
ECG 1 *on the first ECG*										
ECG 1 *on the follow up ECG*										
ECG 2										

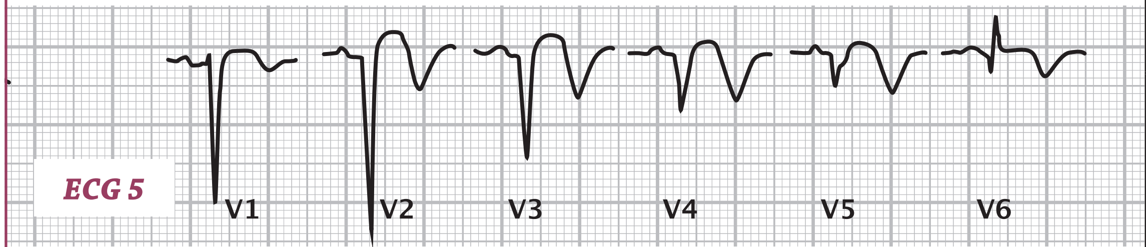


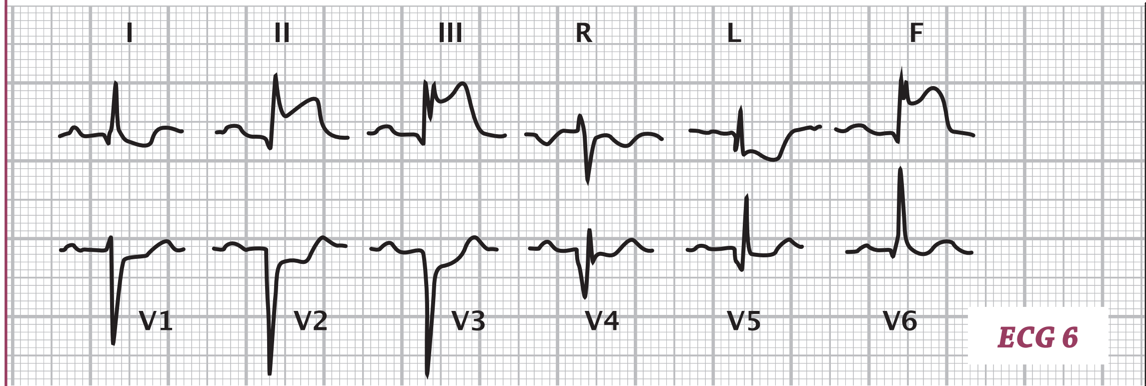
ECG 3

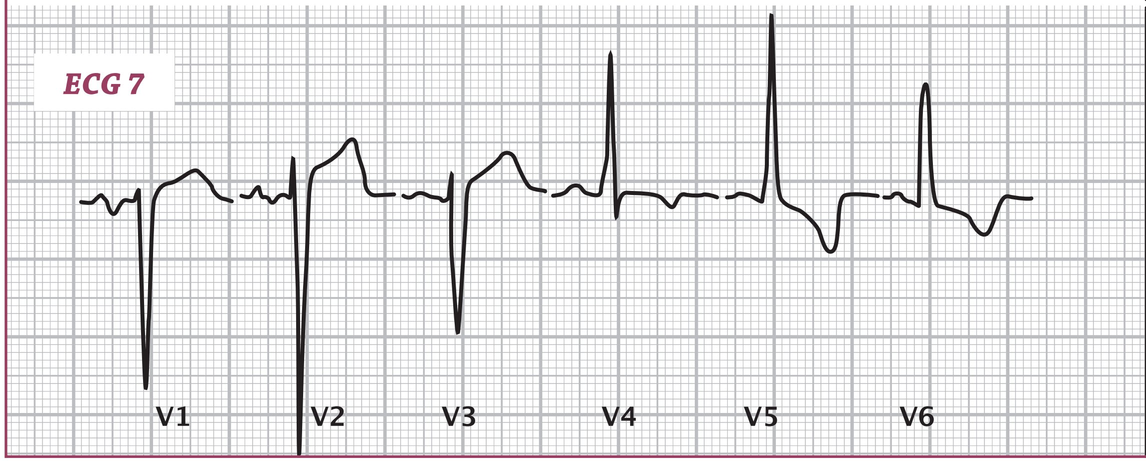


ECG 4

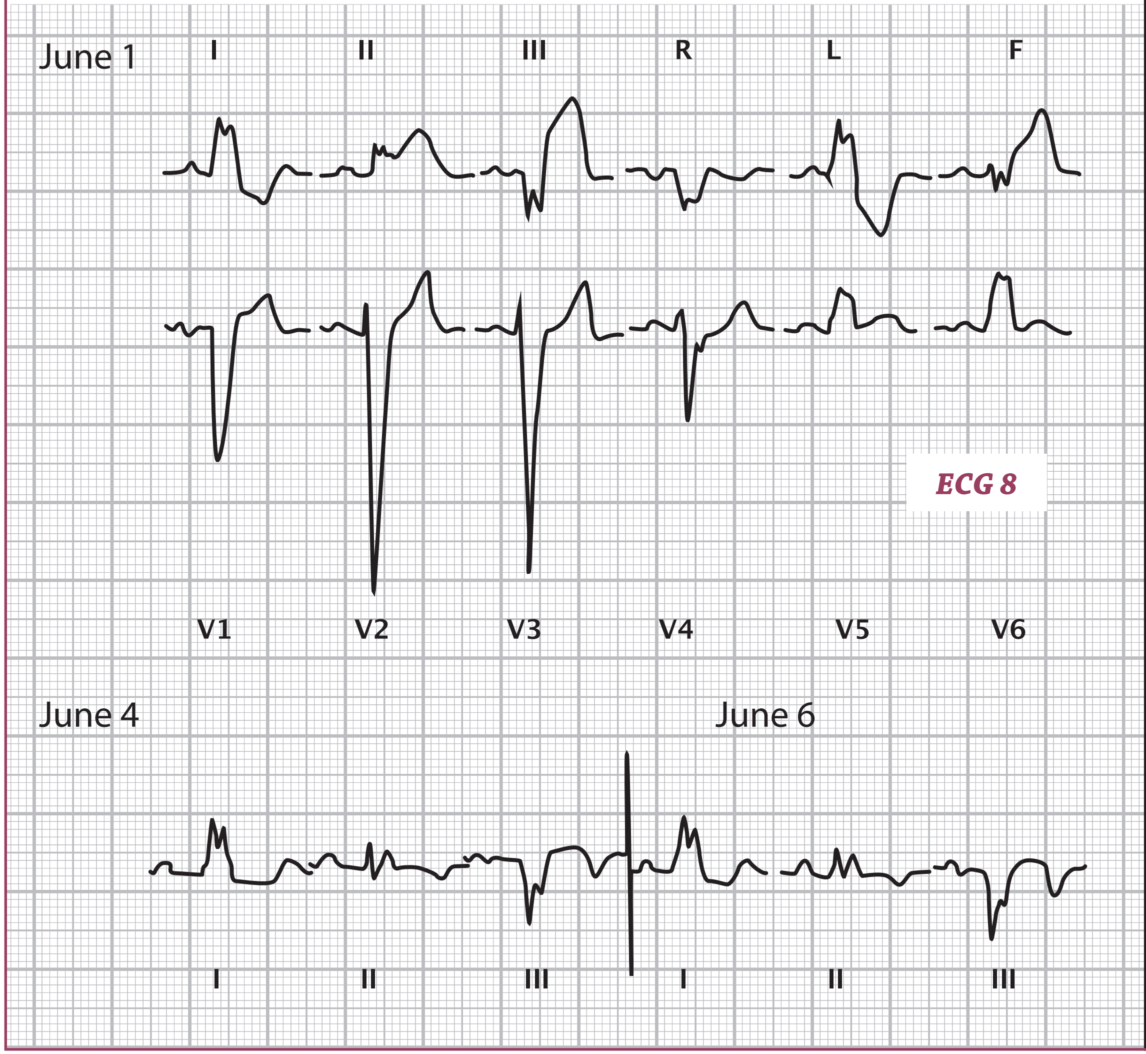
	Pathology					Phase				Which additional pathologies can be found? (use our cookbook)
	Q wave STEMI	Non-Q wave STEMI	Acute coronary syndrome / NSTEMI	Perimyocarditis	None of the pathologies mentioned	Acute	In resolution	Chronic (only applies to STEMI)	Nomenclature cannot be applied	
ECG 3										
ECG 4										







	Pathology					Phase				
	Q wave STEMI	Non-Q wave STEMI	Acute coronary syndrome / NSTEMI	Perimyocarditis	None of the pathologies mentioned	Acute	In resolution	Chronic (only applies to STEMI)	Nomenclature cannot be applied	Which additional pathologies can be found? (use our cookbook)
ECG 5										
ECG 6										
ECG 7										



Pathology: Q wave STEMI	Pathology: Non–Q wave STEMI	Pathology: Acute coronary syndrome / NSTEMI	Pathology: Perimyocarditis	Pathology: None of the pathologies mentioned	Phase: Acute	Phase: In resolution	Phase: Chronic (only applies to STEMI)	Phase: Nomenclature cannot be applied	Which additional pathologies can be found? (use our cookbook)

Level 11: The ECG trio—cardiac axis, atrial hypertrophy, and low-voltage

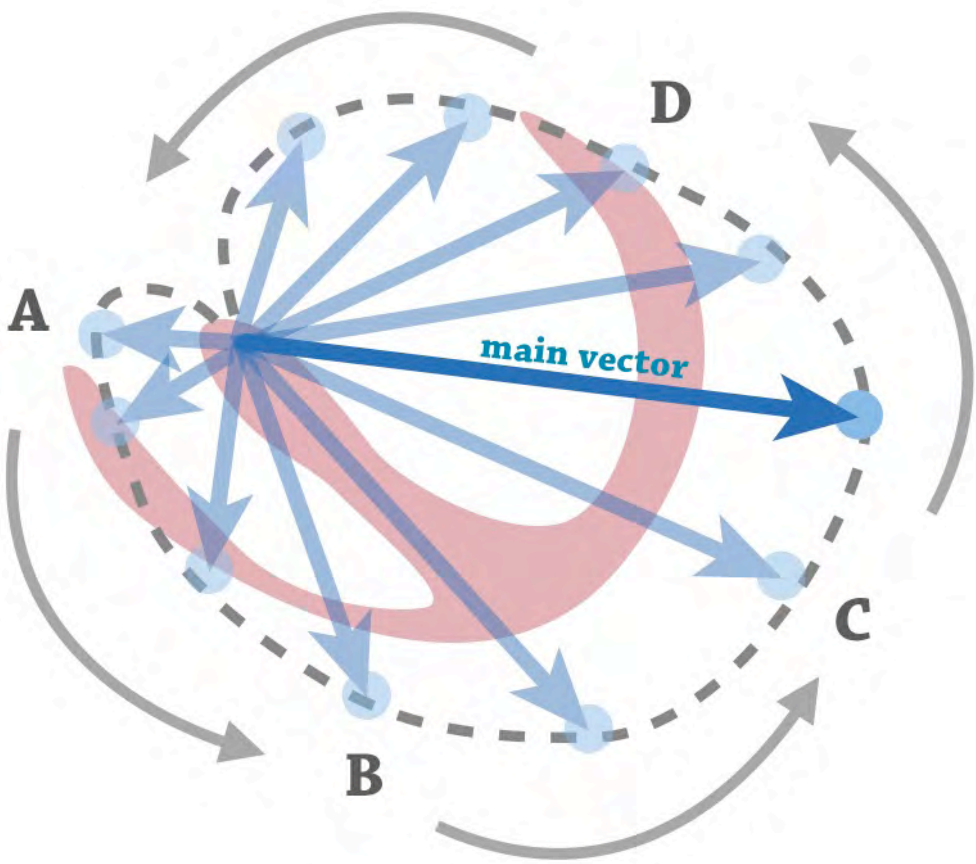
In this level, you are going to learn an easy and fast method for how to determine the cardiac axis. The good news is, it's much easier than everyone tells you.

The shocking truth about the cardiac axis

If you're like most ECG students, you find the evaluation of the cardiac axis utterly confusing, and you are not sure why you have to learn it at all. Quite frankly, you are absolutely right.

When you compare the amount of time most folks spend studying the axis and the actual value it adds to their reports, you'll notice that the return on their time is humble. The good news is that there are only a couple of things that are really important about the axis. In this section, we'll teach you what they are.

With the complicated geometry of the ventricles, you can imagine that at each point in time there are vectors of different amplitudes pointing in different directions inside the heart. From all these momentary vectors, an average vector can be constructed for each point in time.



We know that ventricular depolarization takes about 80 to 100 msec (< 0.1 sec). In this image we have marked a few of these instantaneous average vectors: A: vector at 5 msec; B: vector at 30 msec; C: vector at 60 msec; D: vector at 80 msec. The dashed line connecting the tips of these vectors represents the vector loop*, which used to be used in vectorcardiography. But don't worry, we won't go into further details.*

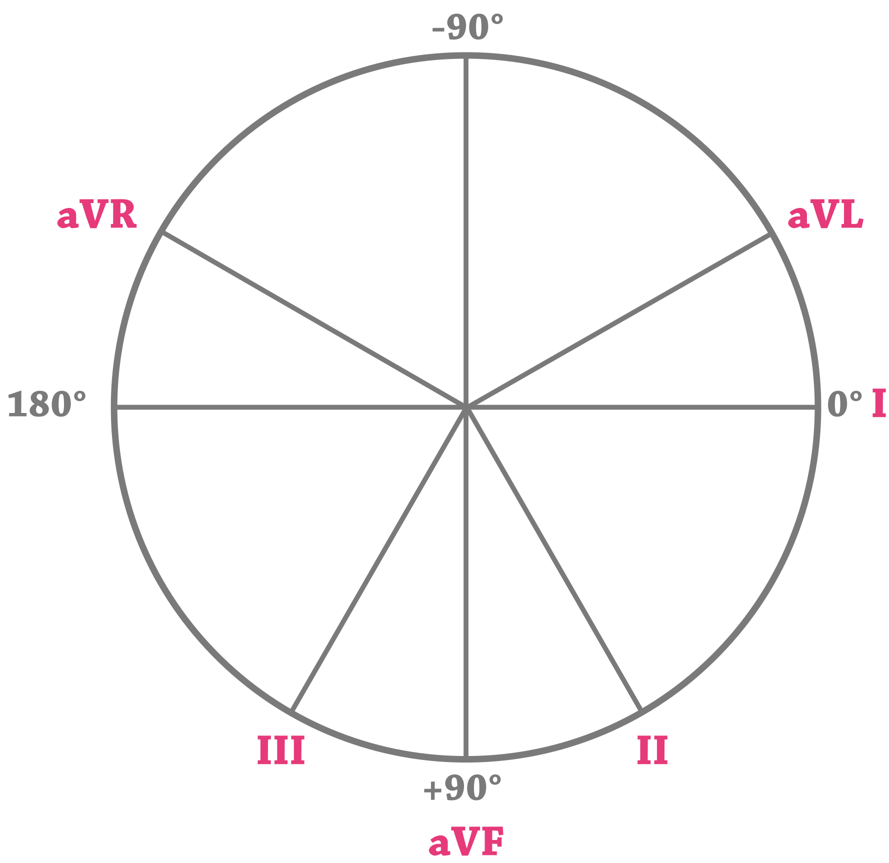
The strongest (i.e., longest) of these average vectors is called the **main vector**; it is the one that determines the electrical axis of the heart in the frontal plane. In other words, the cardiac axis represents the direction of the main electrical vector in the frontal plane.

The most exact way to determine the axis in the frontal plane would be to exactly calculate the direction of the main vector. However, that's too time consuming and not worth the effort because there are only a few situations where knowledge of the axis really makes a difference. You'll learn what they are a little later.

What we should be able to do is to find the most important abnormalities of the electrical axis. Below we outline a simple trick for doing so.

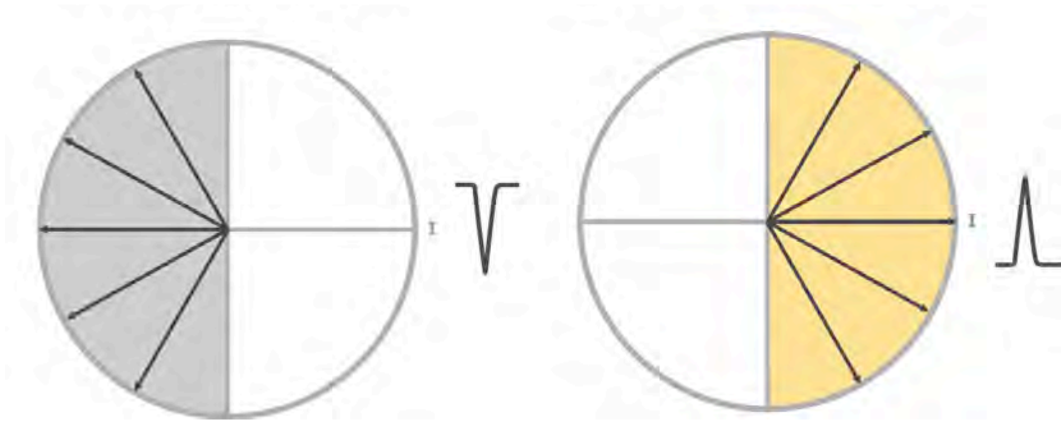
Remember that a lead records a **positive wave** when the **vector points into the direction of that lead**. When the **vector points away from that lead**, the deflection will be mainly **negative**.

First, we have to learn the location of the leads (I, II, III and aVR, aVL, aVF) on the Cabrera circle (or Cabrera system). This system provides a convention for representing the extremity leads in a logical sequence. The location of each lead can be seen in the image below.

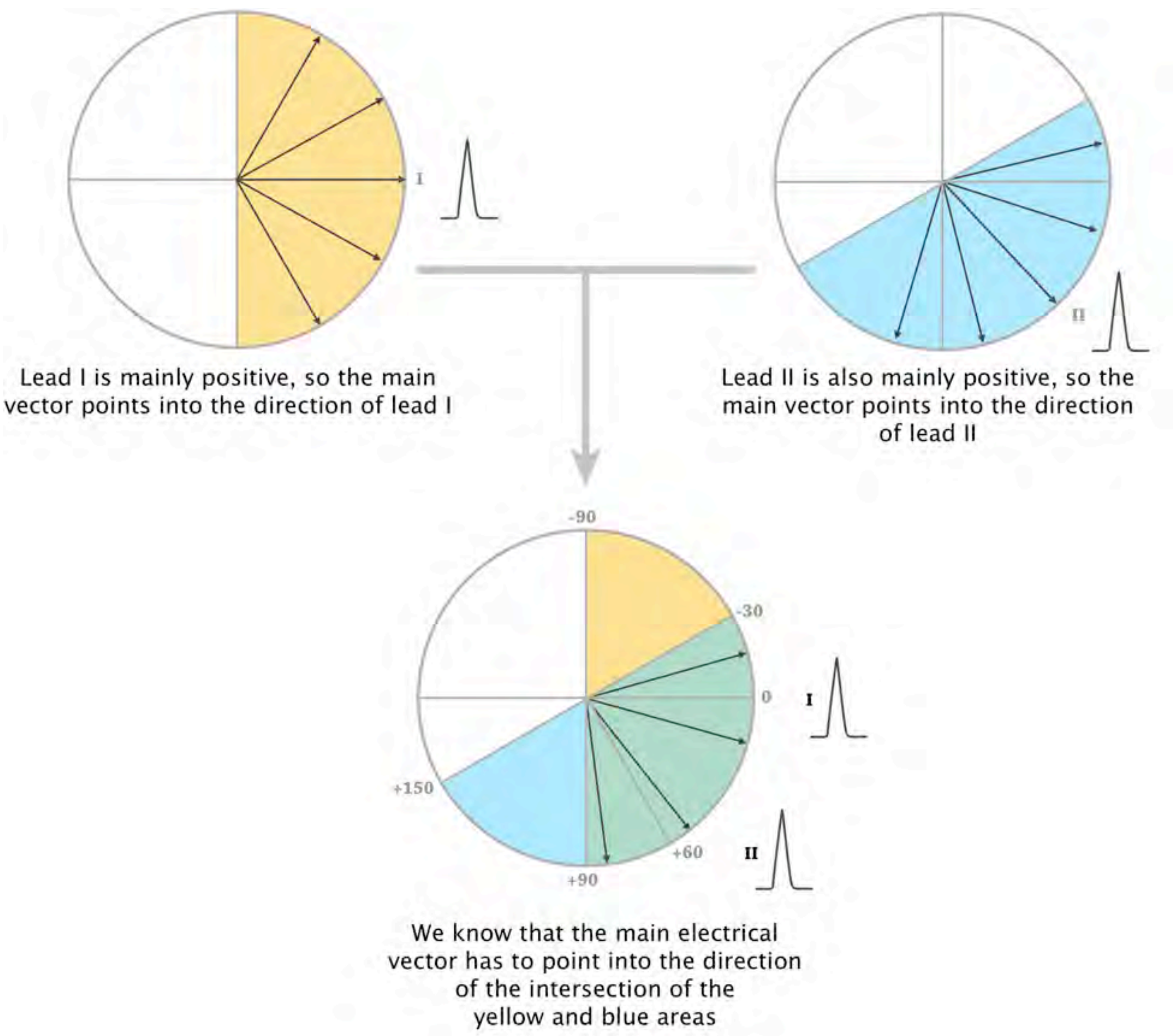


Let us now consider what this means for lead I:

Deflection is **negative** when vectors point **away from** lead I	Deflection is **positive** when vectors point **in the direction** of lead I



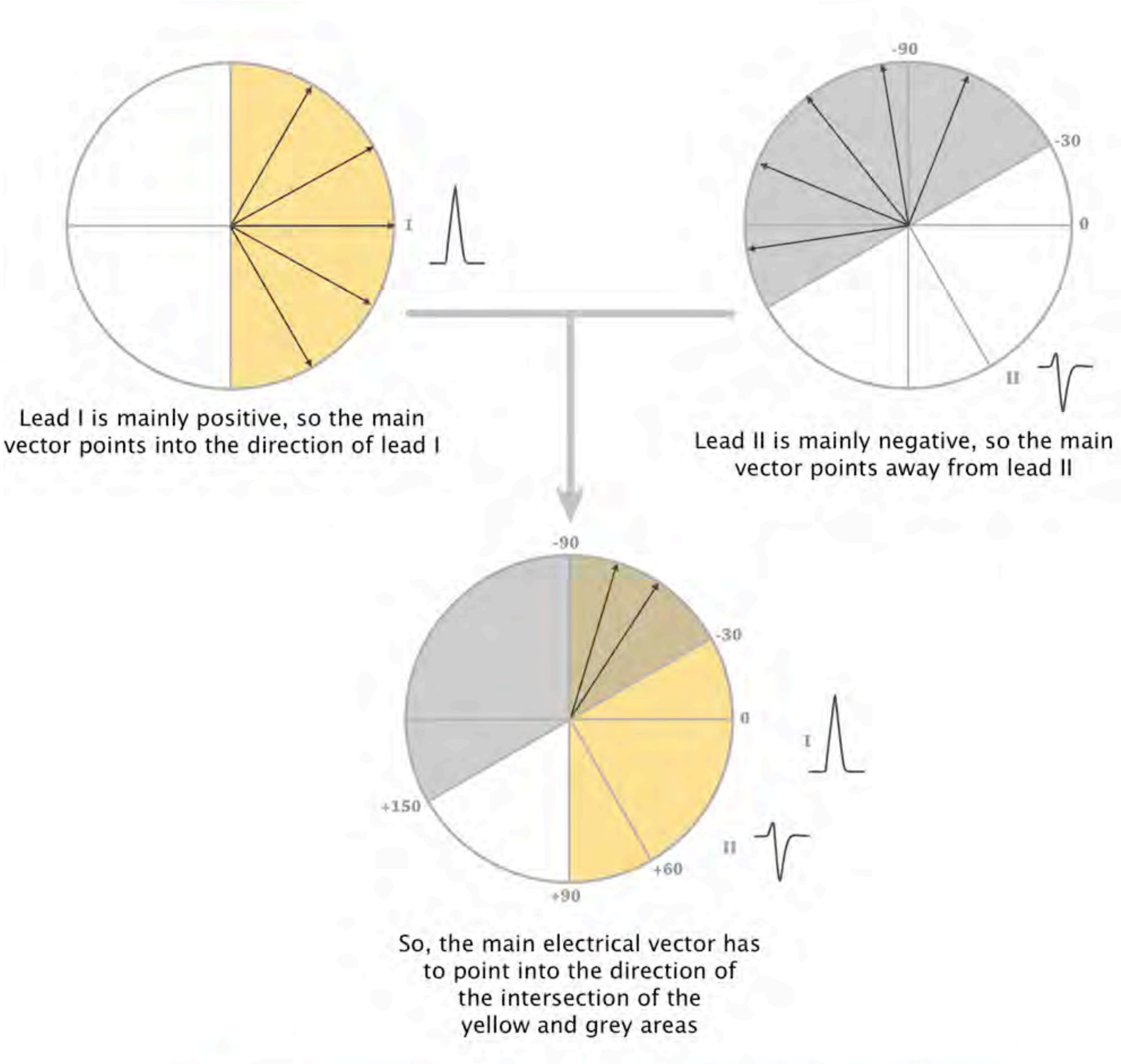
Let's see what happens when leads I and II are mainly positive:



The area between –30° and +90° is called a "normal axis"

So we know that if leads I and II are positive, the vector points at the area between -30° to +90°. Most electrical vectors in humans are located in that sector and that's why we call it a **normal axis**. The terminology varies in different medical schools and countries. We will use the terms mostly used in British and American textbooks.

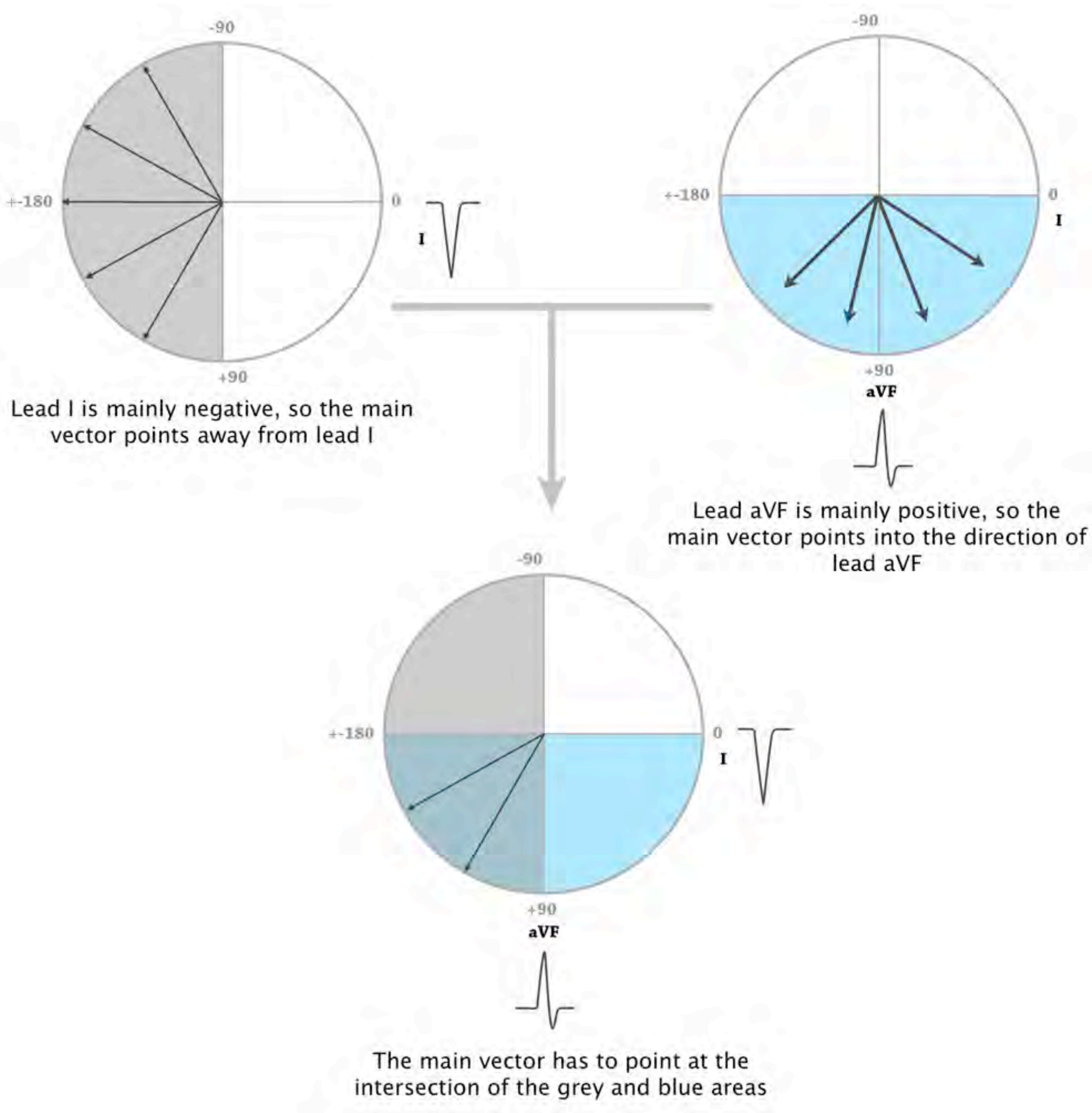
Now let's see what happens when lead I is positive and lead II is negative:



The area between -30° and -90° is called "left axis deviation"

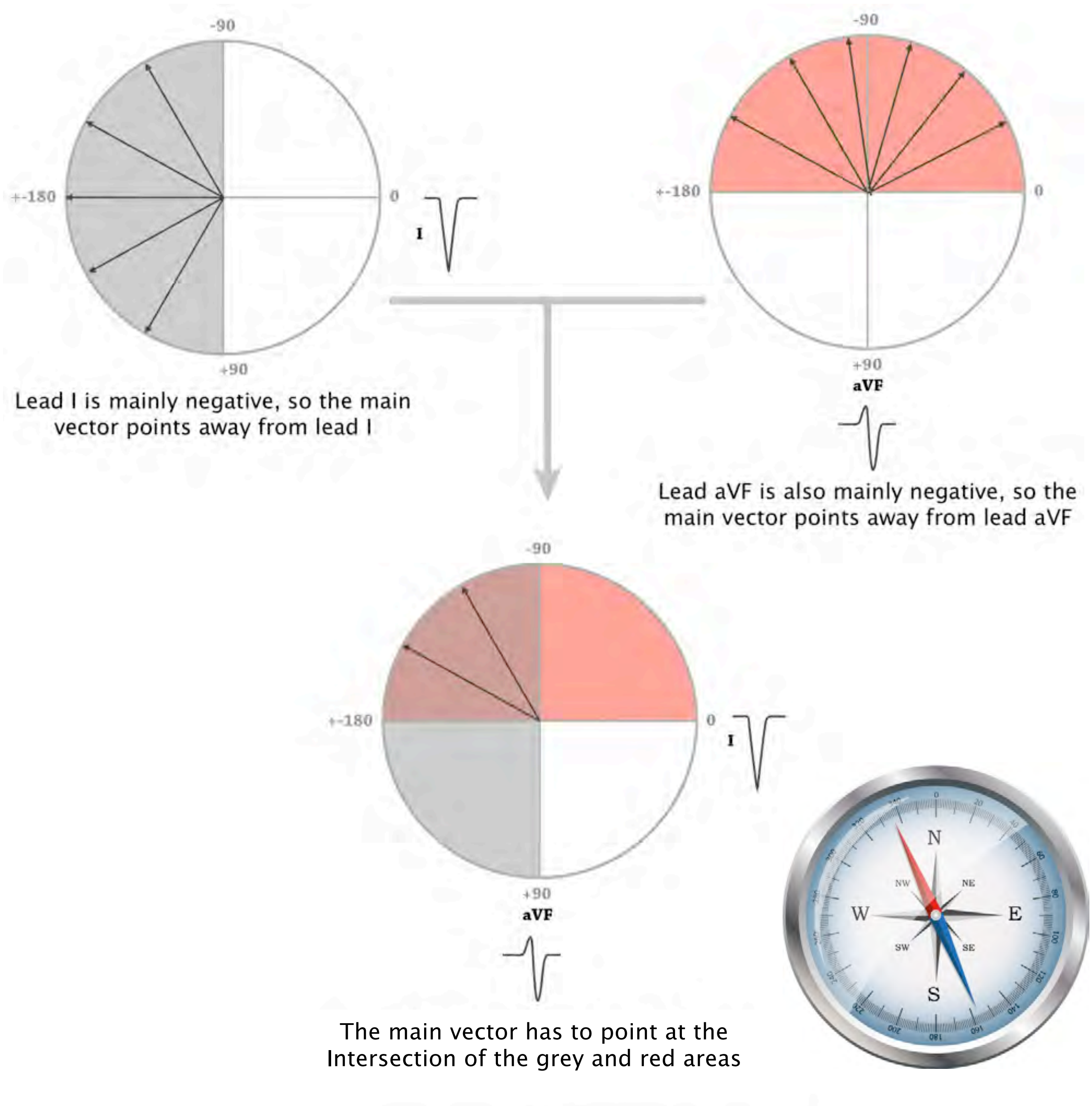
If lead I is negative, you should look at lead aVF instead of lead II in order to determine the axis.

Now let's see what happens when lead I is negative and aVF is positive:



The area between +90° and +-180° is called "right axis deviation"

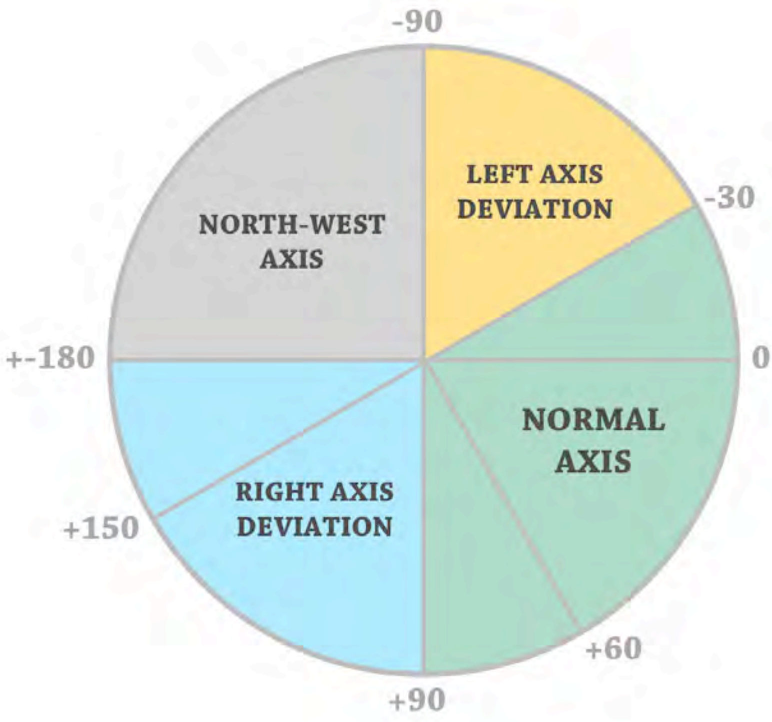
And what's the matter when both leads I and aVF are negative?



The area between −90° and +−180° is called a "North-West axis"

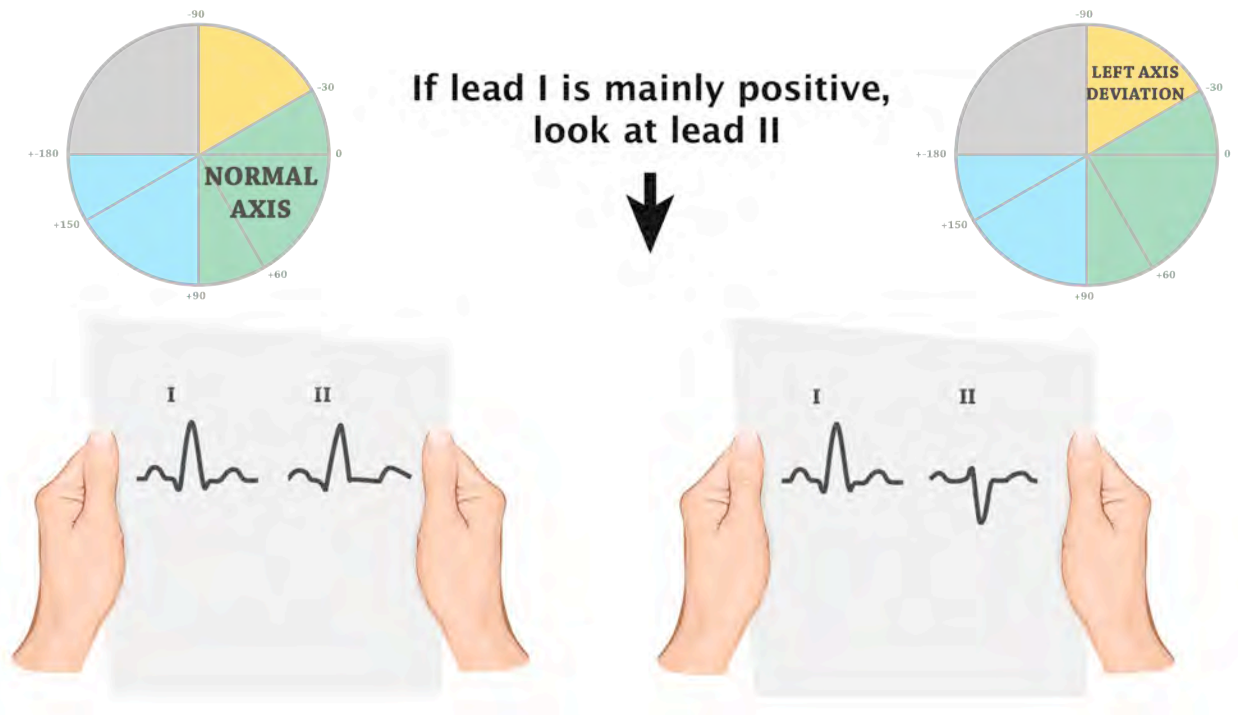
You should only care about left axis deviation and right axis deviation for now. Why? Because when the axis is normal, that won't really help you in refining your diagnosis. A North-West axis is extremely rare—you won't encounter it much as a novice. But you will encounter left axis deviation and right axis deviation, and they will help you in your diagnosis.

So here’s an overview:



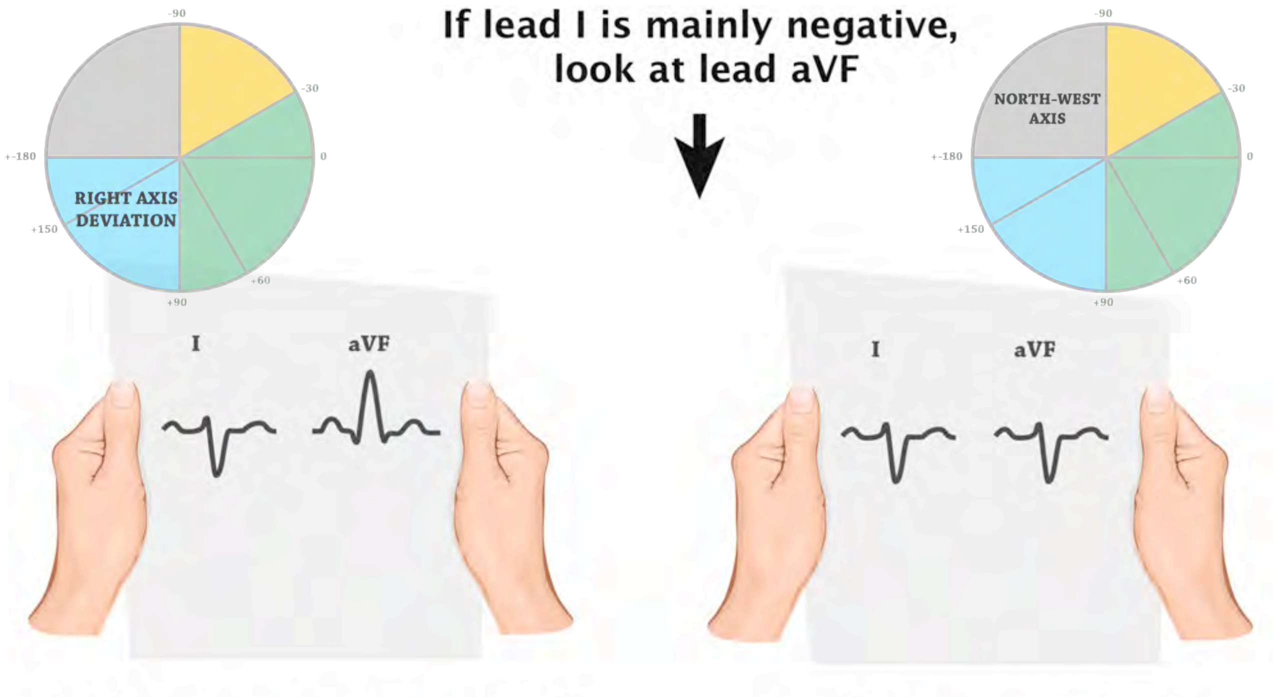
So how can you determine the cardiac axis really easily? Here’s how…

All you have to do in order to determine the cardiac axis is to hold the ECG printout in your hands. Your left thumb should be next to lead I. **If lead I is positive, lead II should be next to your right thumb. If lead I is mainly negative, lead aVF should be next to your right thumb**:



If both leads are mainly positive, it’s a **normal axis**

If the left lead is mainly positive and the right lead is mainly negative, it’s a **left axis deviation**



If the right lead is mainly positive and the left lead is mainly negative, it's **right axis deviation**

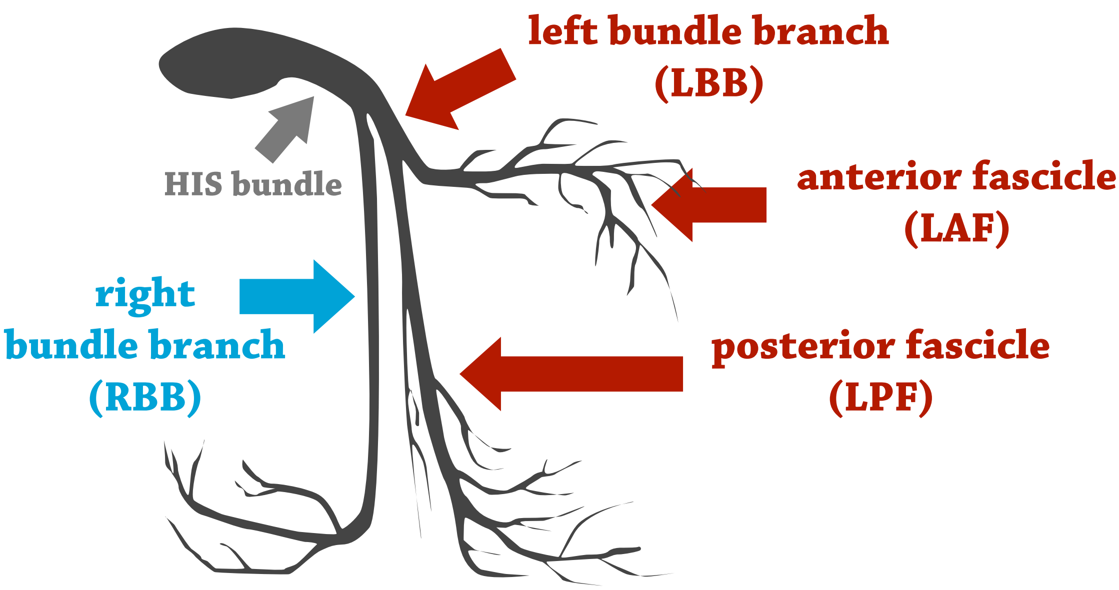
If both leads are mainly negative, it's a **North West axis**

You'll get plenty of opportunities to assess the axis in the exercises!

Now let's turn to the clinical situations where knowledge of the cardiac axis makes a difference.

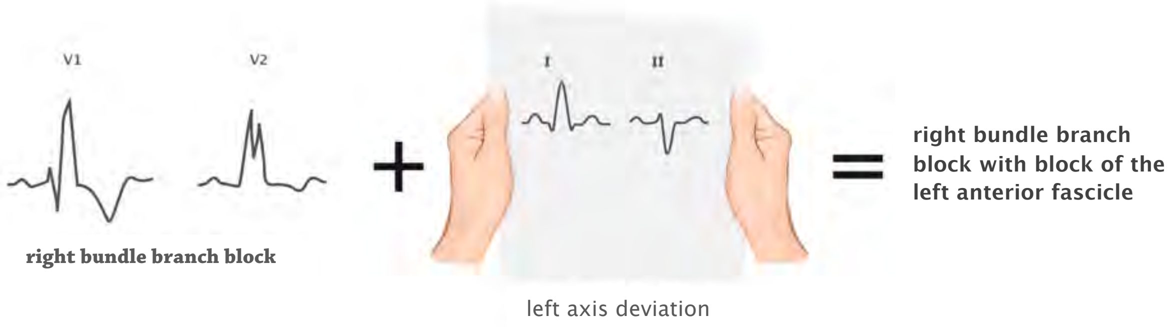
Situation #1

For ventricular depolarization, impulses are conducted down into the ventricles through the so-called bundle branches. There's a right bundle branch and a left bundle branch. The left bundle branch is subdivided into a left anterior fascicle (LAF) and a left posterior fascicle (LPF) as shown in the image:



We have already learned that the QRS complex broadens when either the right or left bundle branches are blocked. Sometimes what happens in right bundle branch block is that one of the left fascicles is also blocked. That's called a bi-fascicular block. It's a pretty dangerous situation, since there's only one fascicle that's left for the impulse to reach the ventricles. If this last fascicle gets blocked as well, the patient ends up in complete heart block, a potentially life-threatening situation.

How can you tell if bi-fascicular block is present? Well, if you have a typical picture of a right bundle branch block in the precordial leads AND you also have left axis deviation, the patient has bi-fascicular block involving the left anterior fascicle (also called "right bundle branch block with left anterior hemiblock"):



The abbreviation for the left anterior fascicle is LAF. So there's a straight-forward mnemonic for this situation:

Left axis deviation = LAF(T) block

When the patient has right bundle branch block plus right axis deviation, she probably also has bi-fascicular block with involvement of the left posterior fascicle:

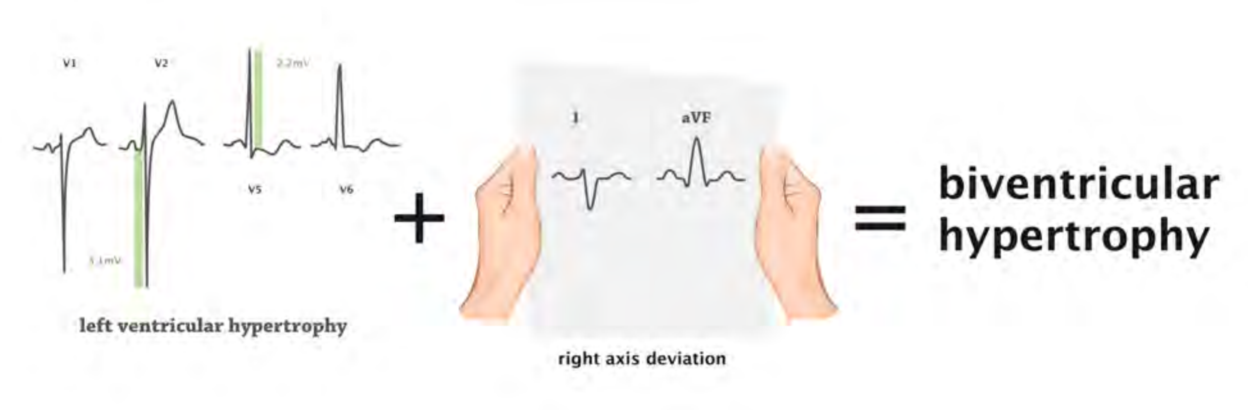
Situation #2

Whenever you suspect **right ventricular hypertrophy** from looking at the precordial leads, it often helps to look for the presence of right axis deviation, which would reinforce your suspicion. So whenever the RSS criteria are positive (e.g., you have a patient with a tall R in V1 and a deep S in V5), and this patient also has **right axis deviation**, then you can be almost certain that **something's wrong with the right heart**:

signs of right ventricular hypertrophy in precordial leads + **right axis deviation** → **increases likelihood of right ventricular hypertrophy**

Situation #3

When there are **signs of left ventricular hypertrophy** in the ECG and the patient also has **right axis deviation**, you should think of **biventricular hypertrophy**. As the name implies, this is a situation where both the left and the right ventricles are hypertrophic.



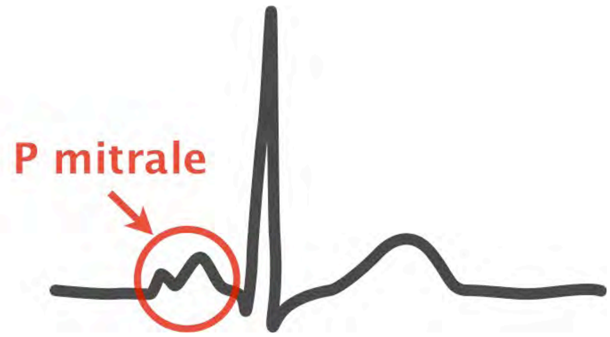
Great! Now you know when knowledge of the cardiac axis really makes a difference. You should now integrate the evaluation of cardiac axis into the steps of the cookbook. Congrats, you've almost made it through the Yellow Belt Training!

Atrial hypertrophy

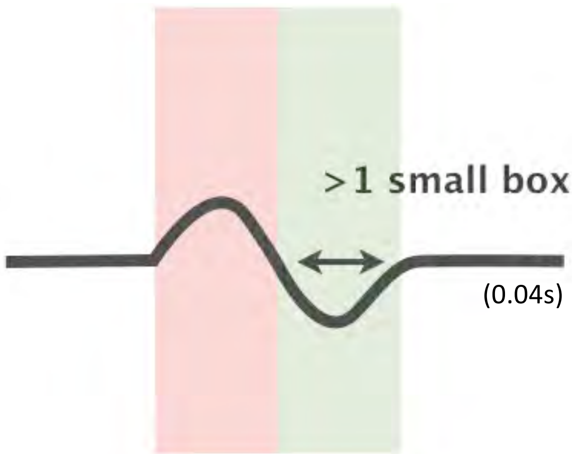
Hypertrophy of the atria can be evaluated by looking at the P waves in the standard leads.

Left atrial hypertrophy

The P wave has two peaks, and usually the second peak is taller than the first one. P wave duration is above 0.1 seconds. These changes are most pronounced in leads I and II. This type of P wave is called **P mitrale**:

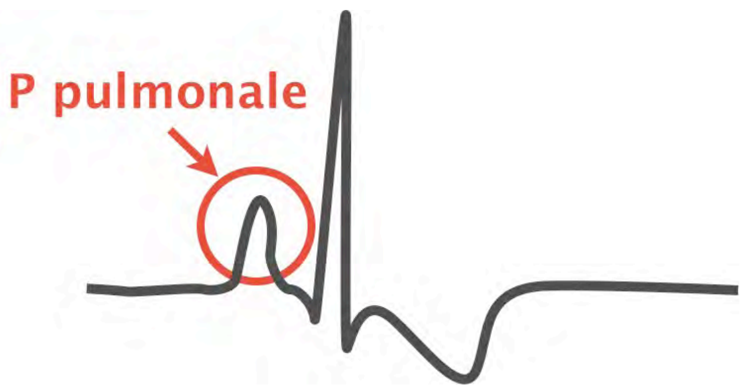


P mitrale can also be nicely depicted in lead V1, where we would typically see a biphasic (i.e., positive-negative) P wave. The negative part of the P wave corresponds to the enlarged left atrium. If the negative part is longer than 1 small box (or > 0.04s), then P mitrale is present:

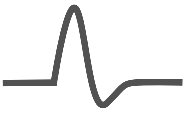
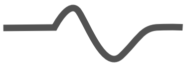


Right atrial hypertrophy

This is best seen in leads II, III, and aVF. The P wave is peaked and exceeds 0.25mV in amplitude. These peaked P waves are called **P pulmonale**.



Here are the criteria again:

	V1	II	criteria
Normal			
right atrial enlargement **P pulmonale**			**P > 2.5mm in II**
left atrial enlargement **P mitrale**			**negative P in V1 > 0.04s and/or P wave duration > 0.12s in most cases**

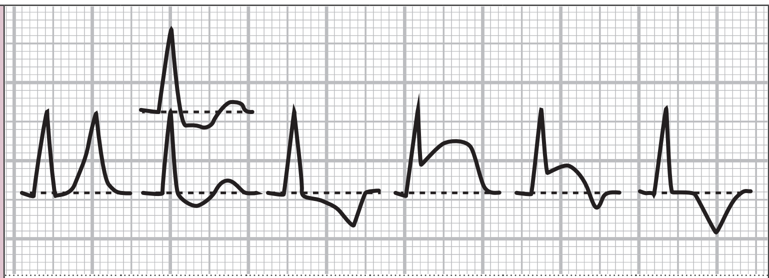
With this knowledge in mind, you should now add the evaluation of P waves to your cookbook approach!

Low voltage

Low voltage refers to a situation in which none of the QRS complexes in the standard leads (i.e., leads I, II, and III) is higher than 0.5mV. Possible reasons for this finding are peripheral edema, pulmonary emphysema, large pericardial effusion, or severe myocardial damage, among others. The ECG cannot provide you with a definitive diagnosis; it can just give you a hint that further workups are necessary.

Question	Answer	Diagnosis
1. Rhythm		
2. Heart rate		
3. P waves	Large P wave amplitude (> 2.5mm in II, III, or aVF)	Right atrial enlargement
	Prolonged negative part of P wave in V1 (>1mm) and P wave with 2 peaks in II, P wave duration > 0.12 sec	Left atrial enlargement
4. PR interval	a) > 0.2 sec (if PR interval constant for all beats & each P wave is followed by a QRS complex)	I° AV block
	b) < 0.12 sec & QRS complex normal	LGL syndrome
	c) < 0.12 sec & visible delta wave	WPW syndrome
5. QRS axis	Determine the axis according to Leads I, II, and aVF	Normal axis Left axis deviation Right axis deviation North-West axis
6. QRS duration	a) ≥ 0.12 sec (always think of the WPW syndrome as a differential)	complete bundle branch block
	b) > 0.1 and < 0.12 sec with typical bundle branch block appearance (notching)	incomplete bundle branch block
7. Rotation	Rotation is defined according to the heart's transition zone. Normally the transition zone is located at V4, which means that right ventricular myocardium is located at V1-V3 and left ventricular myocardium is at V5-V6.	transition zone at V5-V6: clockwise rotation transition zone at V1-V3: counter-clockwise rotation CAVE: don't evaluate rotation in the setting of myocardial infarction, WPW syndrome or bundle branch block
8. QRS amplitude	a) QRS amplitude <0.5 mV in all standard leads	low voltage
	b) Positive criteria for left ventricular hypertrophy	left ventricular hypertrophy
	c) Positive criteria for right ventricular hypertrophy	right ventricular hypertrophy
9. QRS infarction signs	abnormal Q waves, QS waves, missing R wave progression	myocardial infarction - localization according to affected leads

10. ST–T segment

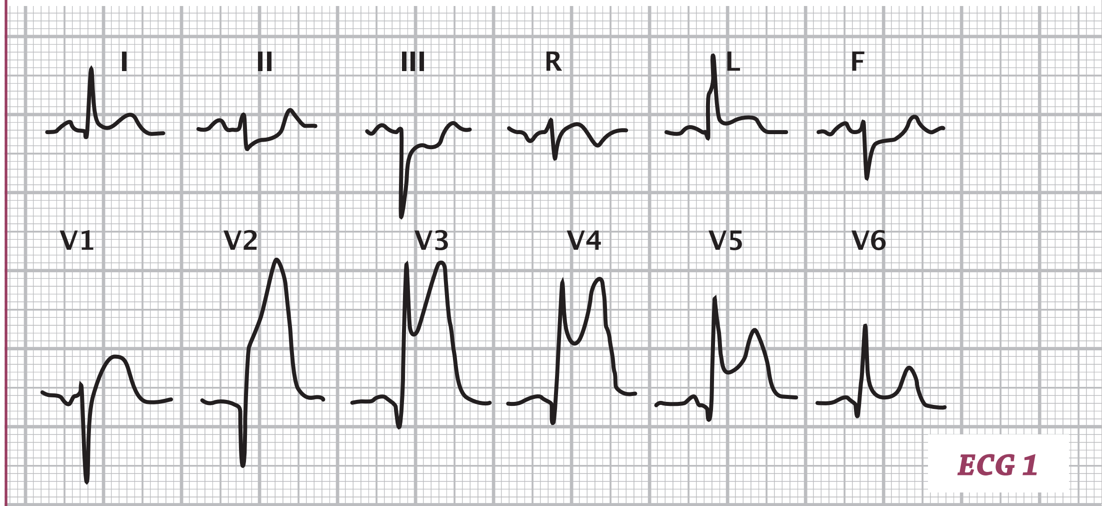


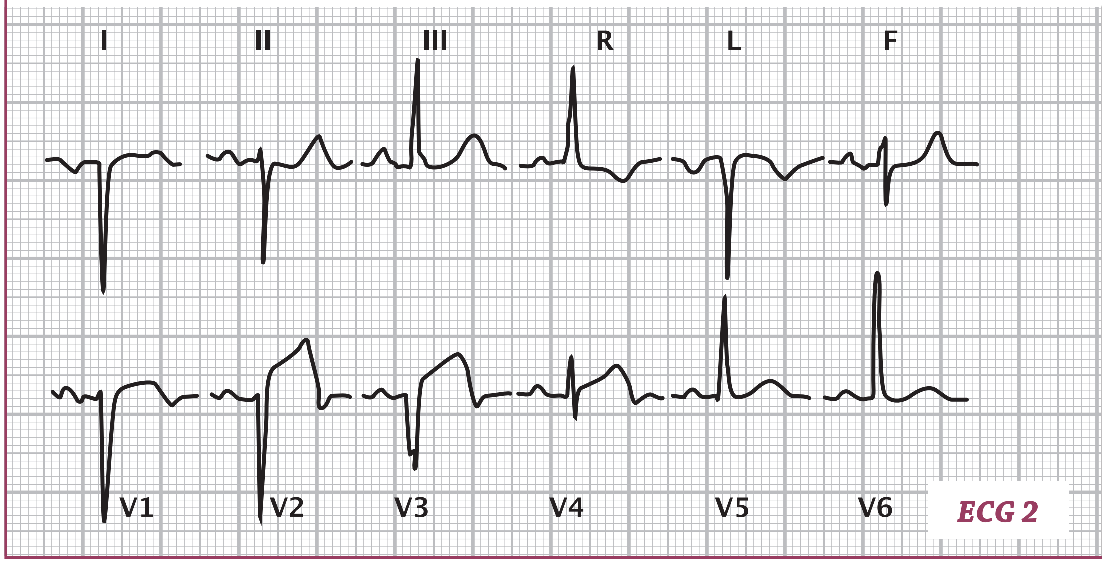
QRS	tall T wave	ST depression	ST depression	ST elevation		negative T	Interpretation
QRS normal	→						hyperkalemia, vagotonia
QRS normal		→					probably ischemia (DD: Digitalis)
QRS normal			→				non-specific repolarization abnormality
QRS normal				→			acute ischemia, perimyocarditis Variant angina
QRS normal					→		STEMI in resolution
QRS normal						→	STEMI in resolution NSTEMI, perimyocarditis
QRS with Q wave				→	(→)	(→)	STEMI acute and in resolution
QRS: left ventricular hypertrophy			→				left ventricular hypertrophy with abnormal repolarization
QRS: right ventricular hypertrophy, bundle branch block or WPW syndrome			→				In these situations an ST segment deviation is almost always present and cannot be interpreted in and of itself. It has to be left out in the ECG report

11. QT duration, T–U waves

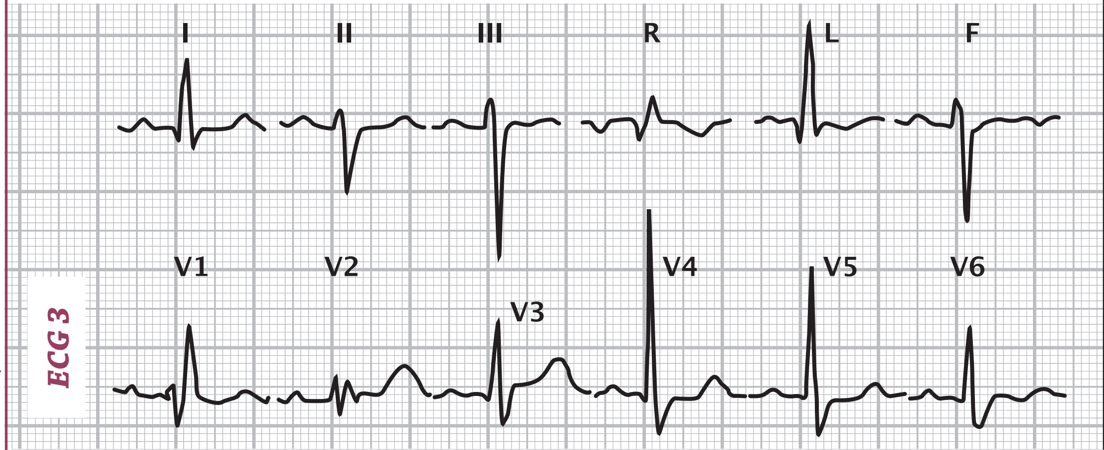
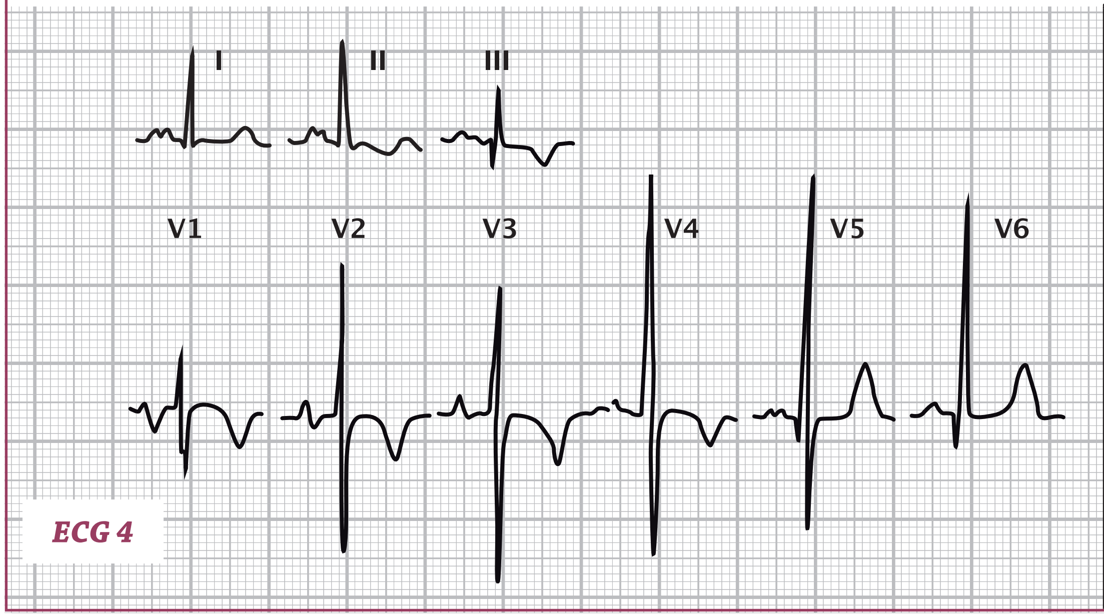
Level 11
QUIZ SECTION

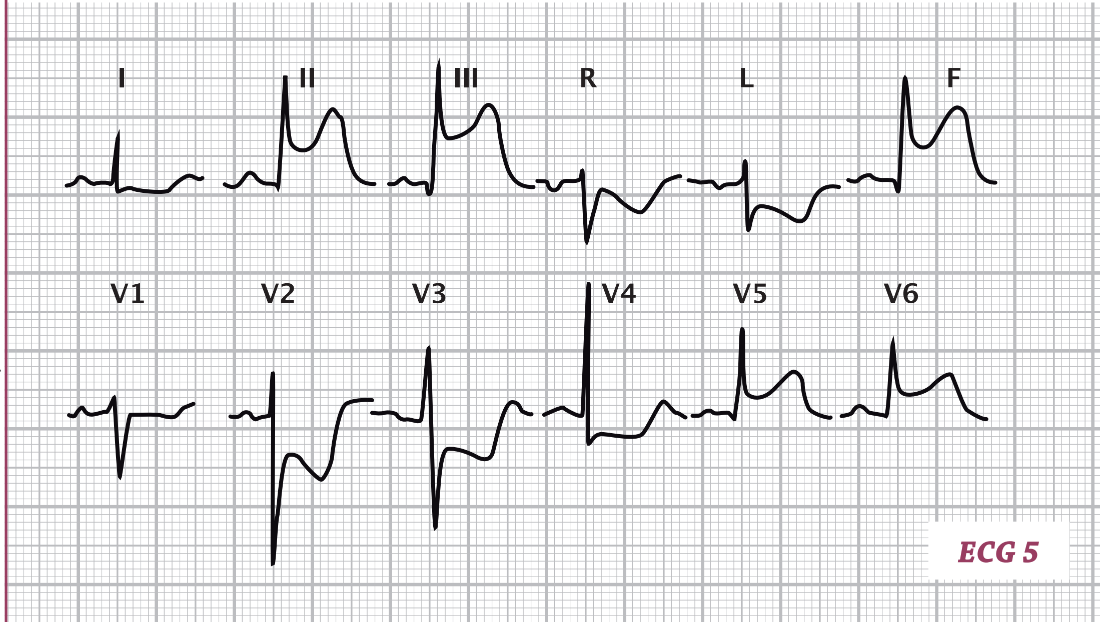
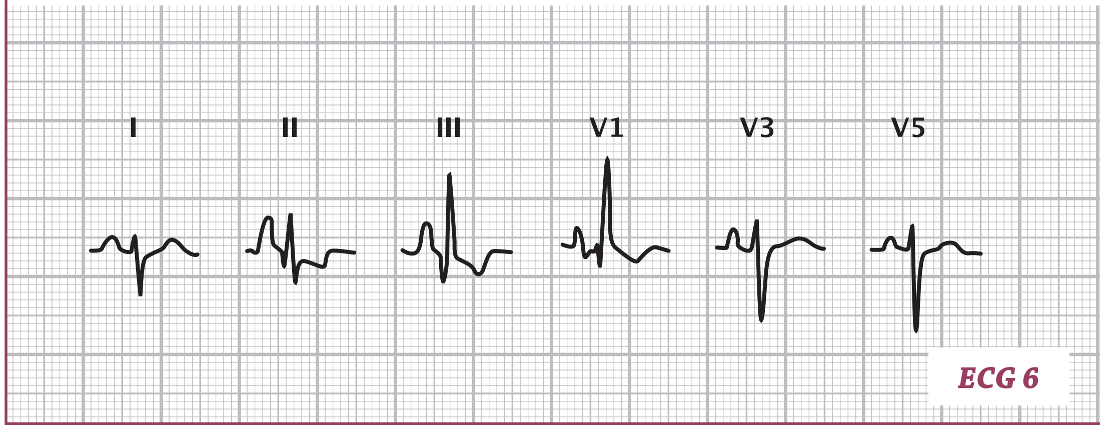
And now it's time for some exercises…





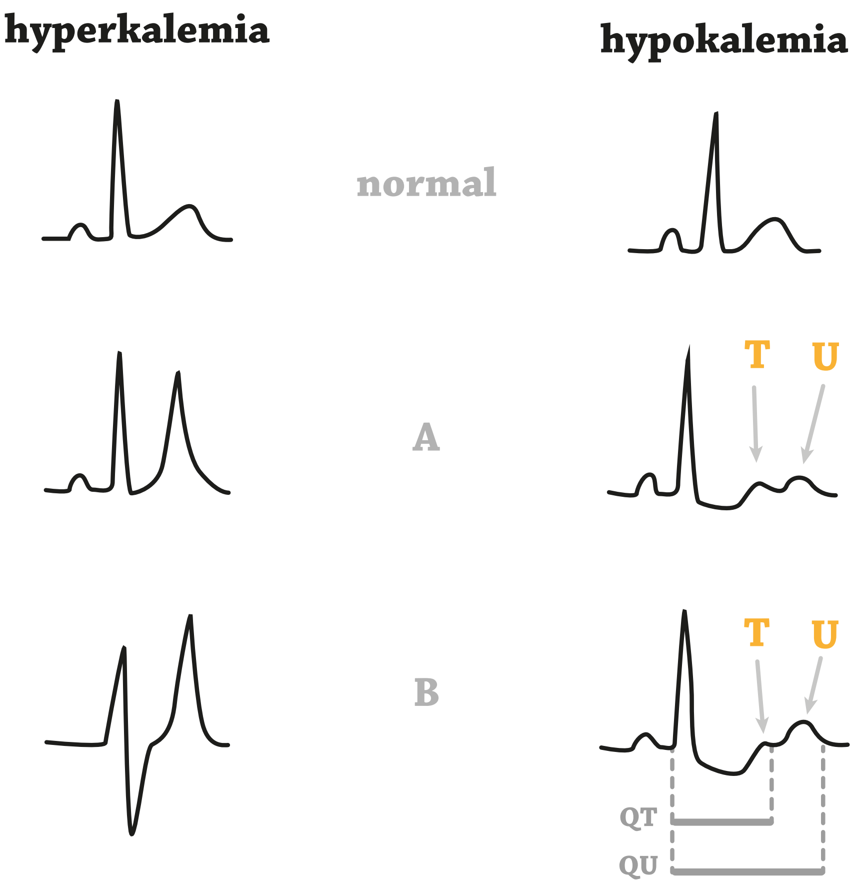
	Electrical axis				
	Normal axis	Left axis deviation	Right axis deviation	North-West axis / extreme axis deviation	Which additional changes can be found? (use our cookbook!)
ECG 1					
ECG 2					

	electrical axis				
	Normal axis	Left axis deviation	Right axis deviation	North-West axis / extreme axis deviation	Which additional changes can be found? (use our cookbook!)
					
					

	Electrical axis				
	Normal axis	Left axis deviation	Right axis deviation	North–West axis / extreme axis deviation	Which additional changes can be found? (use our cookbook!)
					
					

Level 12: A short story about electrolytes and heart rate

The ECG can help you detect various kinds of electrolyte disturbances. Some of them are potentially life-threatening.



Hyperkalemia

Hyperkalemia (as seen in renal failure) is characterized by a **tall and "tented" T wave** (A). Sometimes the ECG can lead to a diagnosis of chronic renal failure even in patients who haven't developed any symptoms yet. In more severe cases (B), the **P wave gets lost** and **QRS complex gets broader**.

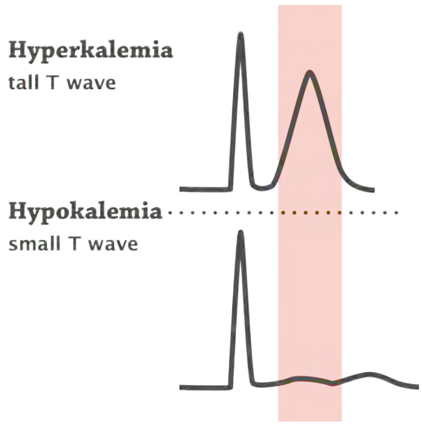
Remember that in vagotonia we can also see tall T waves. But these T waves are not as tall and sharp as the ones seen in hyperkalemia. Measurement of potassium levels will give you the answer.

Hypokalemia

ECG changes seen in hypokalemia are a sign of cellular potassium loss. They are seen even before blood levels start to drop. That's why ECG changes associated with hypokalemia correlate less well with potassium levels than changes associated with hyperkalemia.

The typical ECG changes seen in hypokalemia are:

- Flattening of the T wave
- Appearance of a U wave
- ST depression



So remember:

Hyperkalemia = tall T

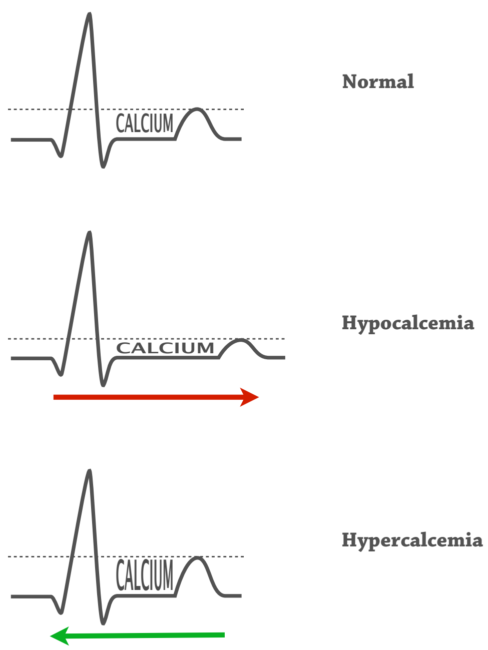
Hypokalemia = small T

A U wave is a second positive deflection that comes after the T wave (A and B in the illustration at the beginning of this level). Note that hypokalemia does not lead to a prolongation of the QT interval. The **QT interval** starts at the beginning of the QRS complex and ends at the end of the T wave.

Don't confuse the QU interval with the QT interval!

Hypocalcemia & Hypercalcemia

In hypercalcemia, the QT interval can be shortened, whereas in hypocalcemia, the QT interval can be prolonged.

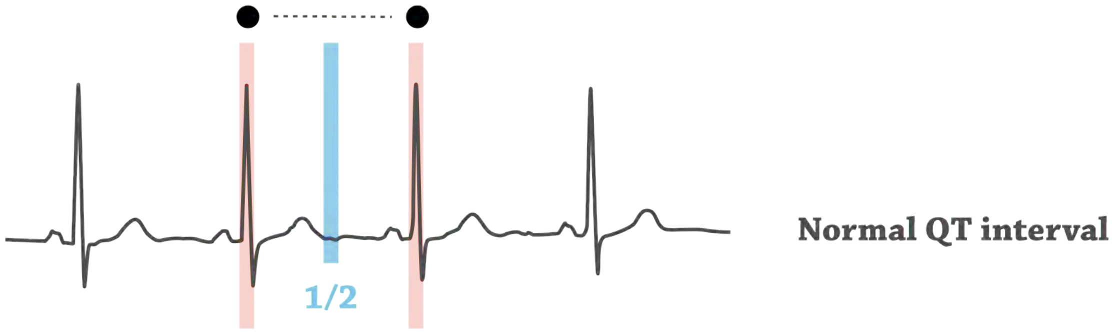


And how will you know if a patient's QT interval is normal or not? Well, the normal QT time varies with heart rate. **When heart rate is fast, the QT time shortens. When heart rate is slow, QT time becomes longer.** So there's no single normal value.

So how can you know if your patient's QT interval is normal or not? There are two approaches that you should know for now:

1. Most ECG machines will calculate the **QTc time** for you. That's the corrected QT interval normalized for a heart rate of 60/sec. The QTc is prolonged if it's > 0.44 seconds in men and > 0.46 seconds in women.

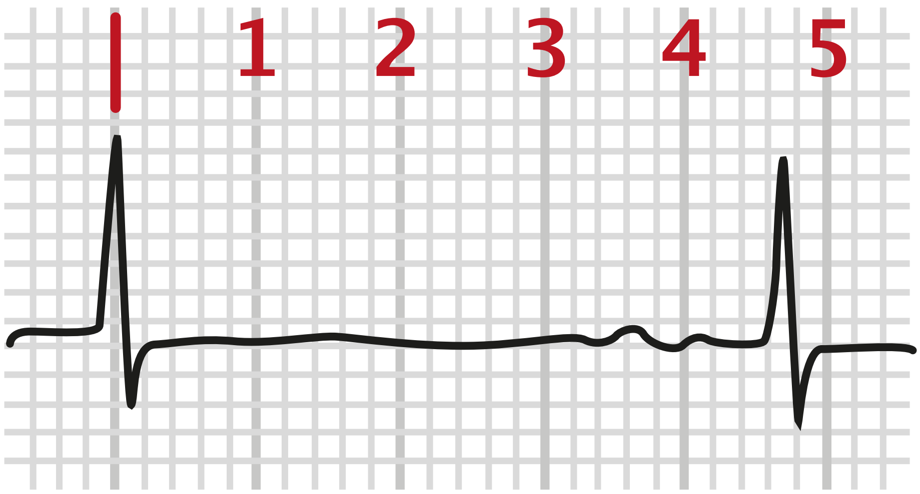
2. And the quick and dirty method goes like this:



Take an RR interval and "cut" it in half. If the T wave ends in the first half of the RR interval (as in the top example), the QT interval is normal. If the T wave ends in the second half of the RR interval (as in the lower example), the QT time is prolonged. If the QT interval is prolonged, you should then calculate the QTc in order to verify your suspicion.

Heart rate quick tip

An easy way to assess heart rate is to divide 300 by the number of big boxes between two QRS complexes:

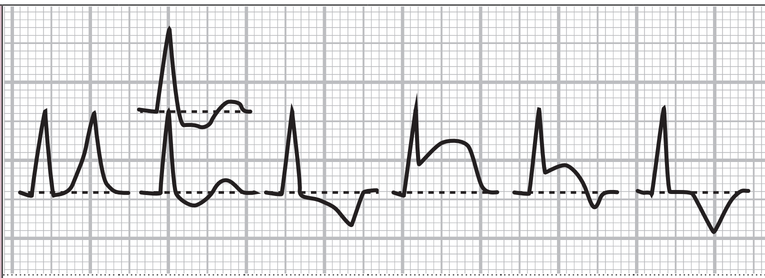


*The distance from one QRS complex to the next is **between 4 and 5 boxes** in length. 300/4 would be 75 beats per minute; 300/5 would be 60 beats per minute. So the heart rate is between 75 and 60 (probably around 65 beats per minute).*

You should now add the evaluation of heart rate, T waves, U waves, and the QT interval into your cookbook approach!

Question	Answer	Diagnosis
1. Rhythm		
2. Heart rate		
3. P waves	Large P wave amplitude (> 2.5mm in II, III, or aVF)	Right atrial enlargement
	Prolonged negative part of P wave in V1 (>1mm) and P wave with 2 peaks in II, P wave duration > 0.12 sec	Left atrial enlargement
4. PR interval	a) > 0.2 sec (if PR interval constant for all beats & each P wave is followed by a QRS complex)	I° AV block
	b) < 0.12 sec & QRS complex normal	LGL syndrome
	c) < 0.12 sec & visible delta wave	WPW syndrome
5. QRS axis	Determine the axis according to Leads I, II, and aVF	Normal axis Left axis deviation Right axis deviation North-West axis
6. QRS duration	a) ≥ 0.12 sec (always think of the WPW syndrome as a differential)	complete bundle branch block
	b) > 0.1 and < 0.12 sec with typical bundle branch block appearance (notching)	incomplete bundle branch block
7. Rotation	Rotation is defined according to the heart's transition zone. Normally the transition zone is located at V4, which means that right ventricular myocardium is located at V1-V3 and left ventricular myocardium is at V5-V6.	transition zone at V5-V6: clockwise rotation transition zone at V1-V3: counter-clockwise rotation CAVE: don't evaluate rotation in the setting of myocardial infarction, WPW syndrome or bundle branch block
8. QRS amplitude	a) QRS amplitude <0.5 mV in all standard leads	low voltage
	b) Positive criteria for left ventricular hypertrophy	left ventricular hypertrophy
	c) Positive criteria for right ventricular hypertrophy	right ventricular hypertrophy
9. QRS infarction signs	abnormal Q waves, QS waves, missing R wave progression	myocardial infarction – localization according to affected leads

10. ST-T segment



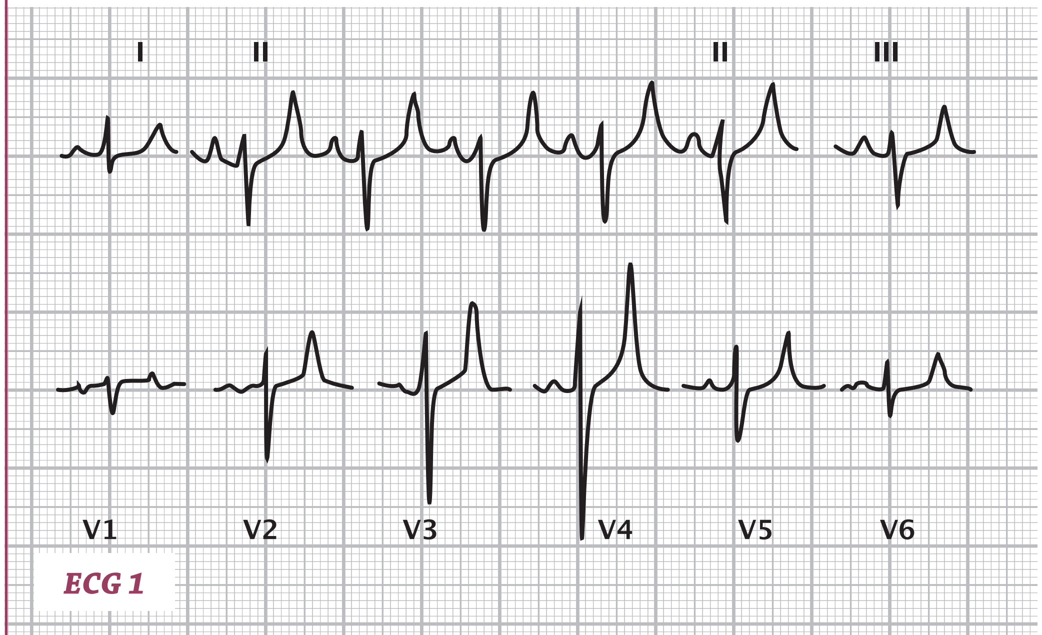
	tall T wave	ST depression	ST depression	ST elevation		negative T	
QRS normal	→						hyperkalemia, vagotonia
QRS normal		→					probably ischemia (DD: Digitalis)
QRS normal			→				non-specific repolarization abnormality
QRS normal				→			acute ischemia, myopericarditis Variant angina
QRS normal					→		STEMI in resolution
QRS normal						→	STEMI in resolution NSTEMI, myopericarditis
QRS with Q wave				→	→	→	STEMI acute and in resolution
QRS: left ventricular hypertrophy			→				left ventricular hypertrophy with abnormal repolarization
QRS: right ventricular hypertrophy, bundle branch block or WPW syndrome			→				In these situations an ST segment deviatiation is almost always present and cannot be interpreted in and of itself. It has to be left out in the ECG report

11. QT duration, T-U waves	a) QT shortening	Hypercalcemia
	b) QT prolongation	Hypocalcemia
	c) tall and peaked T wave	Hyperkalemia
	d) U wave, ST depression, T wave flattening or a combination of these	Hypokalemia

Level 12

QUIZ SECTION

Please use the updated cookbook for the following exercises and go through all the steps that we have covered so far. The numbers in the table to the right of the ECGs correspond to the steps in the cookbook. If at one step during your evaluation you find that something is wrong (e.g., PR interval, QRS width, etc.), just tick off the respective number. You should estimate the heart rate and the axis for each ECG.

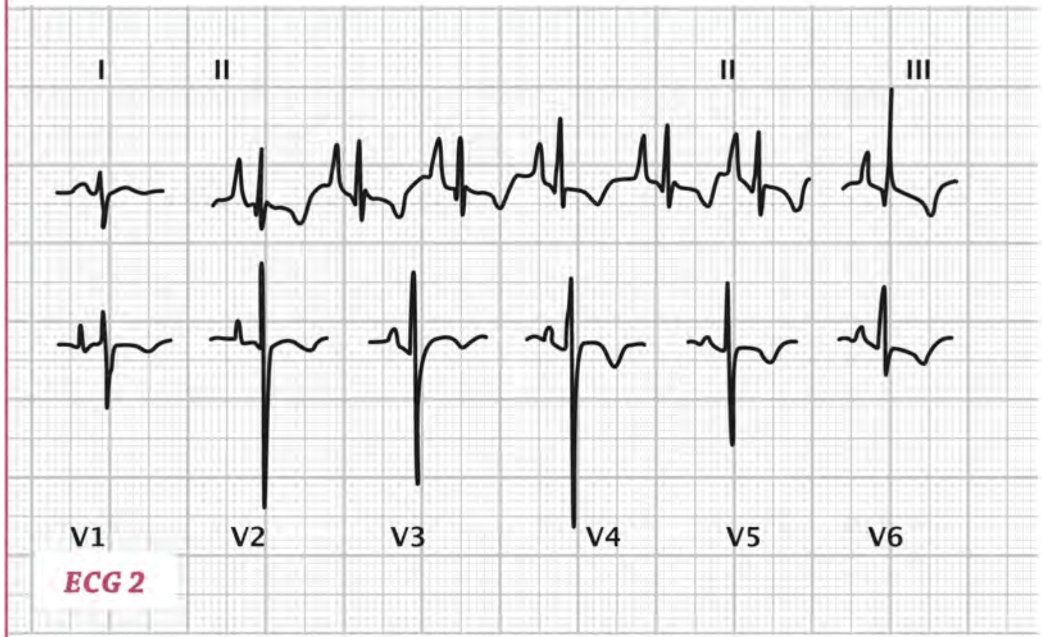


ECG 1

2	3		4			5	6		7	8			9	10	11
	a	b	a	b	c		a	b		a	b	c			

→ ____________ /min → ______________________________

Diagnosis:

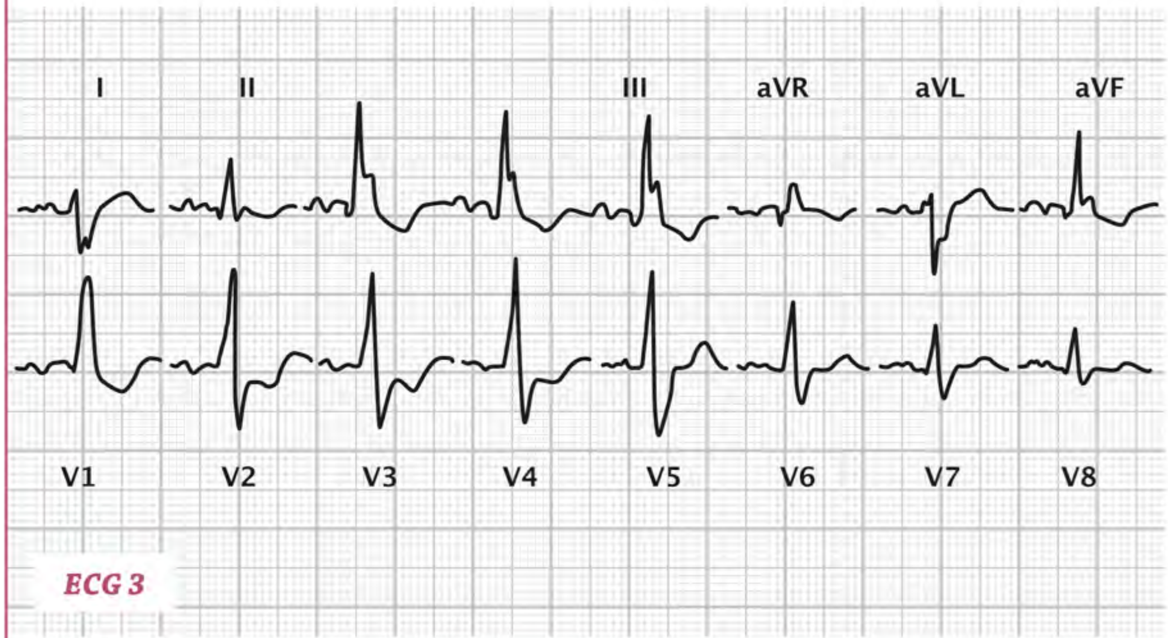


ECG 2

2	3		4			5	6		7	8			9	10	11
	a	b	a	b	c		a	b		a	b	c			

→ __________ /min → ____________________

Diagnosis:

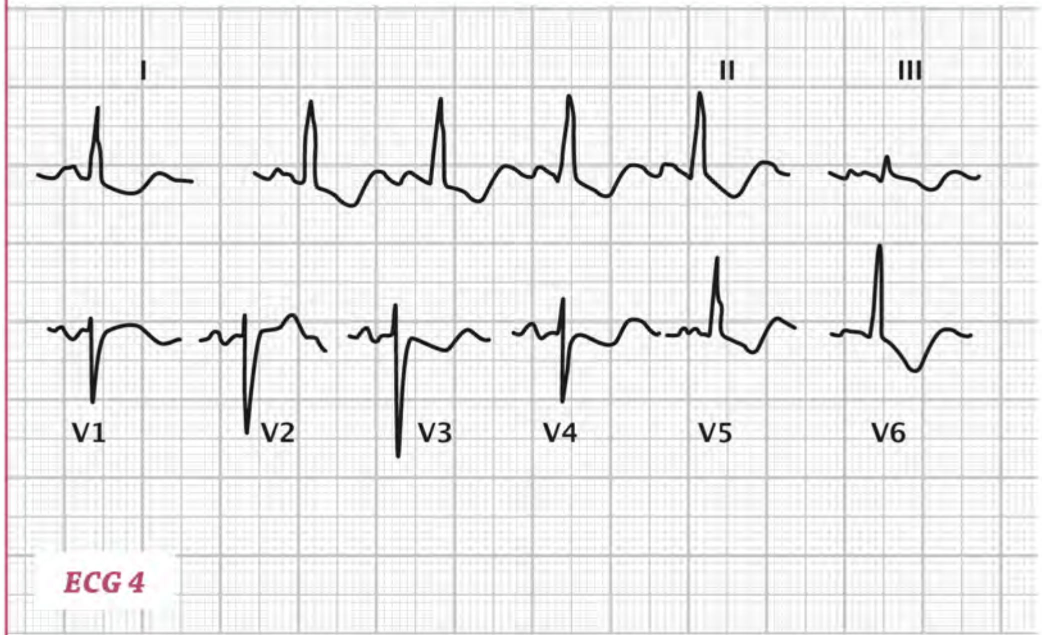


ECG 3

2	3		4			5	6		7	8			9	10	11
	a	b	a	b	c		a	b		a	b	c			

→ __________ /min → ____________________

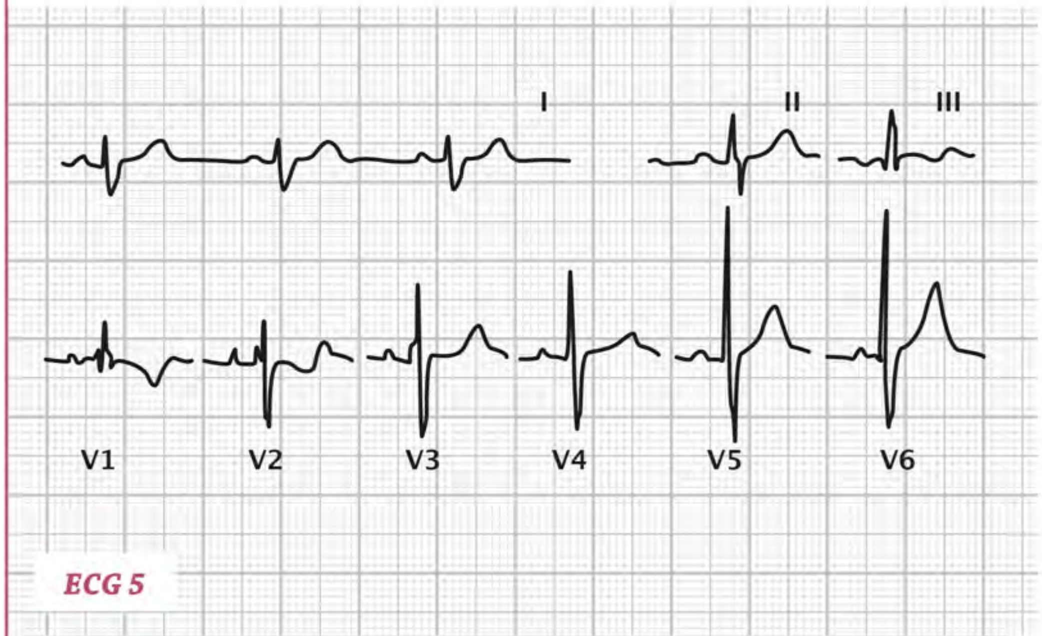
Diagnosis:



2	3		4			5	6		7	8			9	10	11
	a	b	a	b	c		a	b		a	b	c			

↳ ______________ /min ↳ ______________

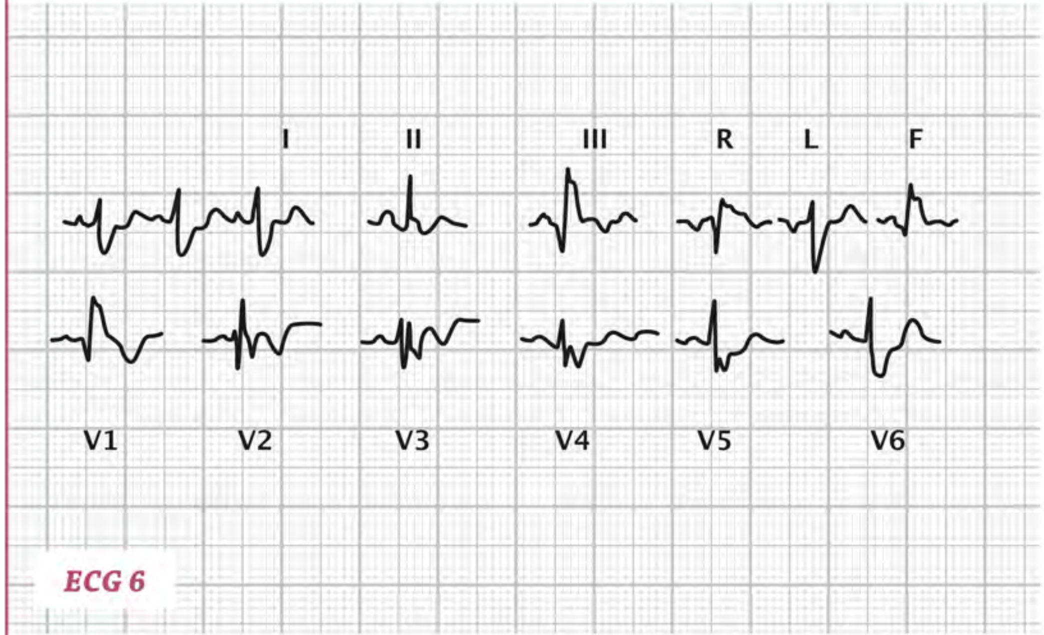
Diagnosis:



2	3		4			5	6		7	8			9	10	11
	a	b	a	b	c		a	b		a	b	c			

↳ ______________ /min ↳ ______________

Diagnosis:

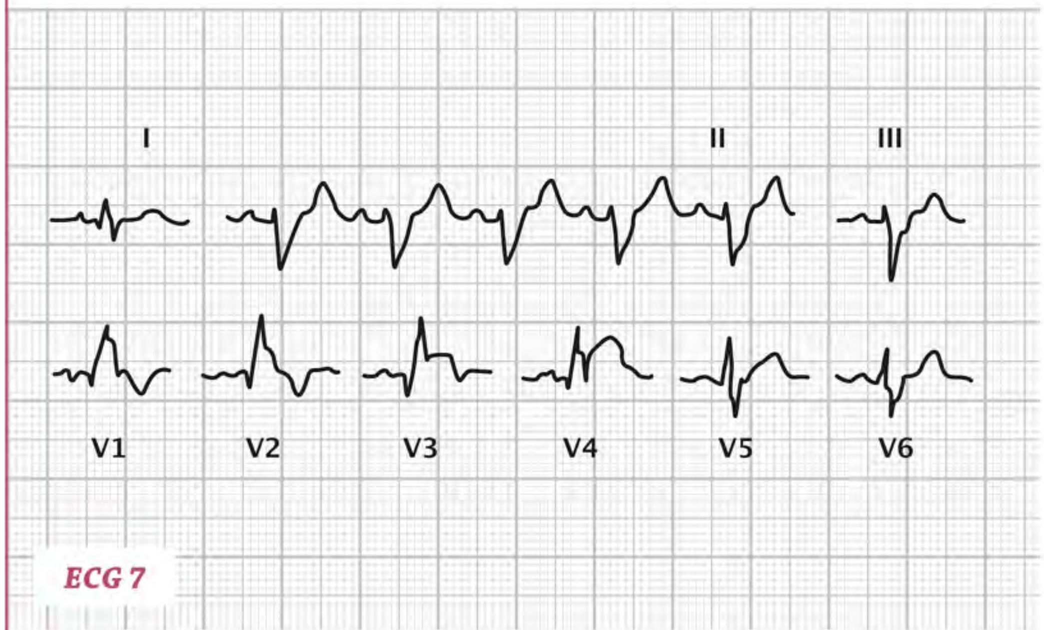


ECG 6

2	3		4			5	6		7	8			9	10	11
	a	b	a	b	c		a	b		a	b	c			

→ ______ /min → ______

Diagnosis:

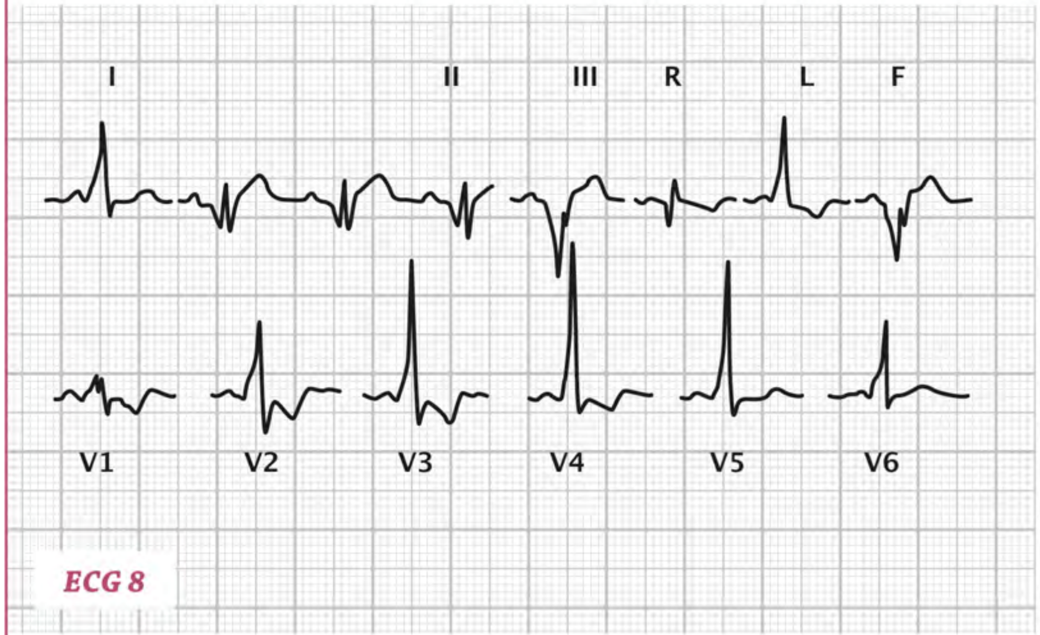


ECG 7

2	3		4			5	6		7	8			9	10	11
	a	b	a	b	c		a	b		a	b	c			

→ ______ /min → ______

Diagnosis:



2	3		4			5	6		7	8			9	10	11
	a	b	a	b	c		a	b		a	b	c			

→ ______________ /min → ______________________________

Diagnosis:

Level 13: Rhythm 101—the normal sinus rhythm

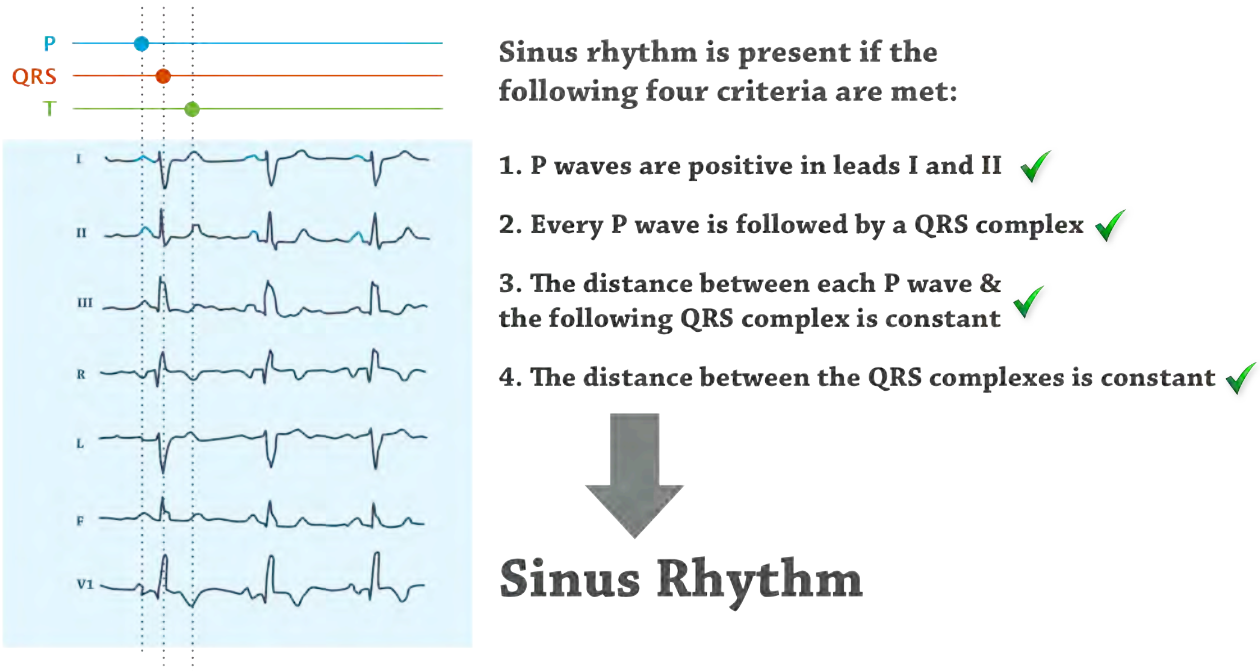
Keep going! You've almost made it through the Yellow Belt Section!

If you want to be able to diagnose rhythm problems, you'll first have to learn what constitutes a normal sinus rhythm. In sinus rhythm there's a regular sequence of P waves and QRS complexes.

All of the following **four criteria** need to be met in order for sinus rhythm to be present:

1. P waves are positive in leads I and II.
2. Every P wave is followed by a QRS complex.
3. The distance between each P wave and the following QRS is constant.
4. The distance between the QRS complexes is constant

Let's check the example below for the presence of sinus rhythm.



Note that apart from the limb leads, we also show you lead ***V1*** *here. This lead is located in close proximity to the right atrium and is therefore* ***ideally suited for the assessment of atrial depolarization****. The P wave is usually biphasic in V1, the initial positive deflection corresponds to right atrial depolarization, and the second (negative) part corresponds to left atrial depolarization.*

We have now covered all the steps of the cookbook!

Question	Answer	Diagnosis
1. Rhythm	Criteria for sinus rhythm: 1. Are the P waves positive in I and II? 2. Is there a QRS after each P wave? 3. Are the PR intervals constant? 4. Are the RR intervals constant?	Sinus rhythm or no sinus rhythm?
2. Heart rate	Estimate heart rate: 300 / number of large boxes between two QRS complexes	Heart rate in beats per min.
3. P waves	Large P wave amplitude (> 2.5mm in II, III, or aVF)	Right atrial enlargement
	Prolonged negative part of P wave in V1 (>1mm) and P wave with 2 peaks in II, P wave duration > 0.12 sec	Left atrial enlargement
4. PR interval	a) > 0.2 sec (if PR interval constant for all beats & each P wave is followed by a QRS complex)	I° AV block
	b) < 0.12 sec & QRS complex normal	LGL syndrome
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5. QRS axis	Determine the axis according to Leads I, II, and aVF	Normal axis Left axis deviation Right axis deviation North-West axis
6. QRS duration	a) ≥ 0.12 sec (always think of the WPW syndrome as a differential)	complete bundle branch block
	b) > 0.1 and < 0.12 sec with typical bundle branch block appea-rance (notching)	incomplete bundle branch block
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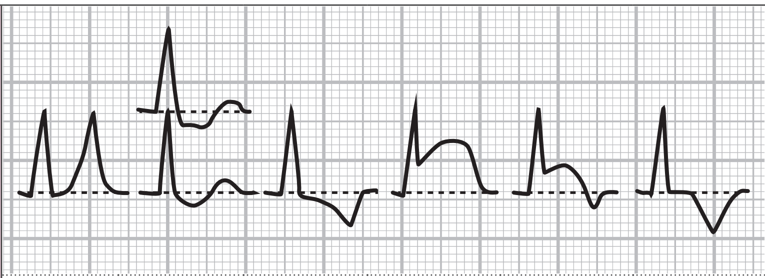
10. ST–T segment							
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QRS normal			→				non-specific repolarization abnormality
QRS normal				→			acute ischemia, perimyocarditis Variant angina
QRS normal					→		STEMI in resolution
QRS normal						→	STEMI in resolution NSTEMI, perimyocarditis
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11. QT duration, T–U waves		
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	b) QT prolongation	Hypocalcemia
	c) tall and peaked T wave	Hyperkalemia
	d) U wave, ST depression, T wave flattening, or a combination of these	Hypokalemia

Now it’s your turn again. Try to find out if sinus rhythm is present in the following exercises. If it is present, carry out a complete evaluation using the steps of our cookbook.

Congratulations, you have made it through the Yellow Belt section. Great job! You are now able to speak the ECG language. You understand the most important principles and are able to carry out a basic evaluation of the ECG. By now, you are well equipped to learn more ECGology on the job. However, if you want to take the express lane to ECG mastery, check out our Blue Belt section as well. There, you will learn the nuts and bolts of rhythm mastery. I'm looking forward to seeing you there. Have fun and enjoy the learning experience!

Level 13

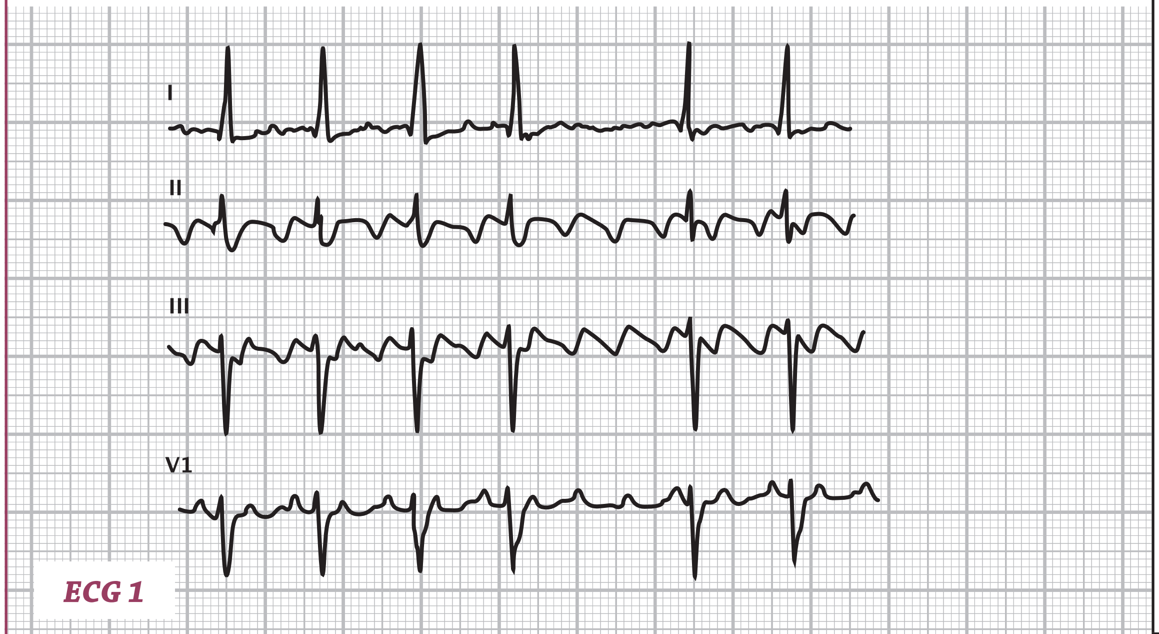
QUIZ Disclosure

Start by marking the P waves and the QRS complexes, then decide if sinus rhythm is present or not. Determine the heart rate in each example.

P ______

QRS ______

T ______



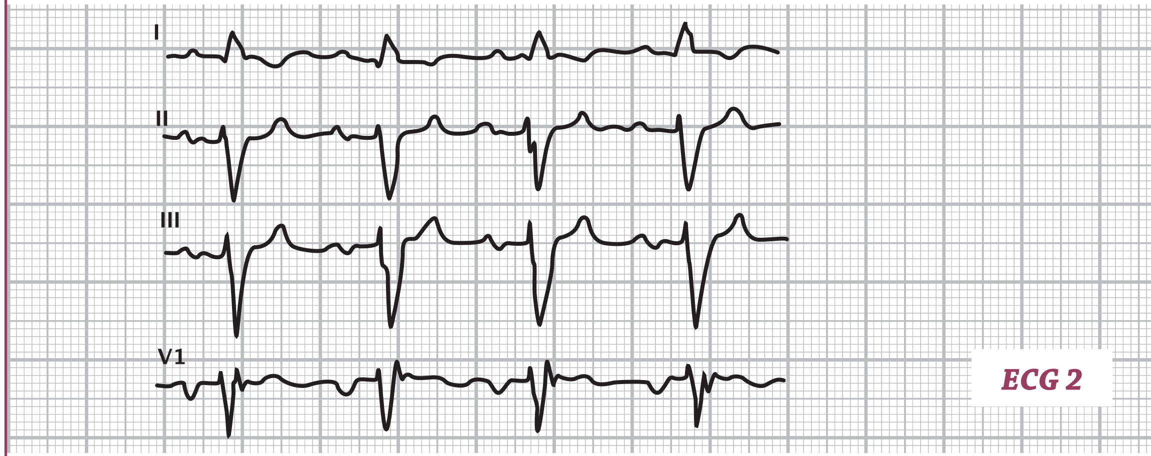
ECG 1

Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ______

QRS ______

T ______

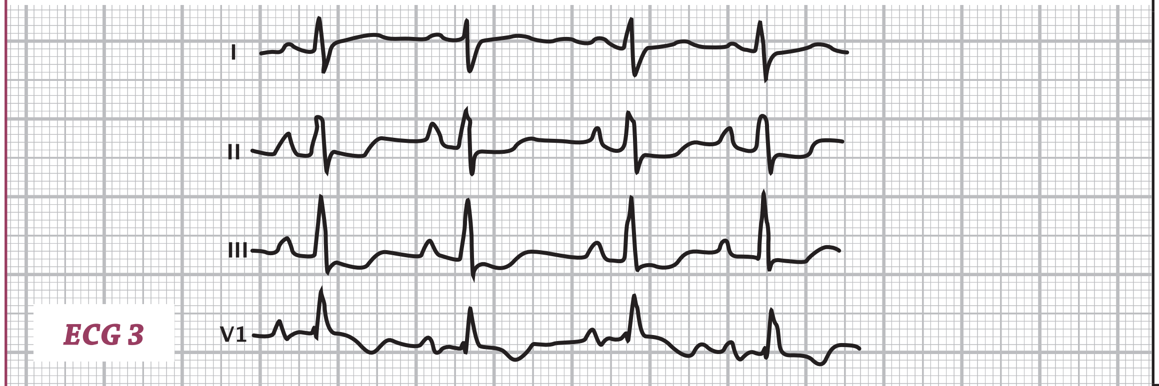


Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ______________________

QRS ______________________

T ______________________

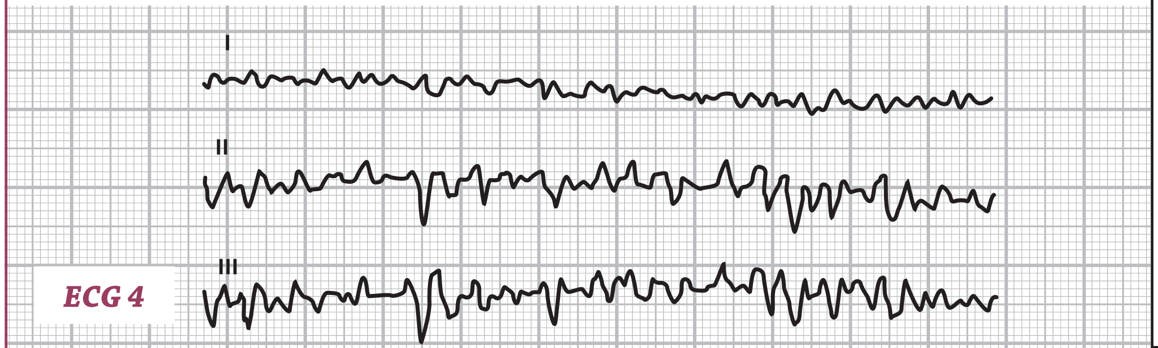


Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ____________________

QRS ____________________

T ____________________

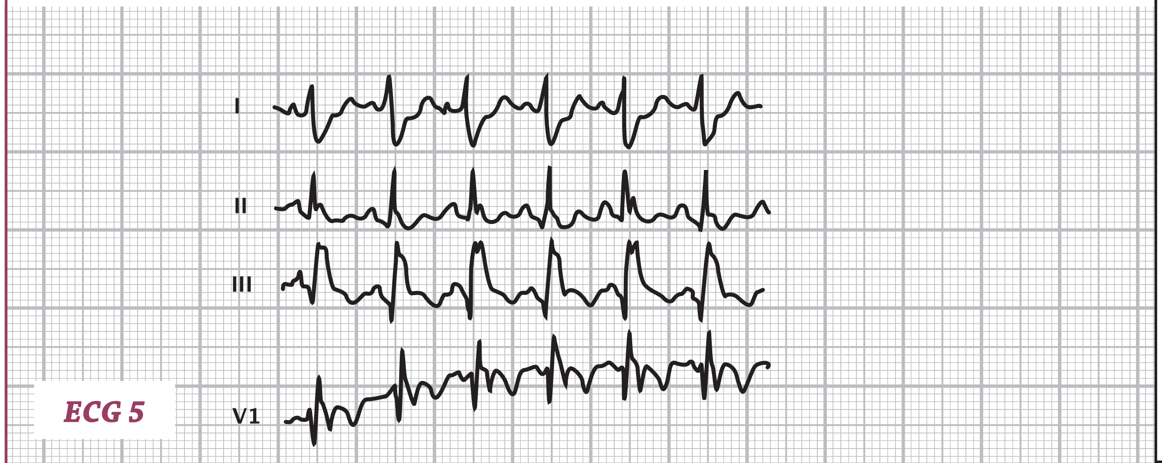


Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ____

QRS ____

T ____

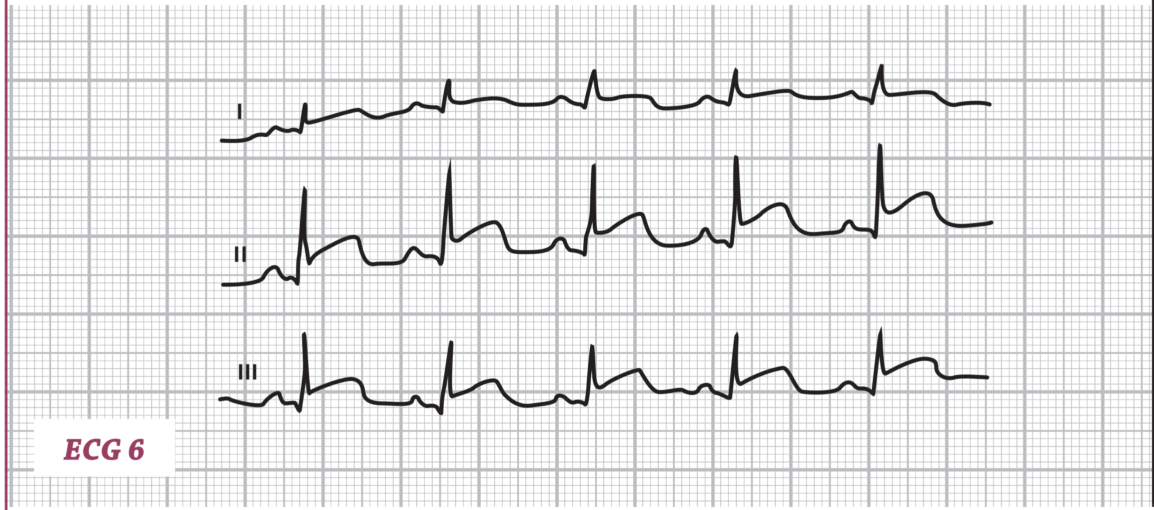


Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ____________________

QRS ____________________

T ____________________

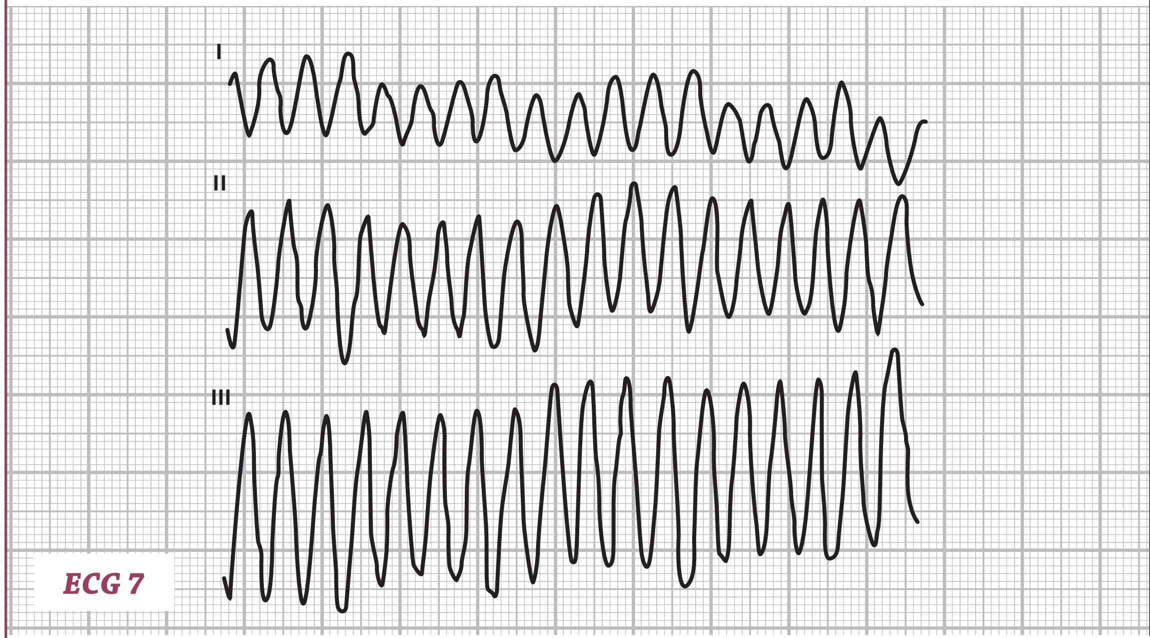


Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ______

QRS ______

T ______

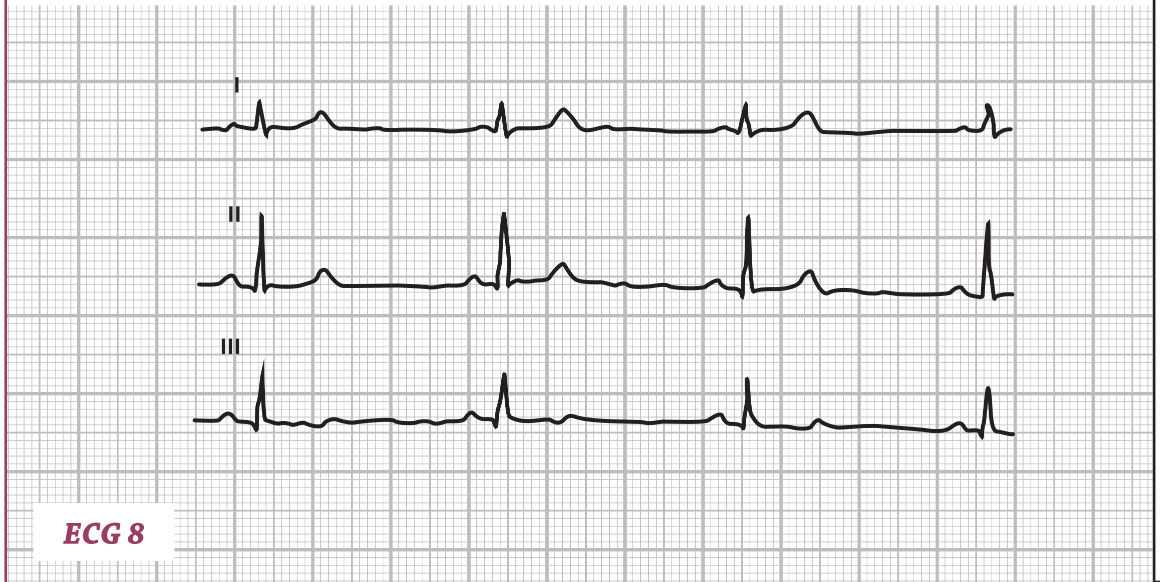


Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ______

QRS ______

T ______



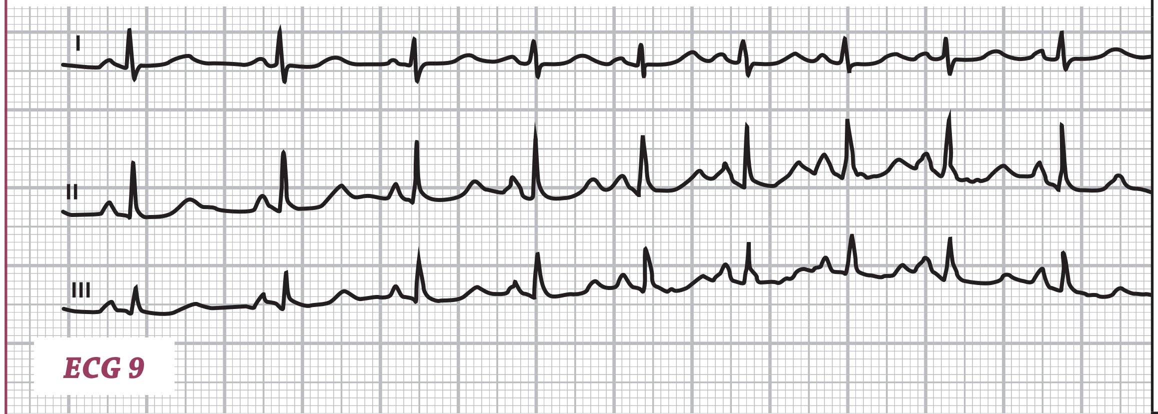
ECG 8

Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ________________

QRS ________________

T ________________



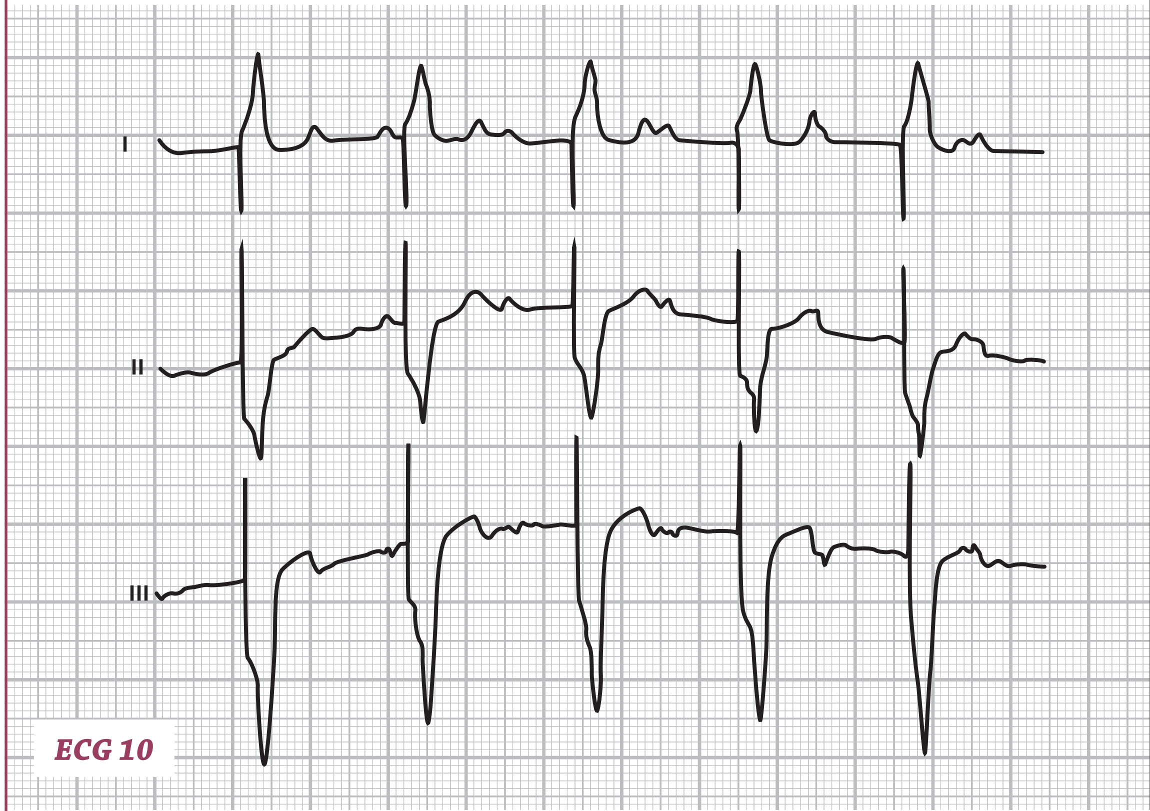
ECG 9

Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		

P ______

QRS ______

T ______



ECG 10

Sinus rhythm		Heart rate	If there is sinus rhythm make additional diagnoses according to our cookbook.
yes	no		