Level 11

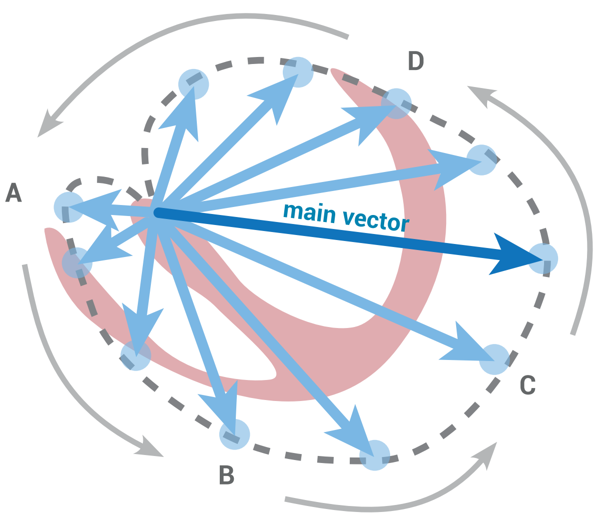
The ECG trio—cardiac axis, atrial hypertrophy, and low voltage

In this chapter, you will 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 ms (<0.1 s). In this image we have marked a few of these instantaneous average vectors: A: vector at 5 ms; B: vector at 30 ms; C: vector at 60 ms; D: vector at 80 ms. The dashed line connecting the tips of these vectors represents the vector loop.

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.

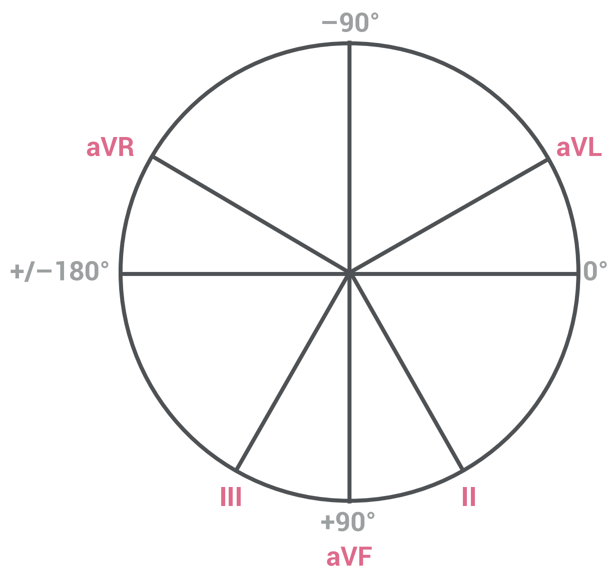
The most precise way to determine the axis in the frontal plane would be to exactly calculate the direction of the main vector. However, that's too time consuming and not worth the effort because there are only a few situations in which knowledge of the axis really makes a difference. You'll learn what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

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

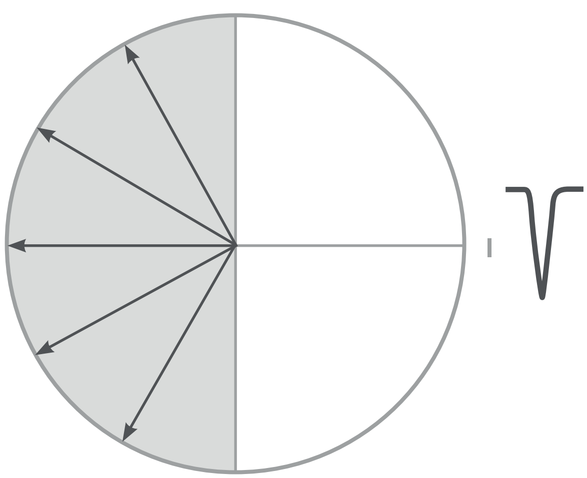
Remember that a lead records a **positive wave** *when the* **vector points into the direction of that lead**. *When the* **vector points away from that lead**, *the deflection will be mainly* **negative**.

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

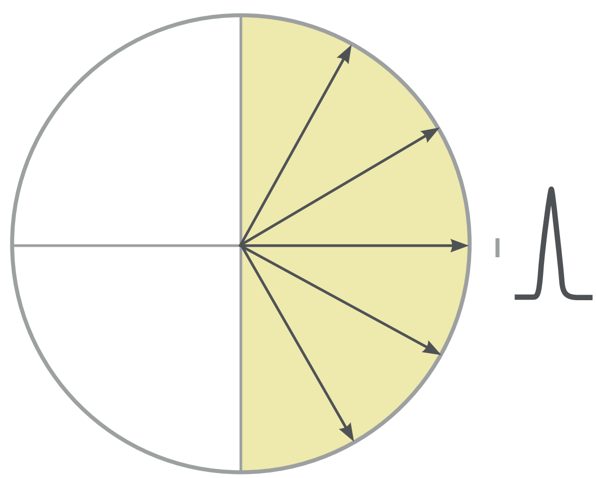
The degrees of the circle start near lead I with 0. When we go clockwise, the degrees are +60º, +90º, etc., and when we go counterclockwise they are negative (-30º, etc.).



Let us now consider what this means for lead I:

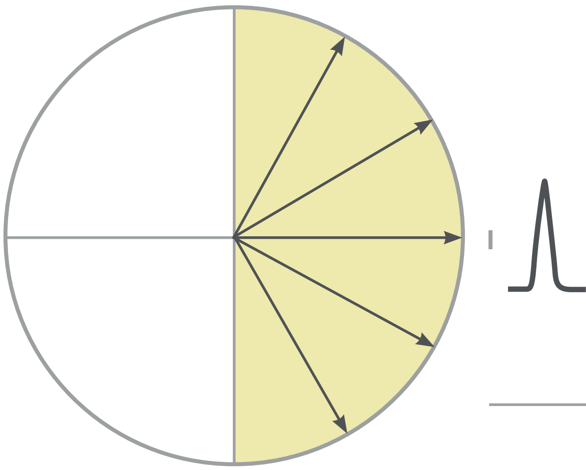


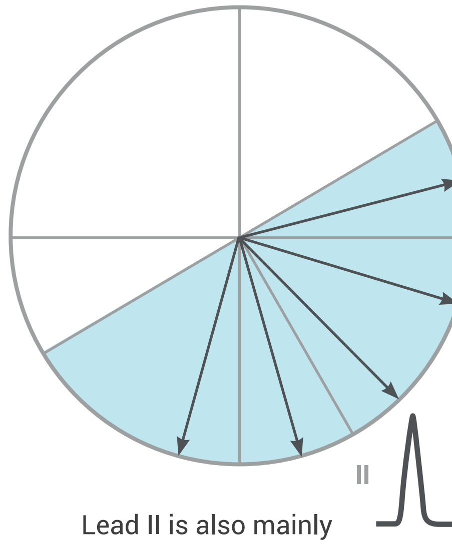
Deflection is **negative** when vectors point **away from** lead I



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

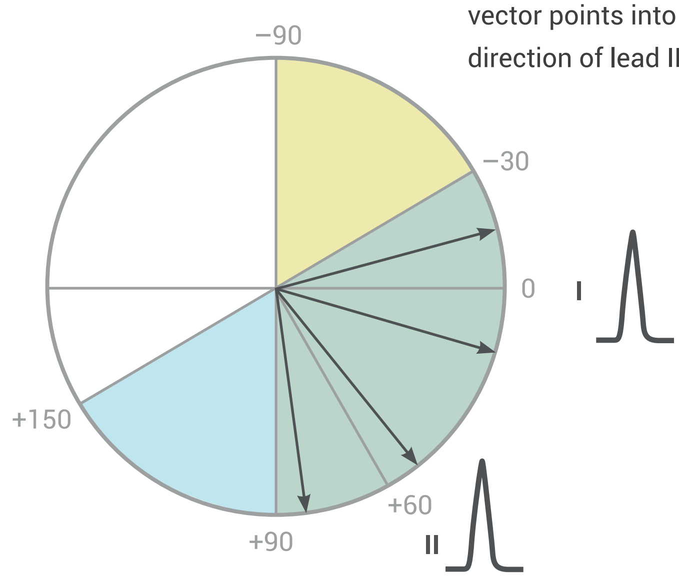
Let's see what happens when leads I and II are mainly positive:





Lead I is mainly positive, so the main vector points into the direction of lead I

Lead II is also mainly positive, so the main vector points into the direction of lead II

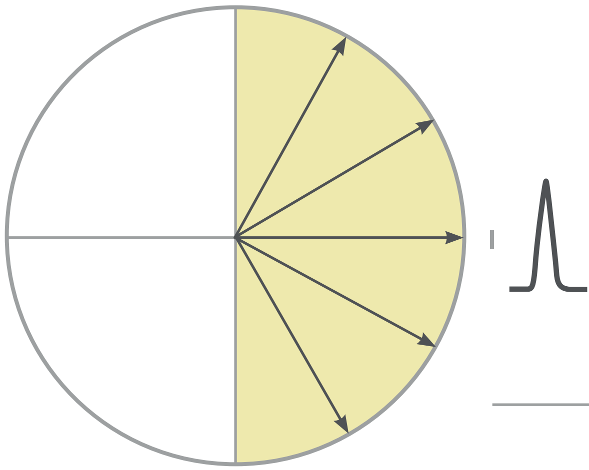


We can see that lead I and lead II will be positive if the main electrical vector points into the intersection of the yellow and blue areas

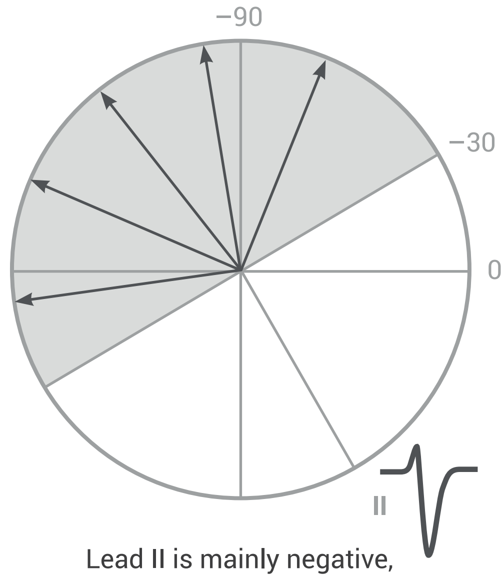
The area between –30° and +90° is called a "normal axis"

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.

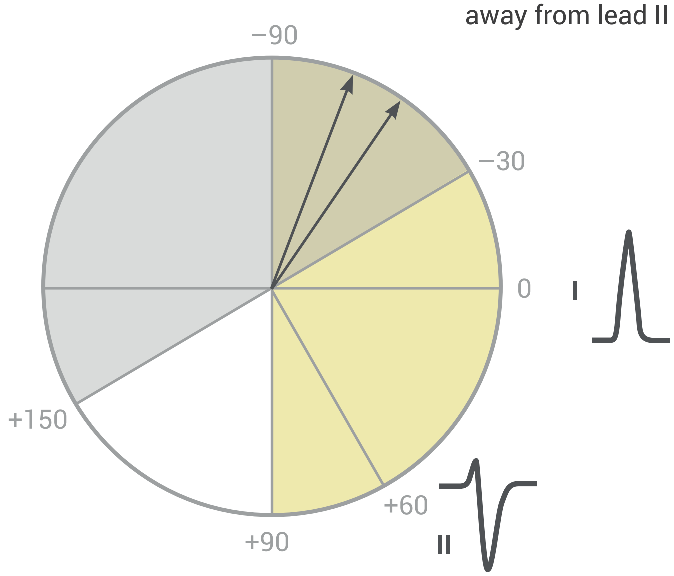
Now let's see what happens when lead I is positive and lead II is negative:



Lead I is mainly positive, so the main vector points into the direction of lead I



Lead II is mainly negative, so the main vector points away from lead II

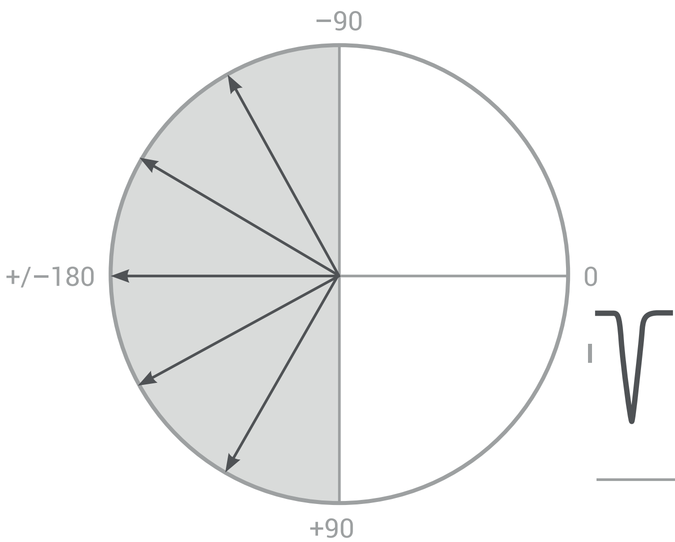


So the main electrical vector has to point into the direction of the intersection of the yellow and gray areas

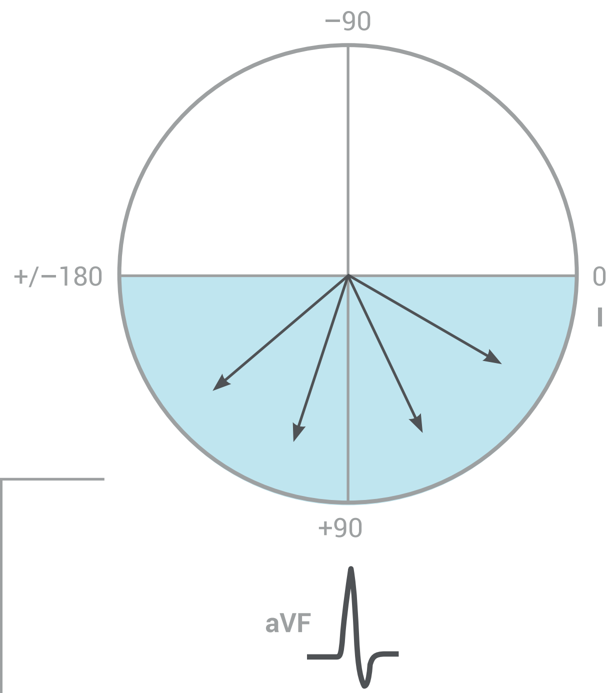
The area between −30° and −90° is called "left axis deviation"

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

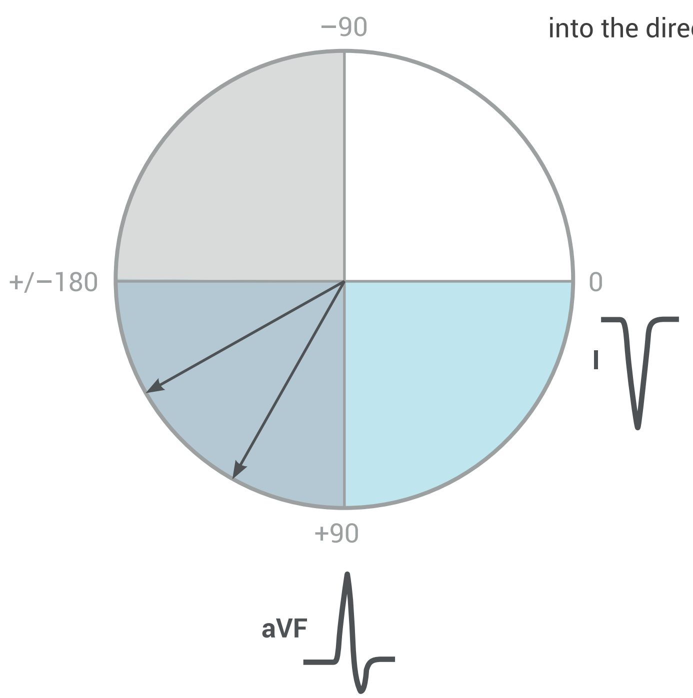
Now let's see what happens when lead I is negative and aVF is positive:



Lead I is mainly negative, so the main vector points away from lead I



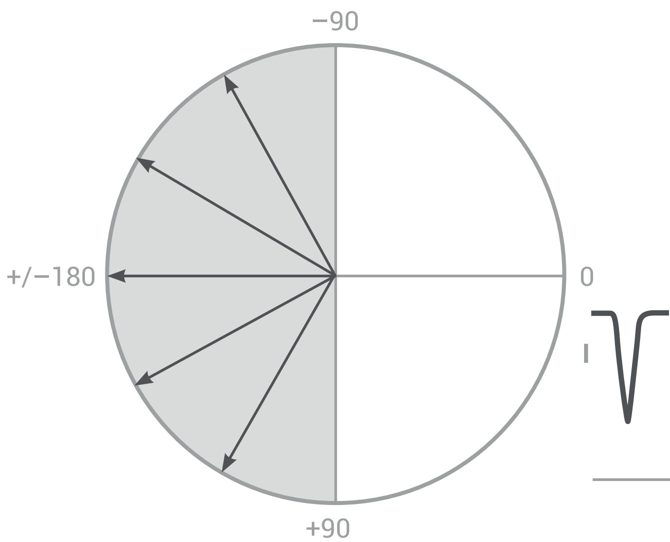
Lead aVF is mainly positive, so the main vector points into the direction of lead aVF



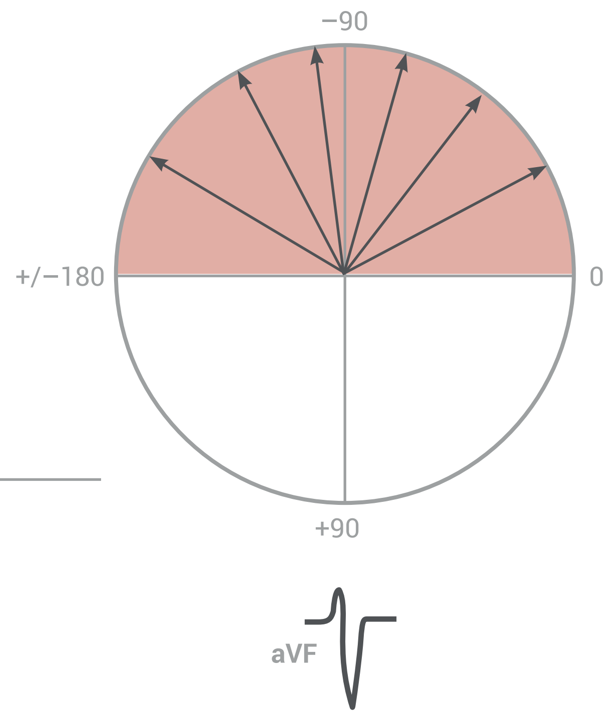
The main vector has to point at the intersection of the gray and blue areas

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

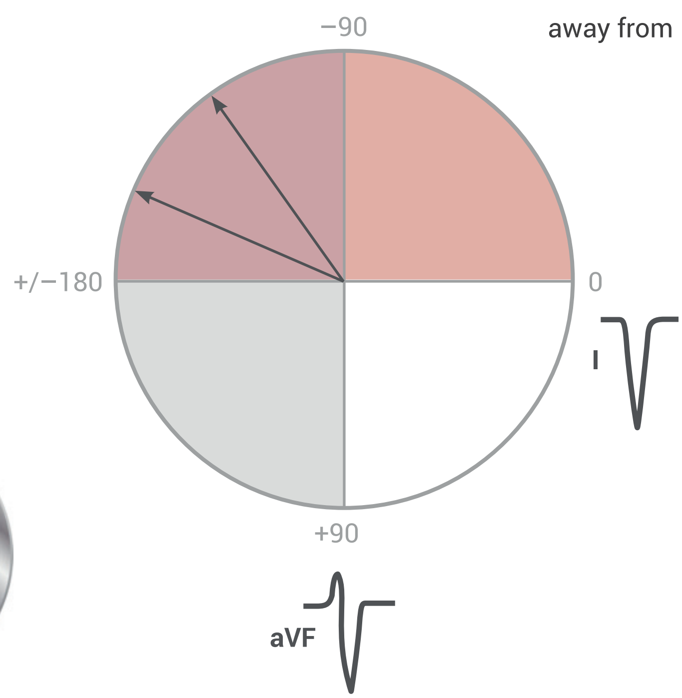
And what's the matter when both leads I and aVF are negative?



Lead I is mainly negative, so the main vector points away from lead I



Lead aVF is mainly negative, so the main vector points away from lead aVF

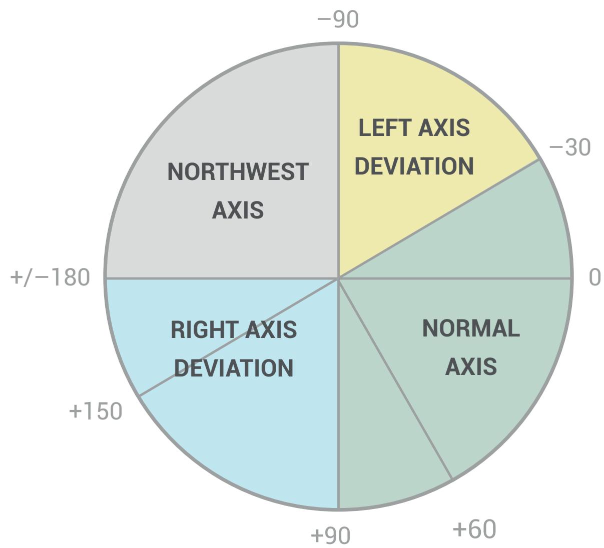


The main vector has to point at the intersection of the grey and blue areas

The area between −90° and +/−180° is called a “northwest axis”

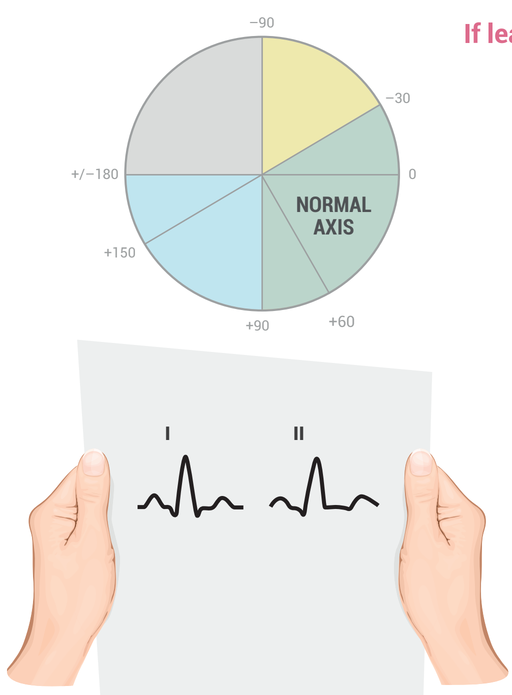
You should only care about left axis deviation and right axis deviation for now. Why? Because when the axis is normal, that won't really help you in refining your diagnosis. A northwest axis is extremely rare—you won't encounter it much as a novice. But you will encounter left axis deviation and right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

So here's an overview:



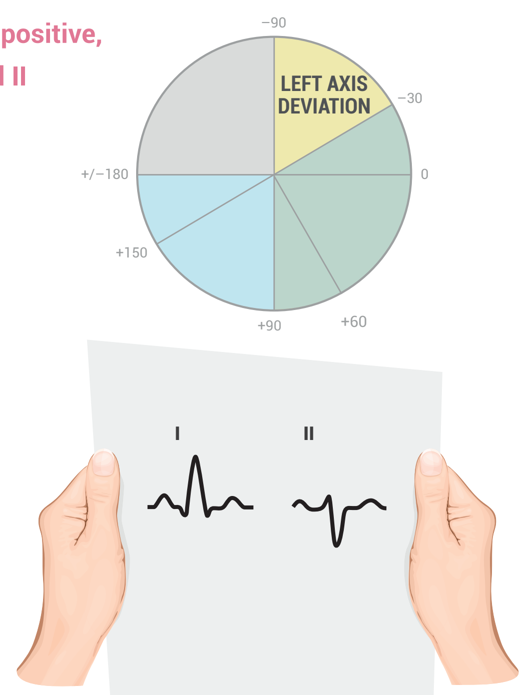
So how can you determine the cardiac axis really easily? Here's how…

All you have to do 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:**



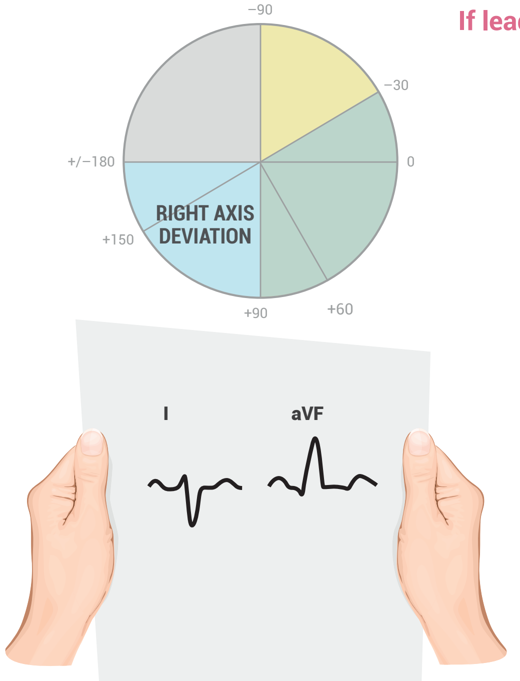
If both leads are mainly positive, it's a **normal axis**

If lead I is mainly positive, look at lead II

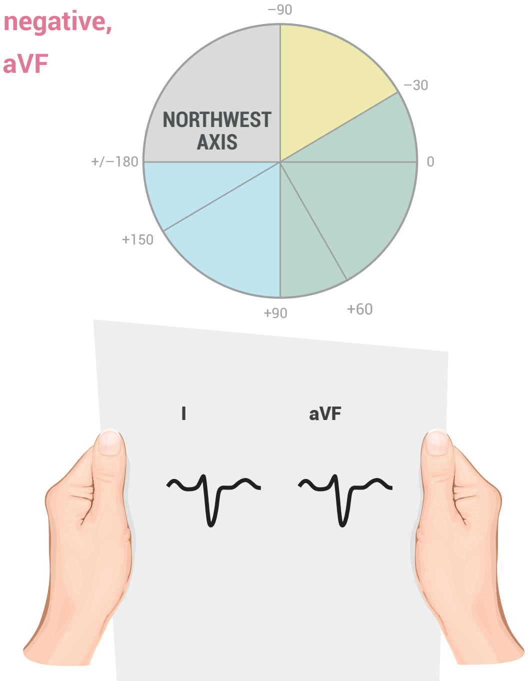


If the left lead is mainly positive and the right lead is mainly negative, it's a **left axis deviation**

If lead I is mainly negative, look at lead aVF



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



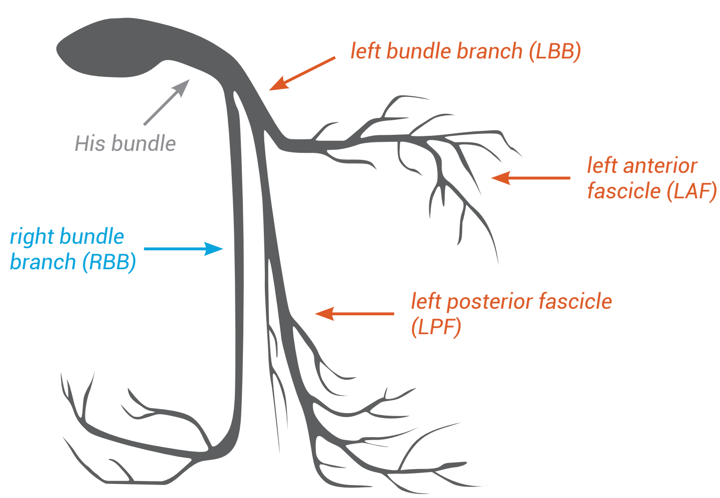
If both leads are mainly negative, it's a **northwest axis**

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

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

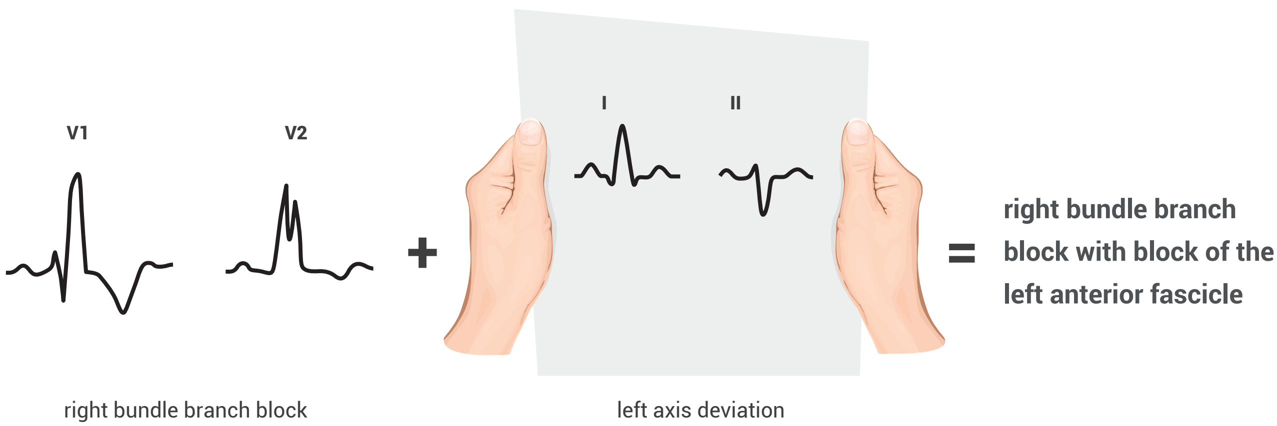
Situation #1

For ventricular depolarization, impulses are conducted down into the ventricles through the so-called bundle branches. There's a right bundle branch (RBB) and a left bundle branch (LBB). 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 the left bundle branch is blocked. Sometimes what happens in right bundle branch block is that one of the left fascicles is also blocked. That's called a bifascicular block. It's a pretty dangerous situation because 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.

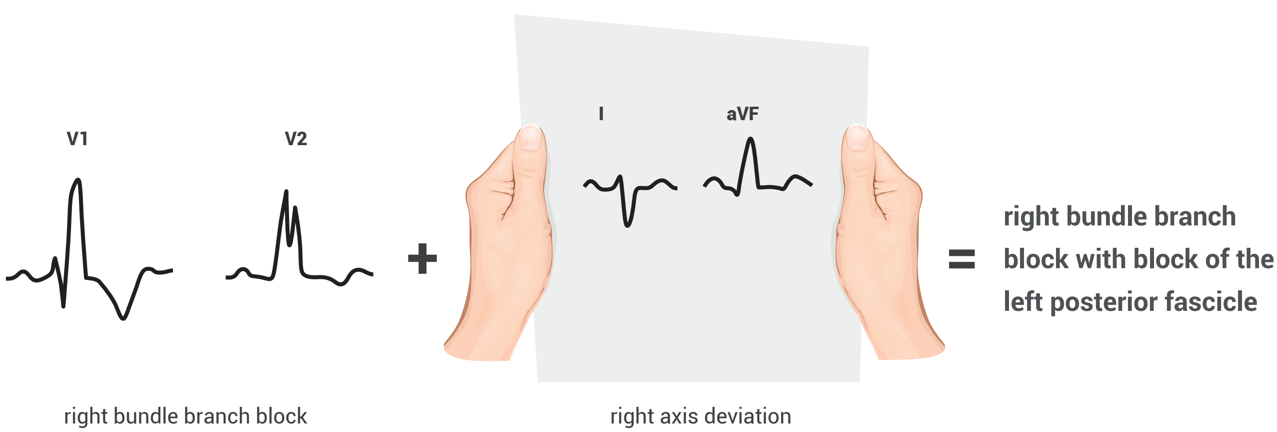
How can you tell whether bifascicular block is present? Well, if you have a typical picture of a right bundle branch block in the precordial leads and you also have left axis deviation, the patient has bifascicular block involving the left anterior fascicle (also called "right bundle branch block with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



The abbreviation for the left anterior fascicle is LAF. So there's a straightforward 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 bifascicular block with involvement of the left posterior fascicle:



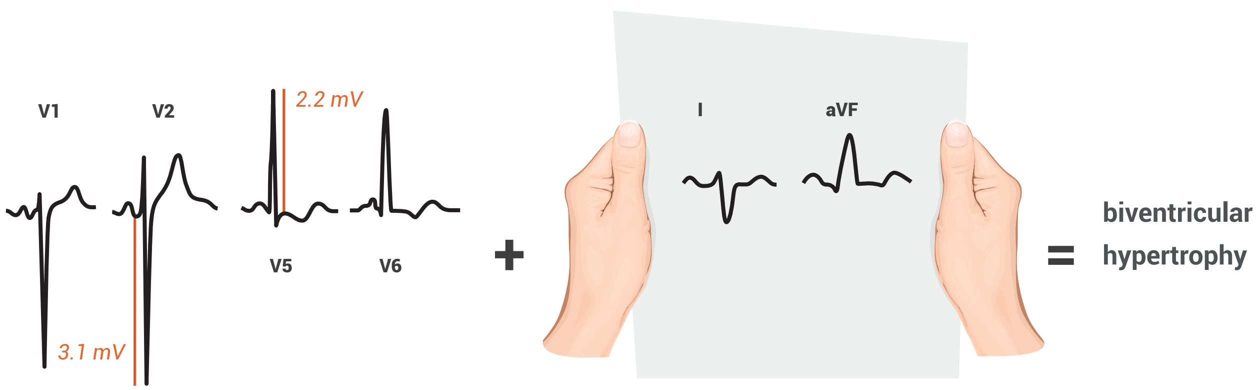
Situation #2

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 in which both the left and the right ventricles are hypertrophic.



left ventricular hypertrophy

right axis deviation

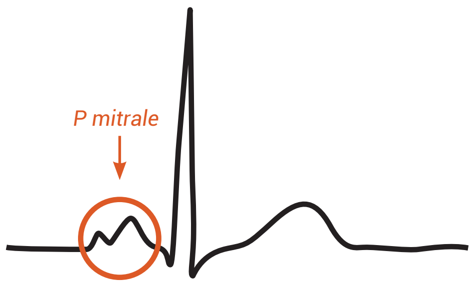
Great! Now you know when knowledge of the cardiac axis really makes a difference. You should now integrate the evaluation of cardiac axis into the steps of the cookbook. Congrats, you've almost made it through the training!

Atrial hypertrophy

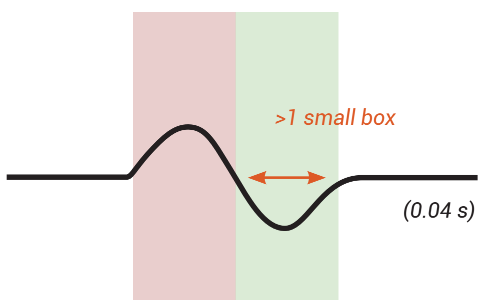
Hypertrophy of the atria can be evaluated by looking at the P waves in the standard leads.

Left atrial hypertrophy

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

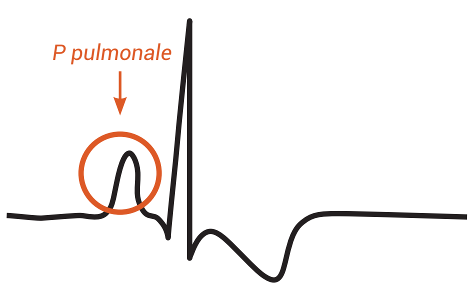


P mitrale can also be nicely depicted in lead V1, where we would typically see a biphasic (i.e., positive–negative) P wave. The negative part of the P wave corresponds to the enlarged left atrium. If the negative part is longer than 1 small box (or >0.04 s), then P mitrale is present:

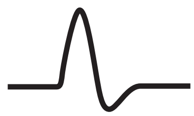
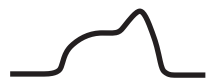


Right atrial hypertrophy

This is best seen in leads II, III, and aVF. The P wave is peaked and exceeds 0.25 mV 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 > 2.5 mm in II
left atrial enlargement **P mitrale**			negative P in V1 >0.04 s and/or P-wave duration >0.12 s 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 0.5 mV. 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	[coming later]	[coming later]
2. Heart rate	[coming later]	[coming later]
3. P waves	a) Large P-wave amplitude (>2.5 mm in II, III, or aVF)	right atrial enlargement
	b) Prolonged negative part of P wave in V1 (1 mm) and P wave with 2 peaks in II, P-wave duration >0.12 s	left atrial enlargement
4. PR interval	a) >0.2 s (if PR interval constant for all beats and each P wave is followed by a QRS complex)	I° AV block
	b) <0.12 s and QRS complex normal	LGL syndrome
	c) <0.12 s and 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 s (always think of WPW syndrome as a differential)	complete bundle branch block
	b) >0.1 s and <0.12 s 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: counterclockwise rotation NOTE: 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							nonspecific repolarization abnormality
QRS normal							acute ischemia, perimyocarditis, variant angina
QRS normal							STEMI/ perimyocarditis in resolution
QRS normal							STEMI subacute, NSTEMI, perimyocarditis
QRS with Q wave							STEMI acute, STE-MI in resolution, STEMI subacute
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	[coming later]						[coming later]