Level 4: The P waves are not normal

We told you in the beginning of this training that you should start with the QRS complexes when evaluating the cardiac rhythm. That's what we did in steps one to three of the Rhythm Cheat Sheet. However, if you did not find any tachycardia, and if you were unable to come up with a rhythm diagnosis so far, it's now time to zoom in on the P waves in steps 4 to 6 of the cheat sheet. Let's start with steps 4 and 5.

Zoom in on the P waves:

		initial question	answer		additional question	rhythm diagnosis
ZOOM IN TO P WAVE	4	Are the P waves neg. in II, III and aVF?	N	Y	P preceding QRS?	"Upper" junctional rhythm
					P following QRS?	"Lower" junctional rhythm
	5	Are the P waves absent or doubtful?	N	Y	QRS totally irregular?	Atrial fibrillation (AF)
					QRS regular?	Mid junctional rhythm AF + 3rd deg. AV block (AVB)

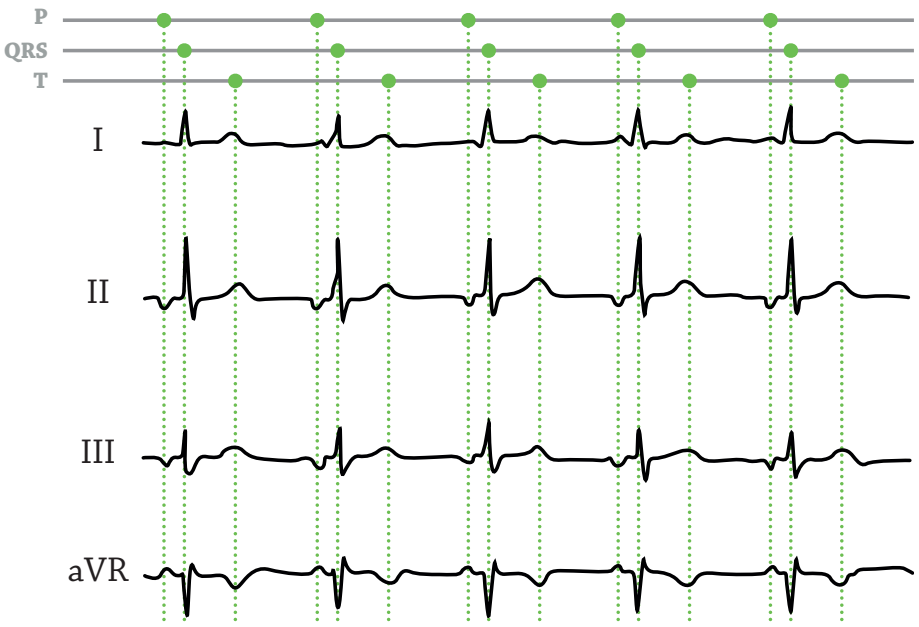
Steps 4 and 5 of the cheat sheet: when P waves are not normal

There are basically two instances when P waves are not normal; these are dealt with in steps 4 and 5 of the cheat sheet:

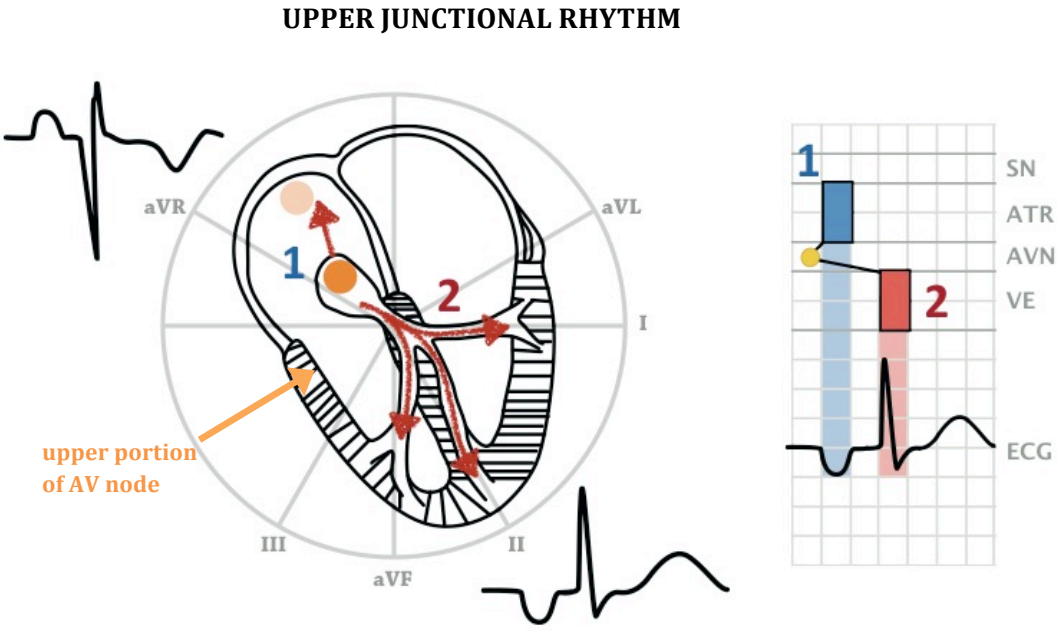
- If they are not positive in I, II and not negative in aVR.
- If they are completely absent.

Let's jump right into a couple of examples.

Upper junctional rhythm



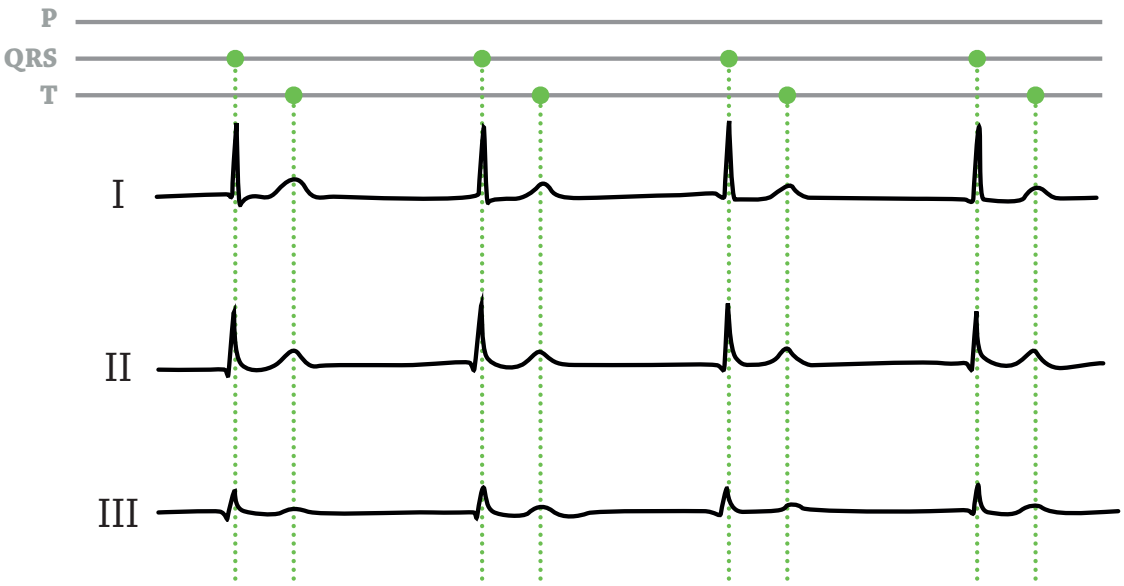
The above ECG shows a regular rhythm (i.e., constant RR intervals). The P waves preceding the QRS complexes are positive in aVR and negative in II and III. Therefore, this cannot be sinus rhythm. This is a case of an **upper junctional rhythm**. The P waves in I can be positive, biphasic, or negative in junctional rhythms.



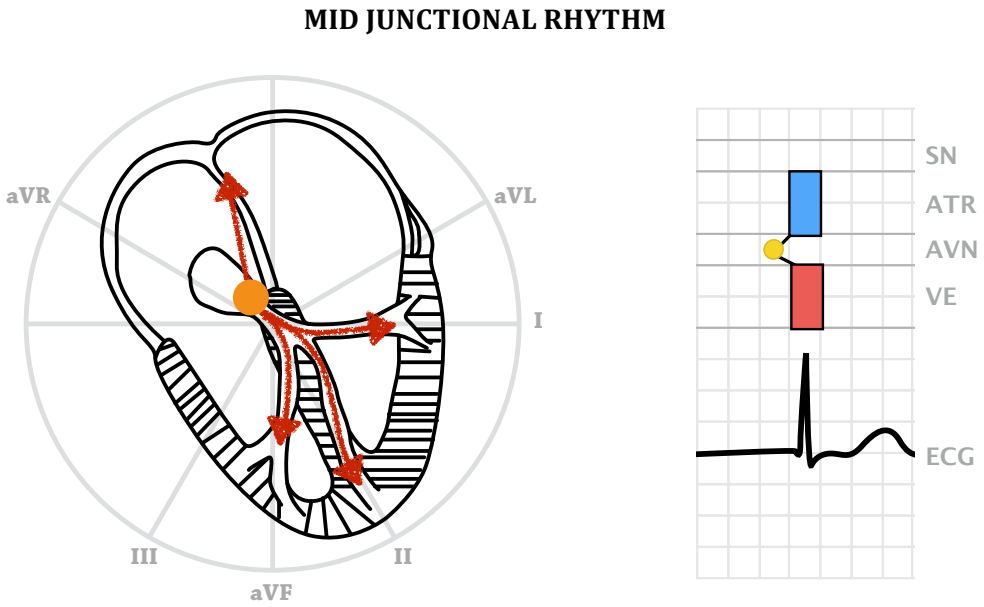
In upper junctional rhythm, depolarization starts in the upper portion of the AV node, then travels up towards lead aVR and away from leads II & III, causing a positive P wave in aVR and negative P waves in II and III (1). Subsequently, the impulse travels down into the ventricles through the normal conduction system, causing a regular and narrow QRS (2). Since atrial depolarization precedes ventricular depolarization, P waves precede QRS complexes.

Let's move on to the next case...

Mid junctional rhythm



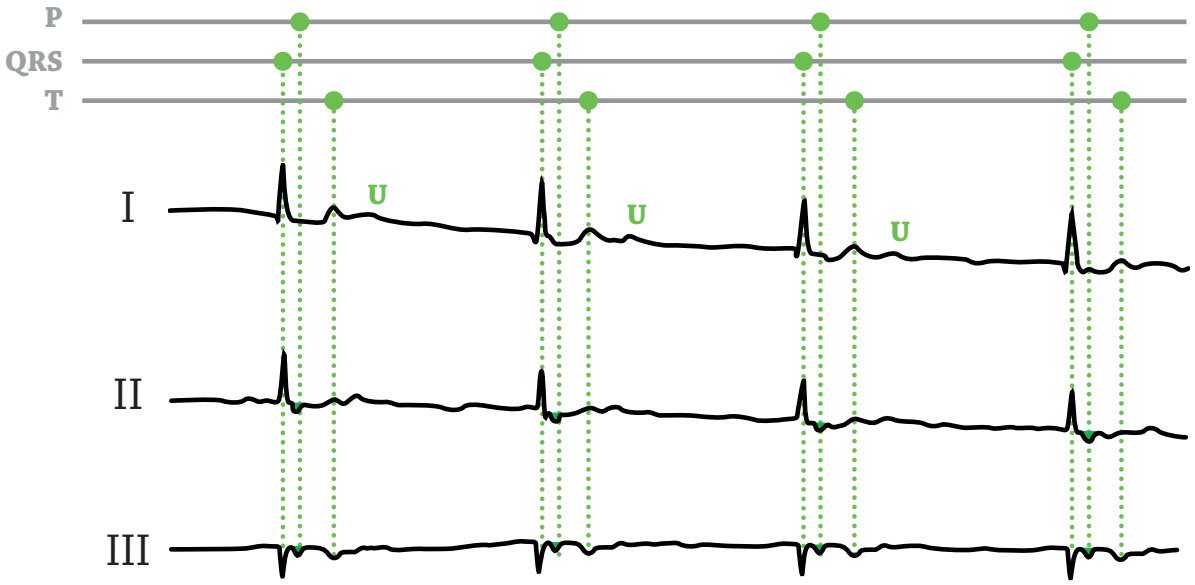
This is an ECG without any P waves. However, the QRS complexes appear regular. Regular QRS complexes in combination with absent P waves are typical for a **mid junctional rhythm** (i.e., it originates from the mid-portions of the AV node).



In mid junctional rhythm, atrial and ventricular depolarization happen simultaneously. Therefore, P waves are hidden within the QRS complexes. Since the AV nodal pacemaker discharges at regular intervals, the QRS complexes also come at regular intervals.

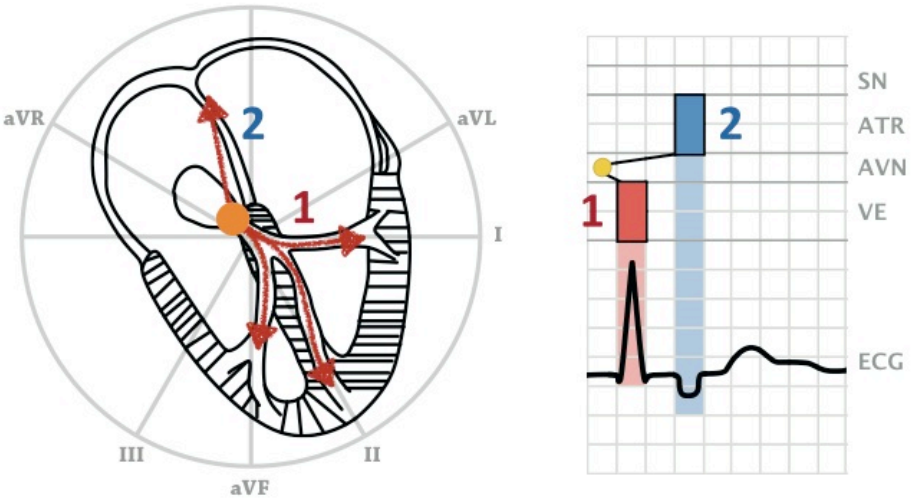
Now take a look at the next case...

Lower junctional rhythm



There are regular QRS complexes without any P waves, right? Well, take a second look. Are there really no P waves? When looking carefully you will find sharp, negative deflections following the QRS complexes, just within the ST segment, that don't belong there. Their steepness is in between that of the QRS and the T waves. So these have to be P waves. This is a case of a **lower junctional rhythm**. As the name implies, the pacemaker is situated in the caudal region of the AV node.

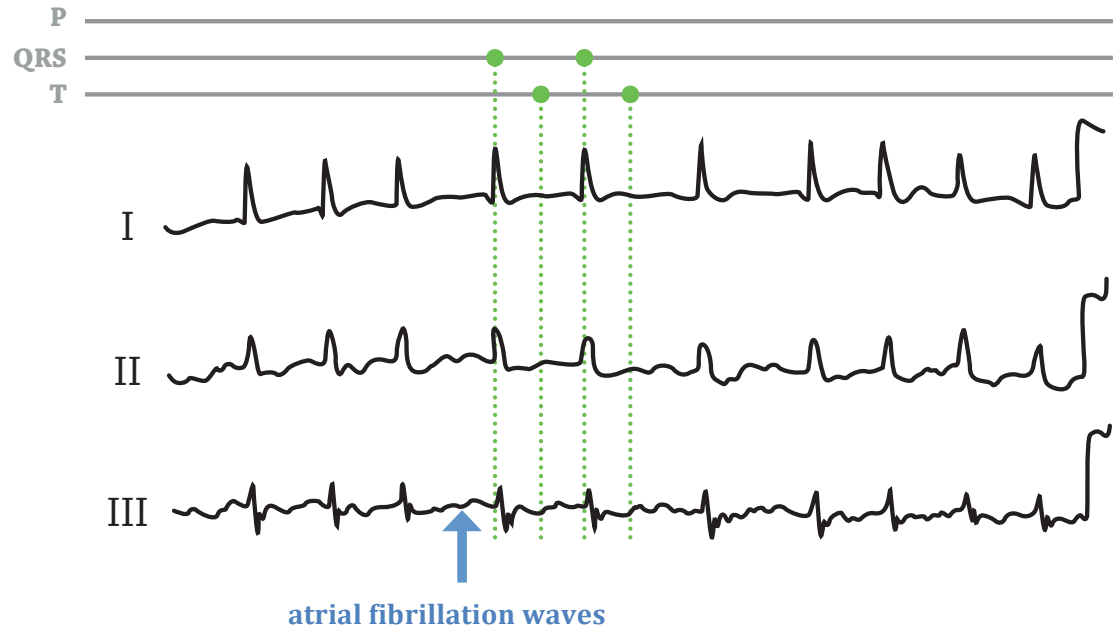
LOWER JUNCTIONAL RHYTHM



In lower junctional rhythm, the impulse from the AV node reaches the ventricular conduction system very quickly and produces a normal QRS complex. The AV nodal impulse takes a little longer to reach the atria; hence, the (negative) P wave occurs somewhat after the QRS. Since the AV nodal pacemaker discharges at regular intervals, the QRS complexes also come at regular intervals.

Let's move on to the next case in which P waves are not normal…

Atrial fibrillation



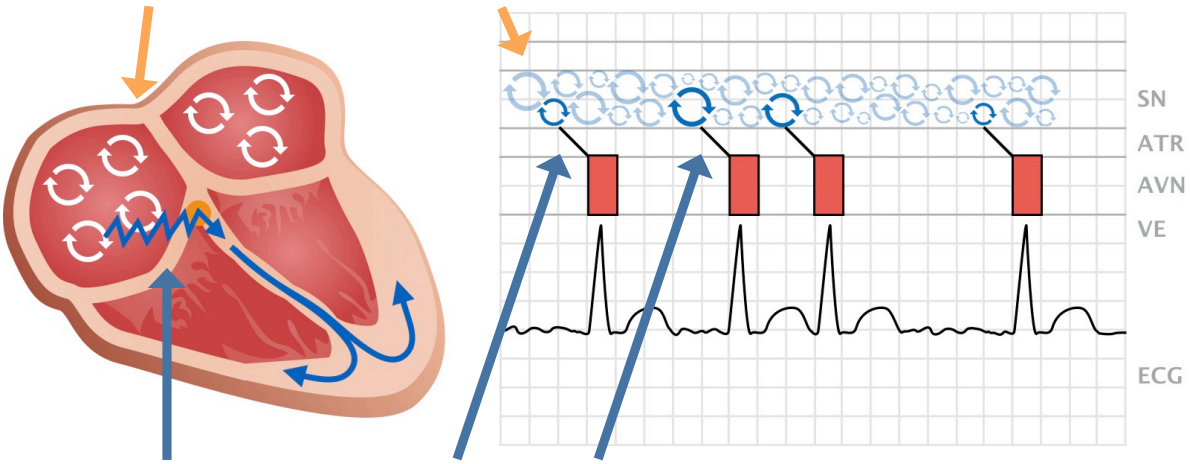
In this example, it's difficult to decide whether P waves are present or not. Several waves are present which could be P waves based on their morphology, but they look quite different from one another. Actually, there is a lot of variability on this ECG:

- The morphology of these waves varies.
- The distance between these waves varies.
- The distance between these waves and the subsequent QRS complexes varies.

This is a case of **atrial fibrillation**. These irregular little waves are so-called **fibrillation waves**. Fibrillation waves are not necessarily visible on the ECG—sometimes their rate is so high that the ECG machine cannot record them, and we'll only see a flat line in between the QRS complexes.

In atrial fibrillation there are multiple **reentrant loops** that whirl around unpredictably in the atria with a rate of up to 800 beats per minute. Thanks to its filter function, the AV node will not let each and every one of these impulses down into the ventricles. Whenever an impulse travels down, a QRS complex is triggered. Since these atrial impulses are completely chaotic, the QRS complexes will appear at completely irregular intervals (i.e., the rhythm will be irregular). This irregularity is the hallmark of this disease.

Atrial reentrant loops whirl around unpredictably

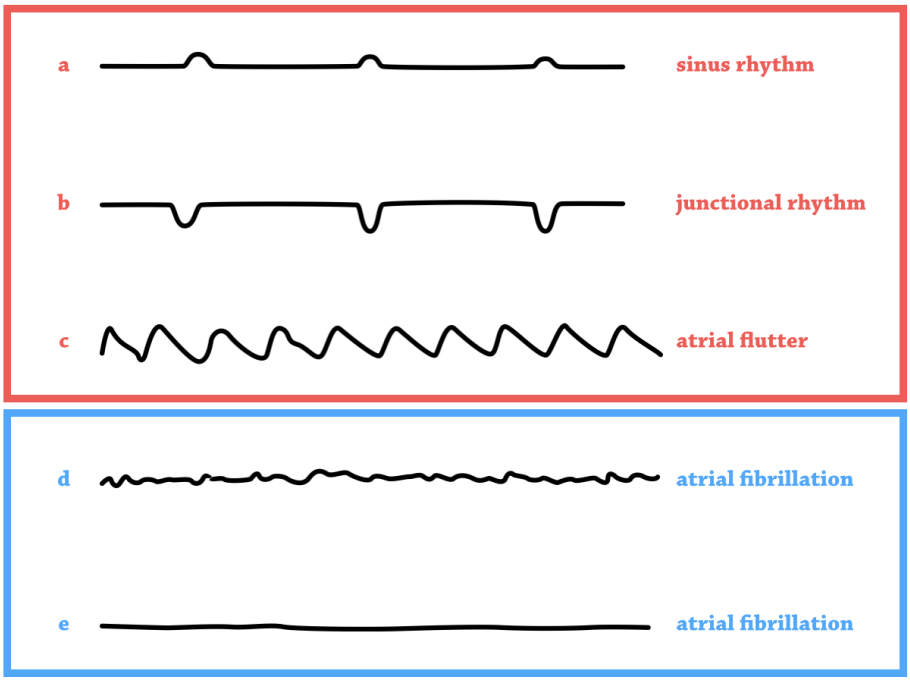


Thanks to the filter function of the AV node, not every impulse will be conducted down into the ventricles.

Atrial fibrillation is also called "arrhythmia absoluta."

Summarizing what we've learned

The following image summarizes the atrial activity in various rhythms that we have discussed so far.



In a, b, and c, the atrial activity is regular:

a) Sinus rhythm (positive P waves in I and II).
b) Junctional rhythm (negative P wave, best seen in II and III).
c) Atrial flutter with its characteristic saw-tooth morphology (best seen in II and III).

In d and e, atrial activity is irregular or completely missing:

d) Atrial fibrillation waves (best seen in V1).
e) Atrial fibrillation: here, the rate of the fibrillation waves is so high that the isoelectric line remains completely flat.

You may wonder how to discriminate between atrial fibrillation and a mid junctional rhythm, as both lack P waves. The answer is: QRS complexes are always irregular in atrial fibrillation, whereas they are regular in mid junctional rhythms!

In summary, here's how to evaluate the types of rhythms we've seen so far:

1. **Negative P waves in II and III**

   P *before* QRS: upper junctional rhythm

   P *after* QRS: lower junctional rhythm

2. **No P waves**

   QRS *regular*: mid junctional rhythm

   QRS *irregular*: atrial fibrillation