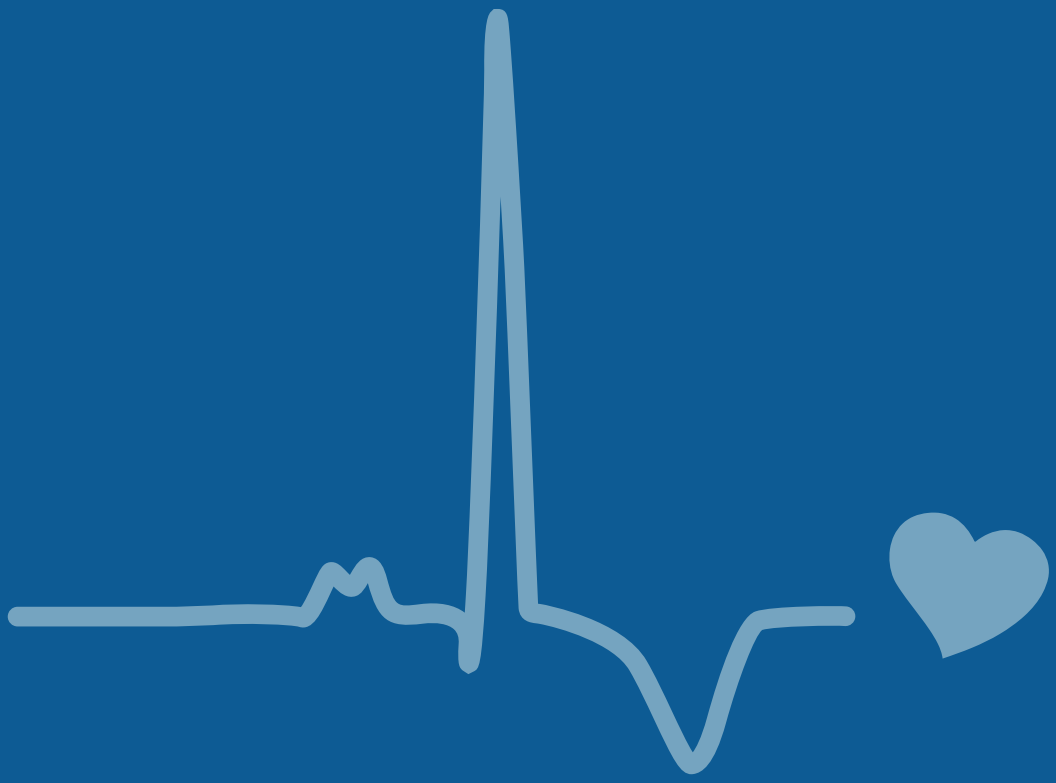
ECG Mastery



BLUE BELT WORKBOOK

ECG Mastery: Blue 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 Blue 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 Blue 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 Blue Belt section of the ECG Mastery Program is the next step after the Yellow Belt section, which teaches ECG basics. The ECG Mastery Blue Belt section goes well beyond the basics to teach 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.

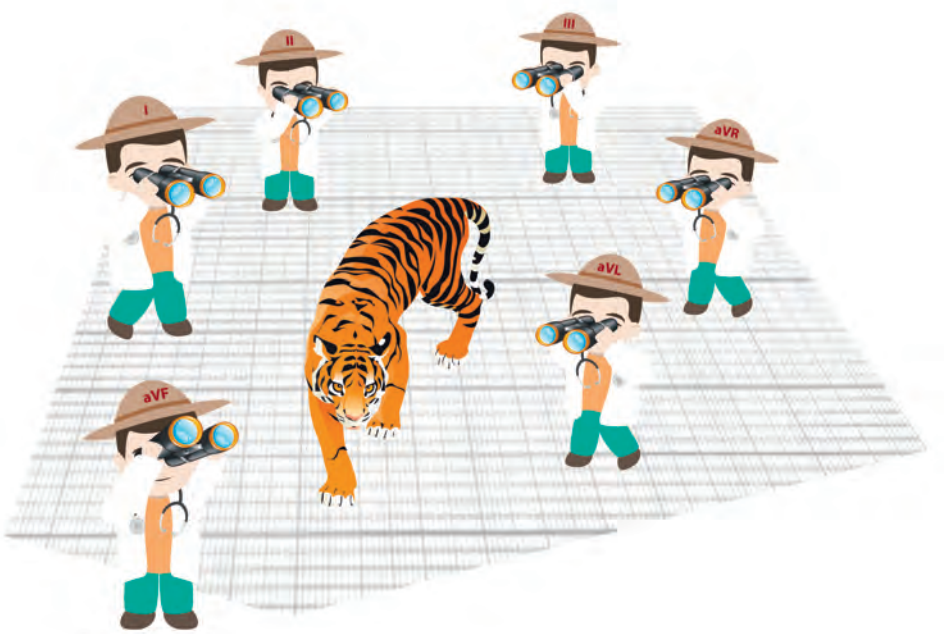
Enjoy the learning!

Contents

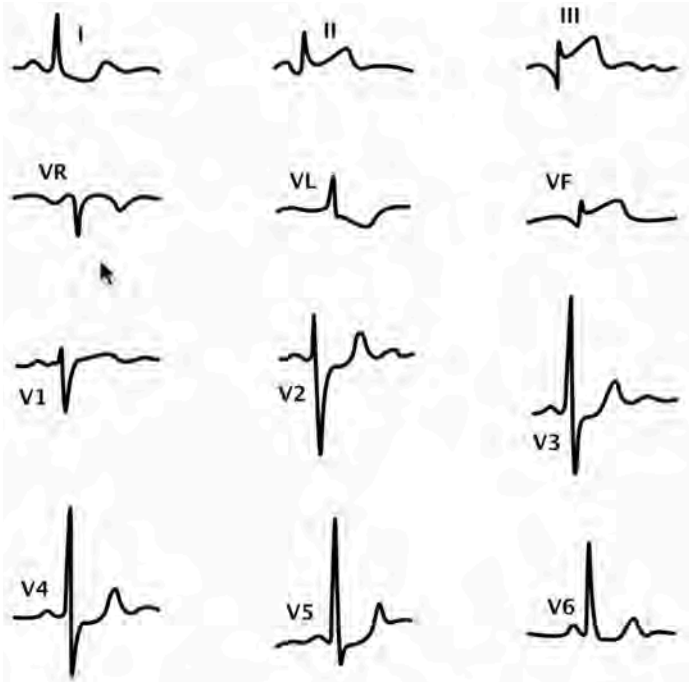
Level 1: A quick introduction to rhythm analysis

In this section we are going to teach you the nuts and bolts of **rhythm analysis**. What is rhythm analysis? Basically, it's taking a sequence of consecutive beats and analyzing their relationship to one another.

This is in contrast to what we did in the Yellow Belt section, in which we learned to evaluate **individual cardiac cycles** from different perspectives.



In the Yellow Belt section, the different perspectives were the different leads: the standard leads, the augmented leads, and the precordial leads. Each of them gives us a different view on the same beat:



snapshots of the same cardiac cycle taken from different perspectives

This gave us clues about different anatomical or physiological states, such as **hypertrophy, ischemia, infarction, hypokalemia,** and so on.

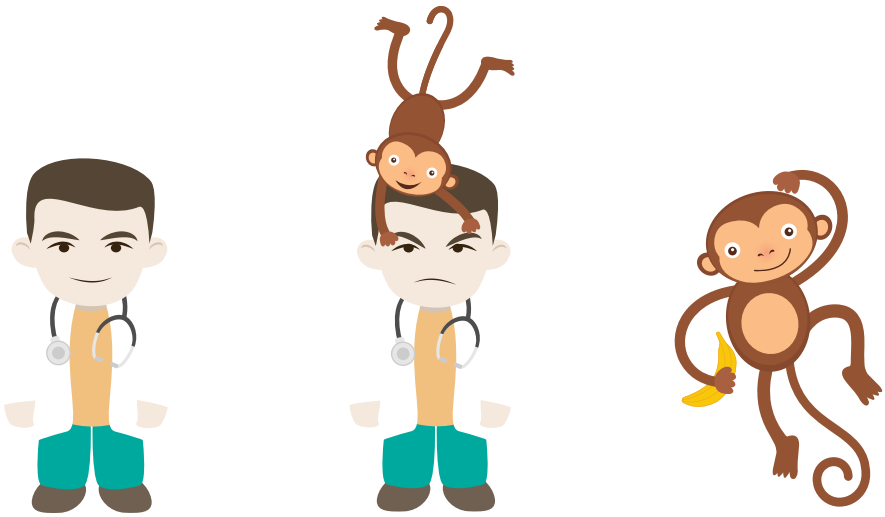
Now in contrast, rhythm analysis is looking at a sequence of consecutive cardiac cycles in a row.

Think about it this way - in the Yellow Belt section we looked at individual frames of a movie. In the Blue Belt section we are going to look at the entire film.

Three questions to guide you through rhythm analysis

There are three broad principles or questions that together will serve as a guidepost throughout this book. You should always ask yourself these questions when assessing the cardiac rhythm. These three questions will serve as a blueprint that will allow you to solve basically any rhythm problem:

Question #1: Is the rhythm normal, and if not, what is the basic rhythm?
Question #2: Is the rhythm disturbed by an extra beat / extra beats or a pause?
Question #3: Is the rhythm replaced by another rhythm? What's the other rhythm?



Normal? *Disturbed?* *Replaced?*

Just remember these three questions—we'll come back to them later. They represent the art of rhythm analysis in a nutshell.

The two types of rhythm problems

We always tell our students to first look at QRS complexes and their relationship to one another when evaluating the rhythm. Only then should you go on to look at the P waves. Why is this important? Well, because QRS complexes represent heartbeats, and heartbeats are responsible for keeping the circulation going (i.e., they're hemodynamically relevant). Sometimes looking at QRS complexes enables you to make a rhythm diagnosis on the spot without much hassle.

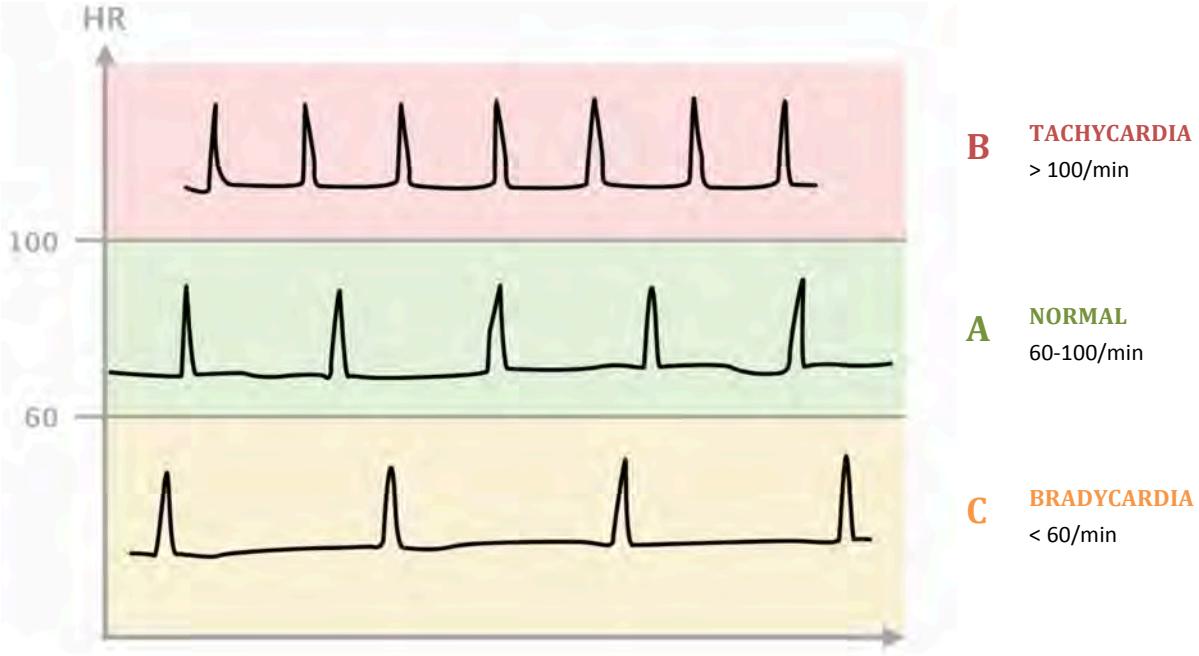
Most experts are intuitively doing this first thing when looking at an ECG.

Using this method, you'll see that there are really only two broad groups of rhythm problems:

1. Regular rhythm problems (i.e., constant R-to-R intervals)
2. Irregular rhythm problems (i.e., irregular R-to-R intervals)

Regular rhythm problems

In these examples, we omitted P waves. For the sake of simplicity, QRS complexes are shown as simple spikes.



When QRS complexes are regular, there are basically two types of possible problems:

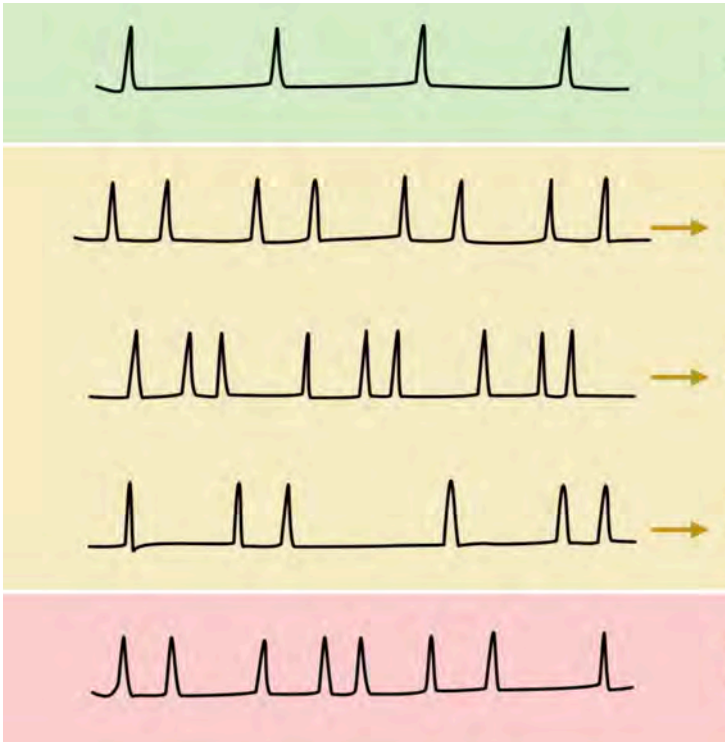
- Tachycardia (i.e., when the heart beats at a rate of > 100 beats per minute)
- Bradycardia (i.e., when the heart beats at a rate of < 60 beats per minute)

There are several different types of tachycardias and bradycardias; you'll learn much more about them in the upcoming chapters.

Irregular rhythm problems

Irregular rhythm abnormalities can be subdivided into

- Regular irregularities and
- Irregular irregularities
-



regular

regular irregularity
BIGEMINUS

regular irregularity
TRIGEMINUS

regular irregularity
single ectopic beats

irregular irregularity **(=AF)**

There are irregular rhythms where some degree of regularity is preserved (**regular irregularities**). Examples include bigeminus and trigeminus, in which a constant sequence of two or three beats is repeated over and over again, and single ectopic beats, in which an additional extra beat occurs every now and then. In these cases it's usually quite simple to recognize the underlying regular rhythm.

The prime example of an **irregular irregularity** is atrial fibrillation (also known as arrhythmia absoluta), in which beats occur at completely irregular intervals and no two R-to-R intervals are quite the same.

The rhythm cheat sheet

Rhythm analysis can be a bit overwhelming for the novice. So we created a tool that will help you come up with a correct diagnosis in just a few simple steps. It's called the "Rhythm Cheat Sheet," and it will help you diagnose over 95% of rhythms without the help of a more senior colleague. Each chapter of this book will introduce you to a new step of the cheat sheet. We suggest you keep it handy. The steps of the Rhythm Cheat Sheet are subdivided into three broad categories:

1. Is the rhythm normal, and if not, what's the basic rhythm?
2. Is the rhythm disturbed?
3. Is the rhythm replaced?

Do these categories sound familiar?

RHYTHM CHEAT SHEET

		initial question	answer		additional question	rhythm diagnosis
FIRST QUICK VIEW	1	Is this sinus rhythm AND is the heart rate < 100 bpm?	N	Y		Sinus rhythm
	2	Can you recognize a "rhythm at a glance"?	N	Y		Ventricular fibrillation Ventricular flutter Atrial flutter Pacemaker
RAPID AND REGULAR	3	Is the rhythm rapid & regular?	N	Y	QRS duration > 0.1 s QRS duration ≤ 0.1 s	Ventricular tachycardia Atrial tachycardia with BBB Sinus tachycardia Atrial tachycardia Atrio-ventricular reentry tachycardia (AVRT) AV nodal reentry tachycardia (AVNRT)
ZOOM IN TO P WAVE	4	Are the P waves neg. in II, III and aVF?	N	Y	P preceding QRS? P following QRS?	"Upper" junctional rhythm "Lower" junctional rhythm
	5	Are the P waves absent or doubtful?	N	Y	QRS totally irregular? QRS regular?	Atrial fibrillation (AF) Mid junctional rhythm AF + 3rd deg. AV block (AVB)
	6	Are there too many P waves?	N	Y	PR constant? PR varying QRS regular PR varying QRS irregular	2nd deg. AVB Mobitz type II 3rd deg. AV block 2nd deg. AVB Mobitz type I
BASIC RHYTHM INTERRUPTED	7	Do you see a rhythm switch?	N	Y		Which ones?
	8	Do you see premature beats?	N	Y	preceding premature P? no preceding premature P?	Supraventricular premature beat (SPB) Ventricular premature beat (VPB)
	9	Do you see a remarkable pause?	N	Y	following ventricular premature beat? after termination of TC? "empty" pause containing premature P? terminated by a QRS with a different shape than the rest of the QRS complexes	Compensatory pause Preautomatic pause SA (sinoauricuar) block Supraventricular premature beat + AV block Escape beat

Is the rhythm disturbed? Is the rhythm replaced? Is the rhythm normal and if not, what's the basic rhythm?

In case of rhythm switch go back and evaluate the second rhythm

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Rhythms at a glance

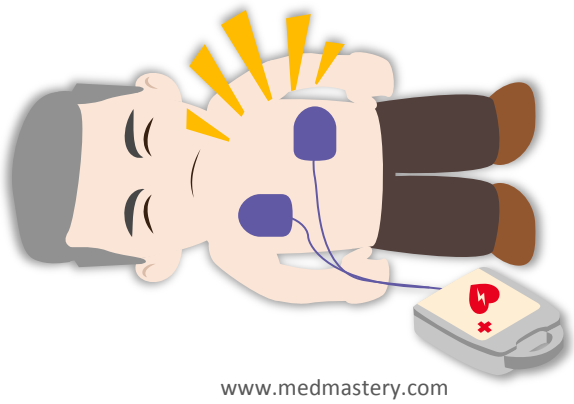
This is the first question you should ask yourself when evaluating a patient's rhythm: "**Is this sinus rhythm? If not, what's the rhythm?**" If it's not sinus rhythm, you might be dealing with one of four "rhythms at a glance." These rhythms are so characteristic that you will literally be able to recognize them in a heartbeat. Here they are:

		initial question	answer		additional question	rhythm diagnosis
FIRST QUICK VIEW	1	Is this sinus rhythm AND is the heart rate < 100 bpm?	N	Y		Sinus rhythm
	2	Can you recognize a "rhythm at a glance"?	N	Y		Ventricular fibrillation Ventricular flutter Atrial flutter Pacemaker

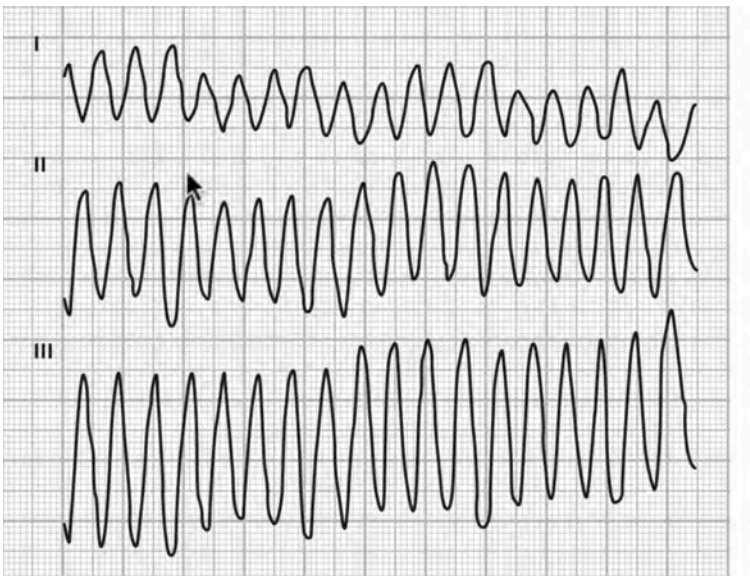
First two steps of the Cheat Sheet called "First Quick View." If it's not sinus rhythm, you should ask yourself if you are dealing with one of four "rhythms at a glance."

Rhythm at a glance #1: ventricular fibrillation

Ventricular fibrillation is characterized by bizarre-shaped and irregular spikes of up to 1mV in amplitude. You should imprint this characteristic tracing into your brain. The ventricles don't contract properly and the patient is in circulatory arrest. Without proper resuscitation and defibrillation, this patient will die.



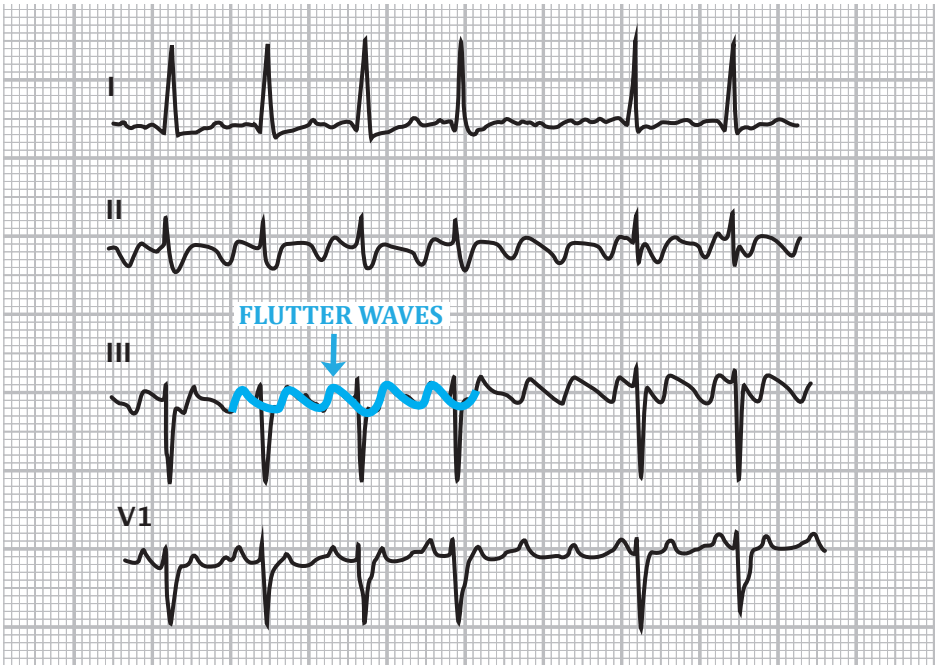
Rhythm at a glance #2: ventricular flutter



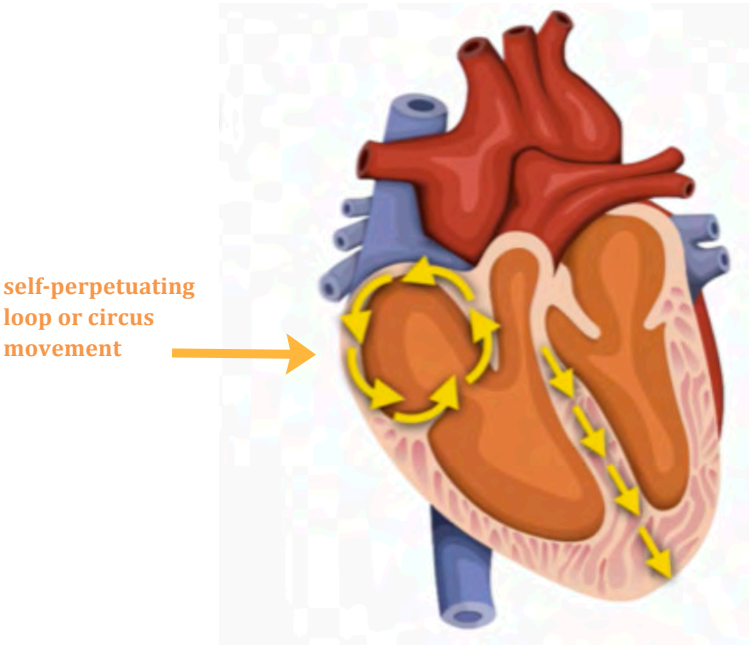
This tracing shows wide and uniform waves with a heart rate of around 280 beats per minute and an amplitude of over 2mV. The high amplitude of these waves suggests that they originate from the strong ventricular myocardium. This is a case of **ventricular flutter,** a special form of ventricular tachycardia where differentiation between depolarization and repolarization is impossible (i.e, you cannot tell where the isoelectric line is).

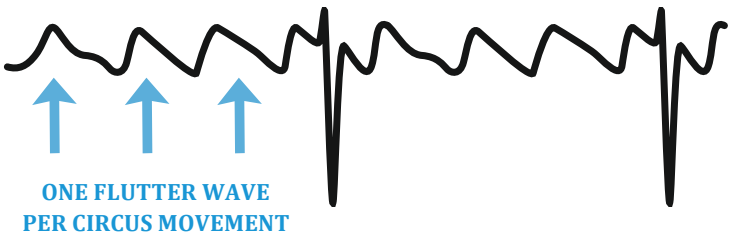
The clinical situation of these patients strongly depends upon the rate of the arrhythmia and the original condition of the ventricular myocardium. In patients with heart disease (e.g., cardiomyopathy), this arrhythmia may cause circulatory arrest and require resuscitation. In others it might just lead to dizziness with a slight drop in arterial pressure.

Rhythm at a glance #3: atrial flutter



In this example, QRS complexes appear fairly regularly (at least during the first four beats) with an average heart rate of 125 beats per minute. In between these QRS complexes we can see waves that are typical for the underlying arrhythmia: they have a saw-tooth morphology and are known as **flutter waves**. This type of rhythm is called **atrial flutter**. These flutter waves have a rate of around 250 beats per minute. They are caused by a self-perpetuating loop (or circus movement) that whirls around in the atria.

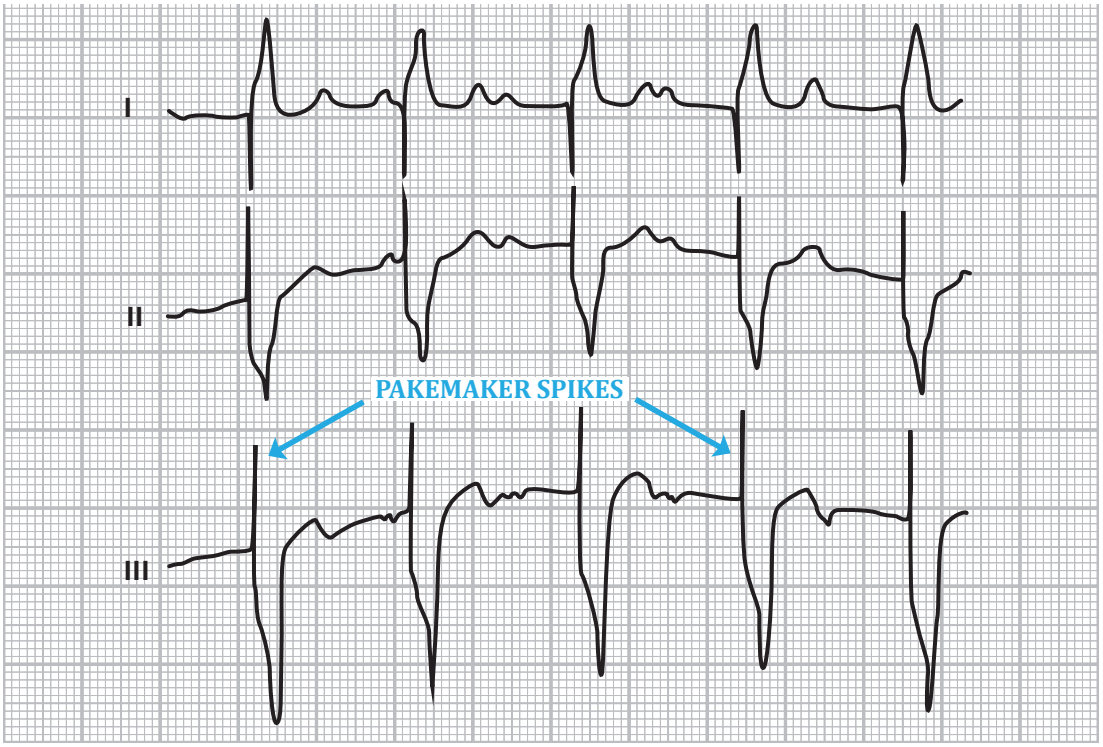




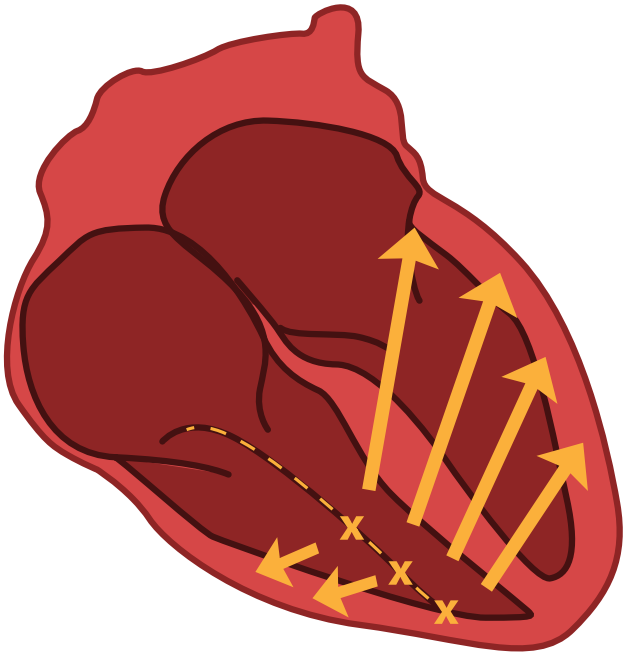
Atrial flutter waves are best seen in leads II, III, and aVF. Thanks to the filter function of the AV node, not all flutter waves are conducted down into the ventricles. This conduction may be constant (e.g., 2:1, 3:1, and so on) or it may be variable.

Note that if you only look at lead I, you will miss the diagnosis!

Rhythm at a glance #4: pacemaker ECG



What strikes us in this example are the straight vertical lines (or spikes) preceding the broad QRS complexes. These spikes do not occur naturally. They are the product of a pacemaker stimulus that's delivered via a pacemaker lead located in the right ventricle.



The heart is stimulated via an electrode located in the right ventricle.

Just as in LBBB, the ventricles are stimulated from the right side of the heart. Thus, the QRS complexes exhibit an LBBB morphology.

For now you just need to recognize if a pacemaker is present or not. In a later chapter, we will also teach you how to identify the type of pacemaker and whether it's functioning properly.

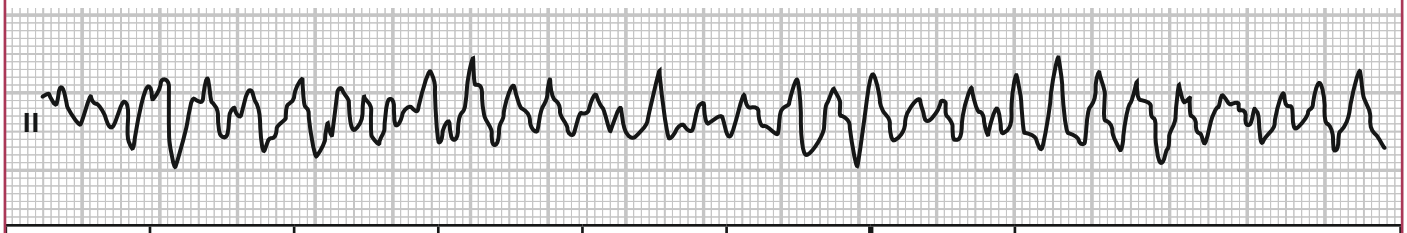
Level 1

QUIZ SECTION

Now it's your turn again. Can you identify a "rhythm at a glance" in these ECG tracings? If so, which one? If you are not sure, try to identify P waves, QRS complexes and T waves and you'll be one step closer to making the right diagnosis.

P
QRS
T

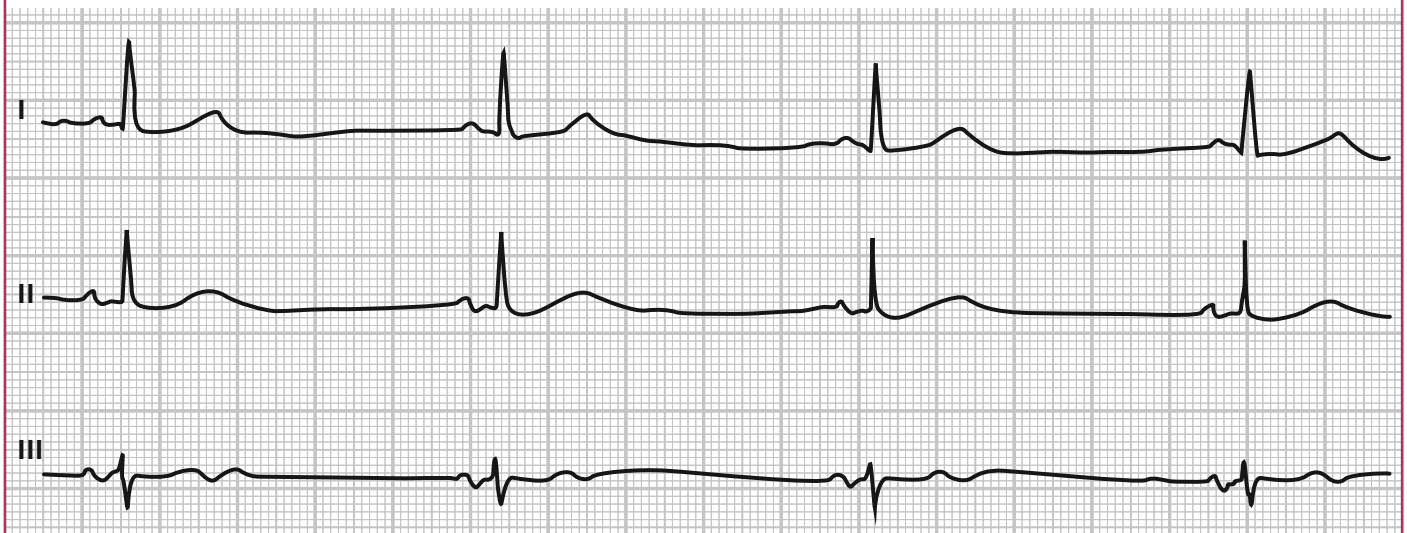
ECG 1



sinus rhythm	ventricular fibrillation	ventricular flutter	atrial fibrillation	atrial flutter	pacemaker	heart rate	additional comments

P
QRS
T

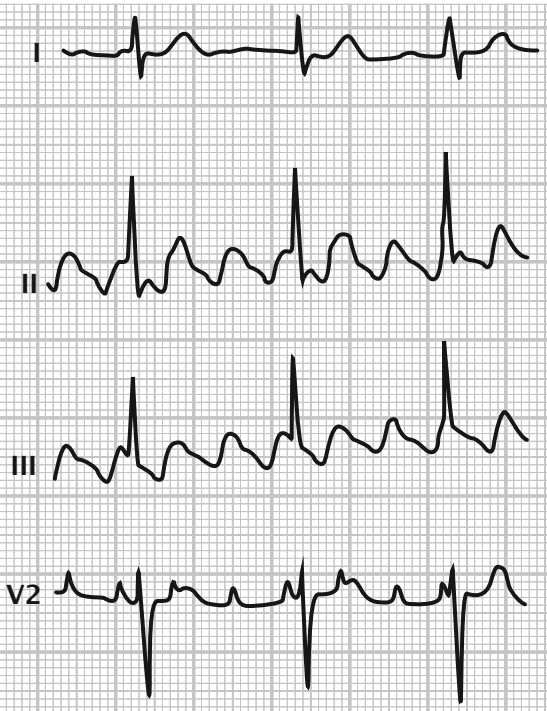
ECG 2



sinus rhythm	ventricular fibrillation	ventricular flutter	atrial fibrillation	atrial flutter	pacemaker	heart rate	additional comments

P
QRS
T

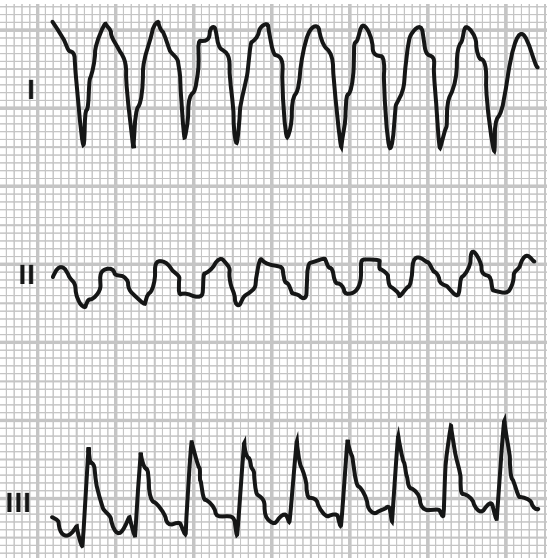
ECG 3



sinus rhythm	ventricular fibrillation	ventricular flutter	atrial fibrillation	atrial flutter	pacemaker	heart rate	additional comments

P
QRS
T

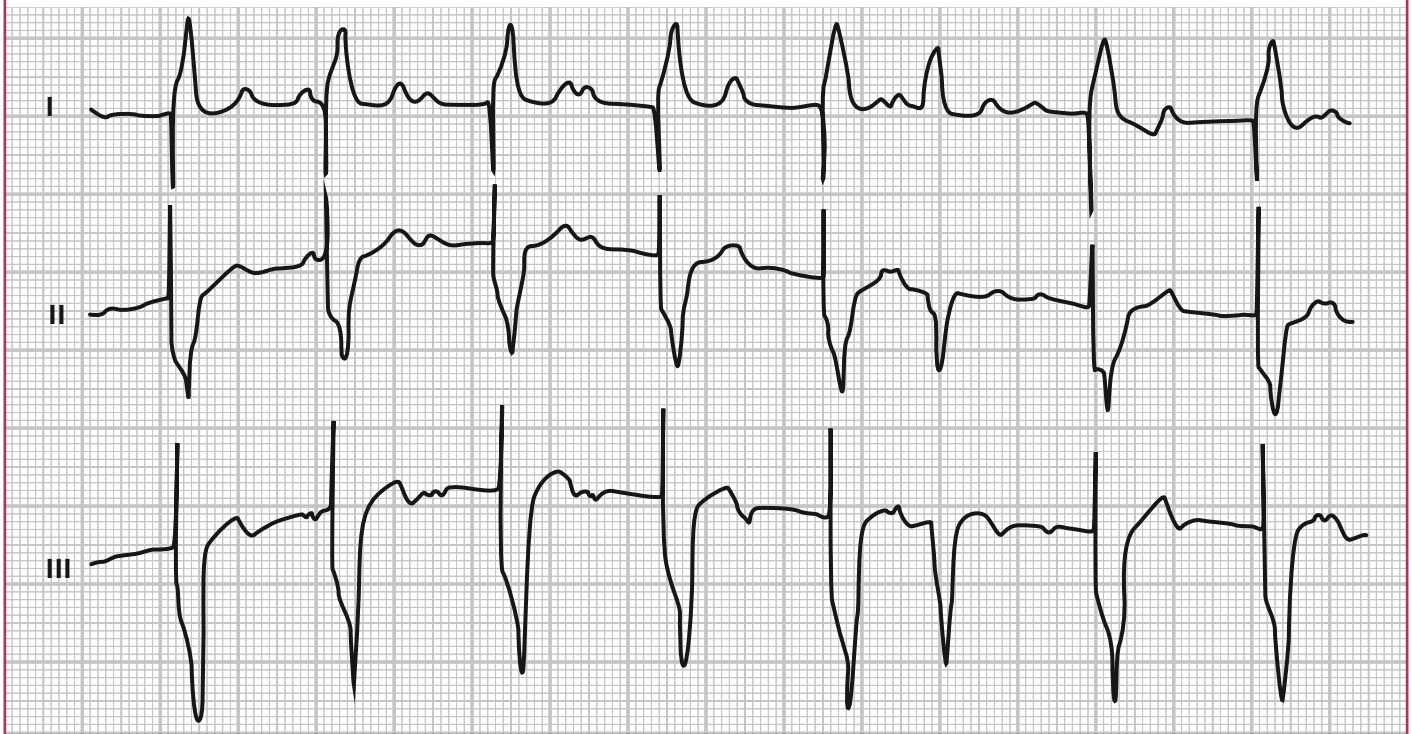
ECG 4



sinus rhythm	ventricular fibrillation	ventricular flutter	atrial fibrillation	atrial flutter	pacemaker	heart rate	additional comments

P
QRS
T

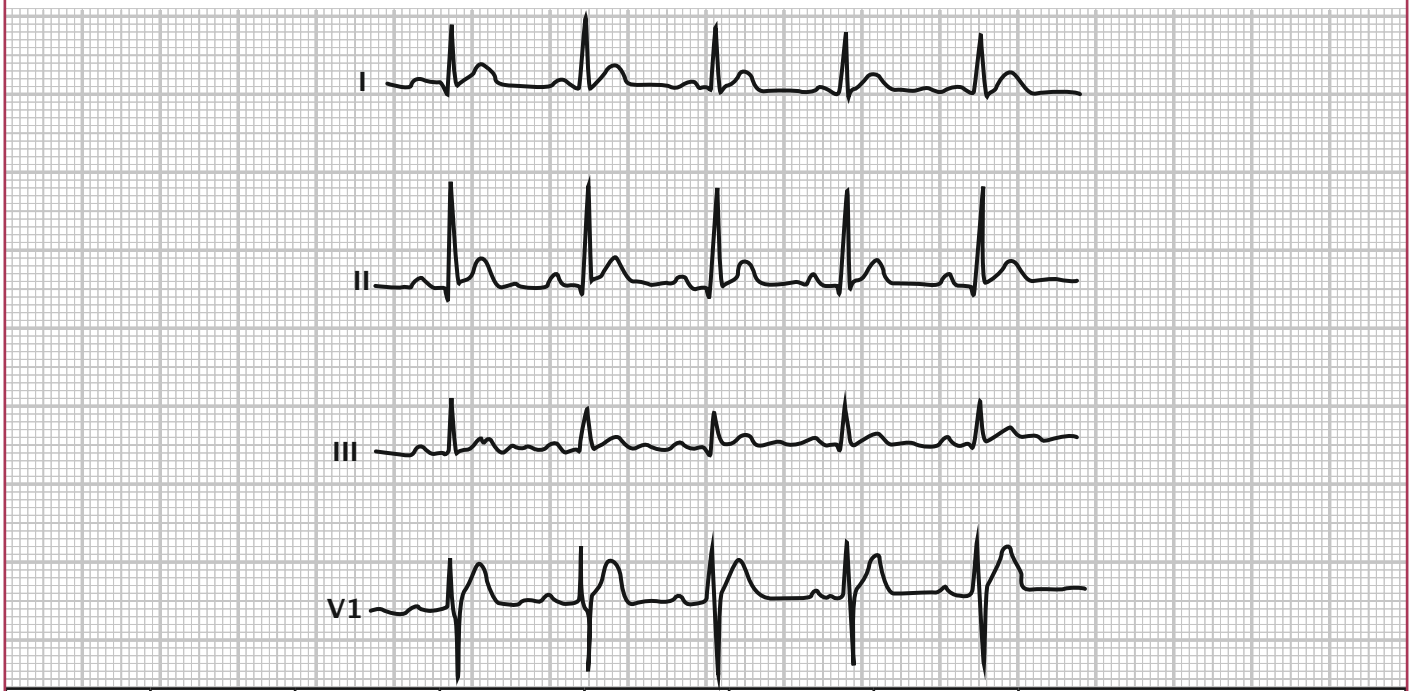
ECG 5



sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial fibrillation	pacemaker	heart rate	additional comments

P
QRS
T

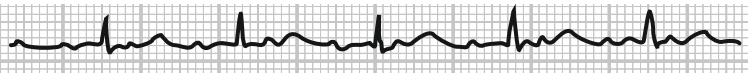
ECG 6



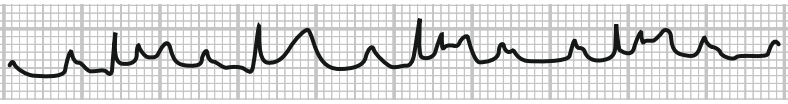
sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial fibrillation	pacemaker	heart rate	additional comments

P
QRS
T

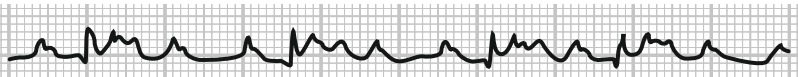
ECG 7



P
QRS
T



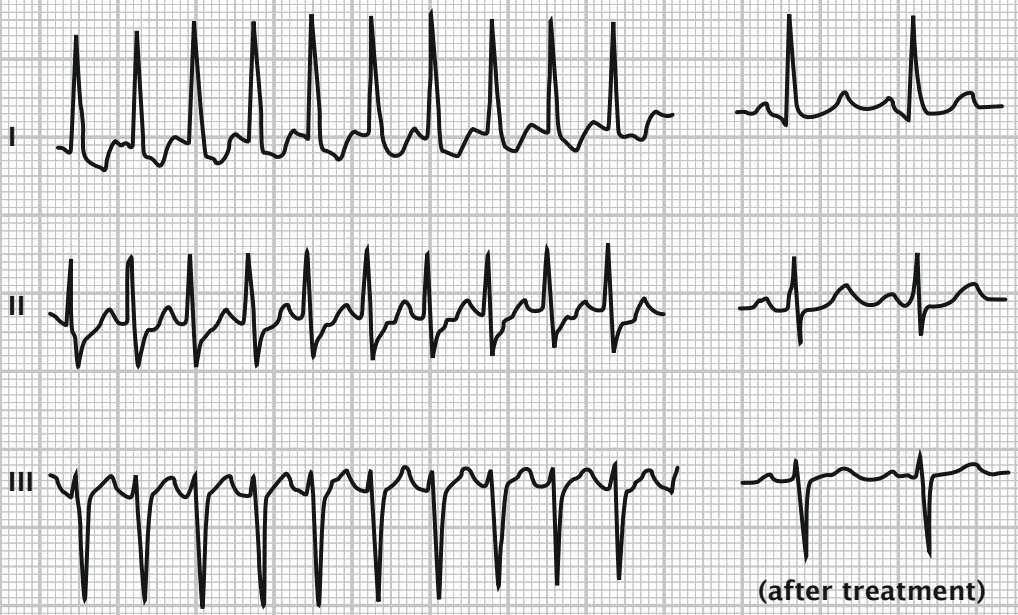
P
QRS
T



sinus rhythm	ventricular fibrillation	ventricular flutter	atrial fibrillation	atrial flutter	pacemaker	heart rate	additional comments

P
QRS
T

ECG8



sinus rhythm	ventricular fibrillation	ventricular flutter	atrial fibrillation	atrial flutter	pacemaker	heart rate	additional comments

Level 2: A quick intro to tachycardias

After having ruled out the "rhythms at a glance," which are so typical that you should be able to recognize them immediately, we shall now continue the evaluation of rhythm problems in a more systematic way. One feature of a rhythm strip that is a real eye-catcher is when the heart runs in a rapid manner (> 100 beats per minute), something that we call **tachycardia**.

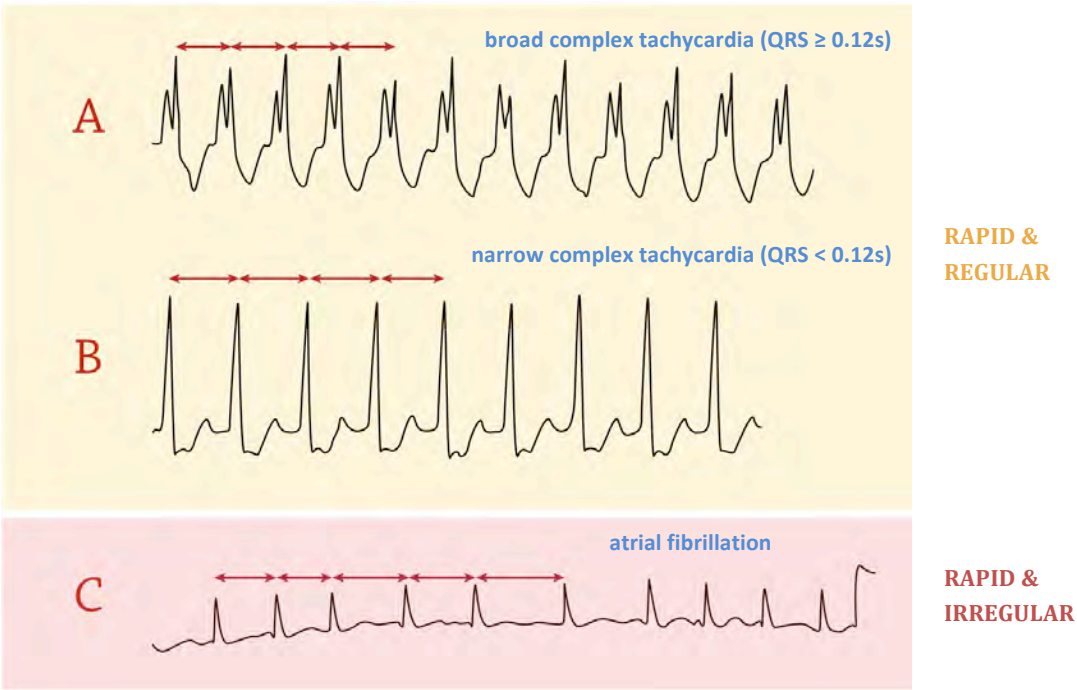
	initial question		answer		additional question	rhythm diagnosis
RAPID AND REGULAR	3	Is the rhythm rapid & regular?	N	Y	QRS duration > 0.1 s	Ventricular tachycardia Atrial tachycardia with BBB
					QRS duration ≤ 0.1 s	Sinus tachycardia Atrial tachycardia Atrio-ventricular reentry tachycardia (AVRT) AV nodal reentry tachycardia (AVNRT)

Step 3 of the Cheat Sheet

Evaluating tachycardias

Step 3 of our Cheat Sheet is dealing with tachycardias. Here, you should ask yourself the following **two questions**:

1. Is the rhythm **rapid and regular?** That is, is the heart rate > 100 beats/minute and the distance between the QRS complexes constant?
2. If the answer to the above question is "yes," you should ask yourself: Are the QRS complexes **broad (≥ 0.12s) or narrow (< 0.12s)**? Merely knowing whether a regular tachycardia is broad or narrow will bring you much closer to the underlying diagnosis.

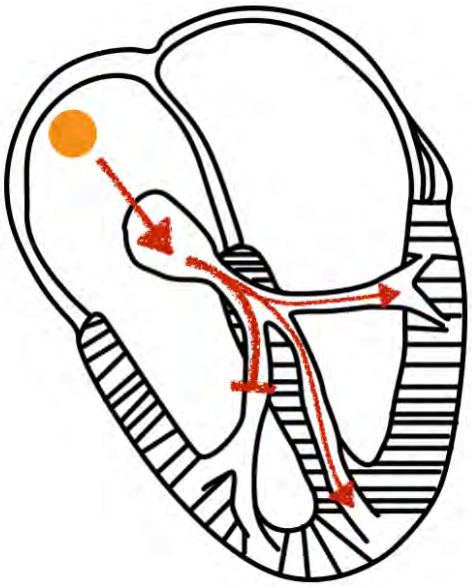


Rapid and irregular rhythms are most often due to atrial fibrillation (AF)

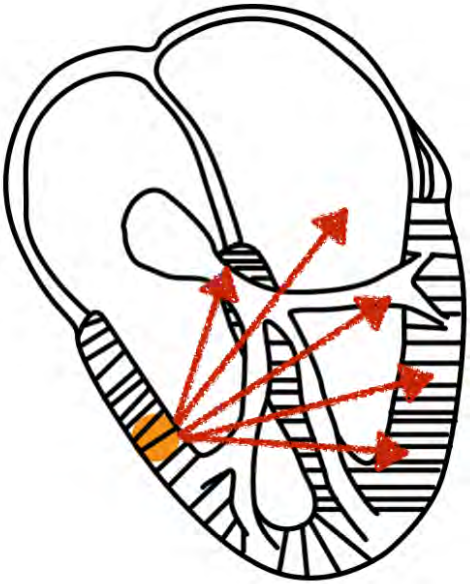
Broad complex tachycardias = rapid + regular + broad

Let's recap the two most common instances when the QRS complex is broad (≥ 0.12s):

BUNDLE BRANCH BLOCK:



VENTRICULAR PACEMAKER CENTER:



The QRS complex will be broad in bundle branch block and in cases with a ventricular pacemaker center. What follows is that there are two types of broad complex tachycardias—instances when the rhythm will be rapid and regular and the QRS complexes will be broad:

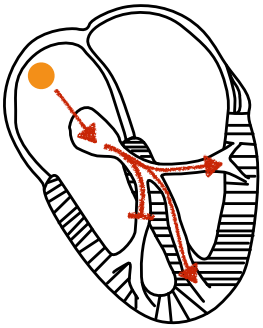
1. Supraventricular tachycardias with bundle branch block (supraventricular tachycardia with aberration).
   and
2. Ventricular tachycardias.

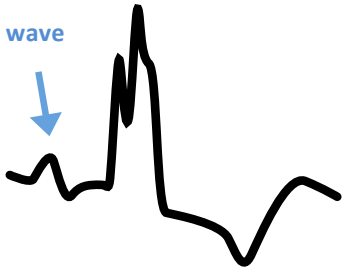
And how can you discriminate between these types of tachycardias?

- In **supraventricular (atrial) tachycardias with aberration**, each QRS complex is preceded by a P wave at a constant distance.
- In **ventricular tachycardia**, on the other hand, atria and ventricles are beating independently of one another. Hence, QRS complexes are not preceded by P waves at a constant distance.

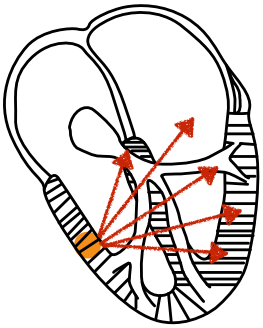
Narrow tachycardias are covered in the next level.

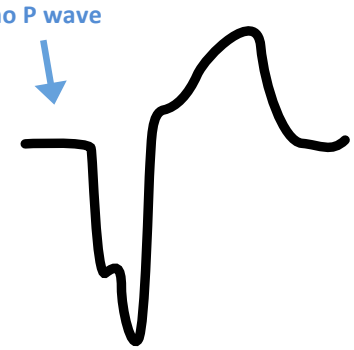
atrial tachycardia with aberration





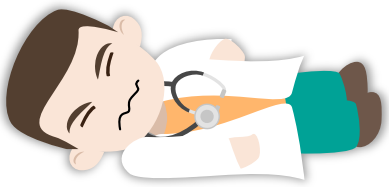
ventricular tachycardia





These two types of tachycardia are very different from a clinical perspective: Atrial tachycardia with aberration is usually not a life-threatening condition. Conversely, ventricular tachycardia can be life-threatening (as we have just mentioned in ventricular flutter), and in most cases you have to take action immediately. So it's really important to check how the patient is doing clinically. Is the patient in circulatory arrest or is he hemodynamically stable? How's the blood pressure doing? You really have to be on the lookout.

ATRIAL TACHYCARDIA



VENTRICULAR TACHYCARDIA

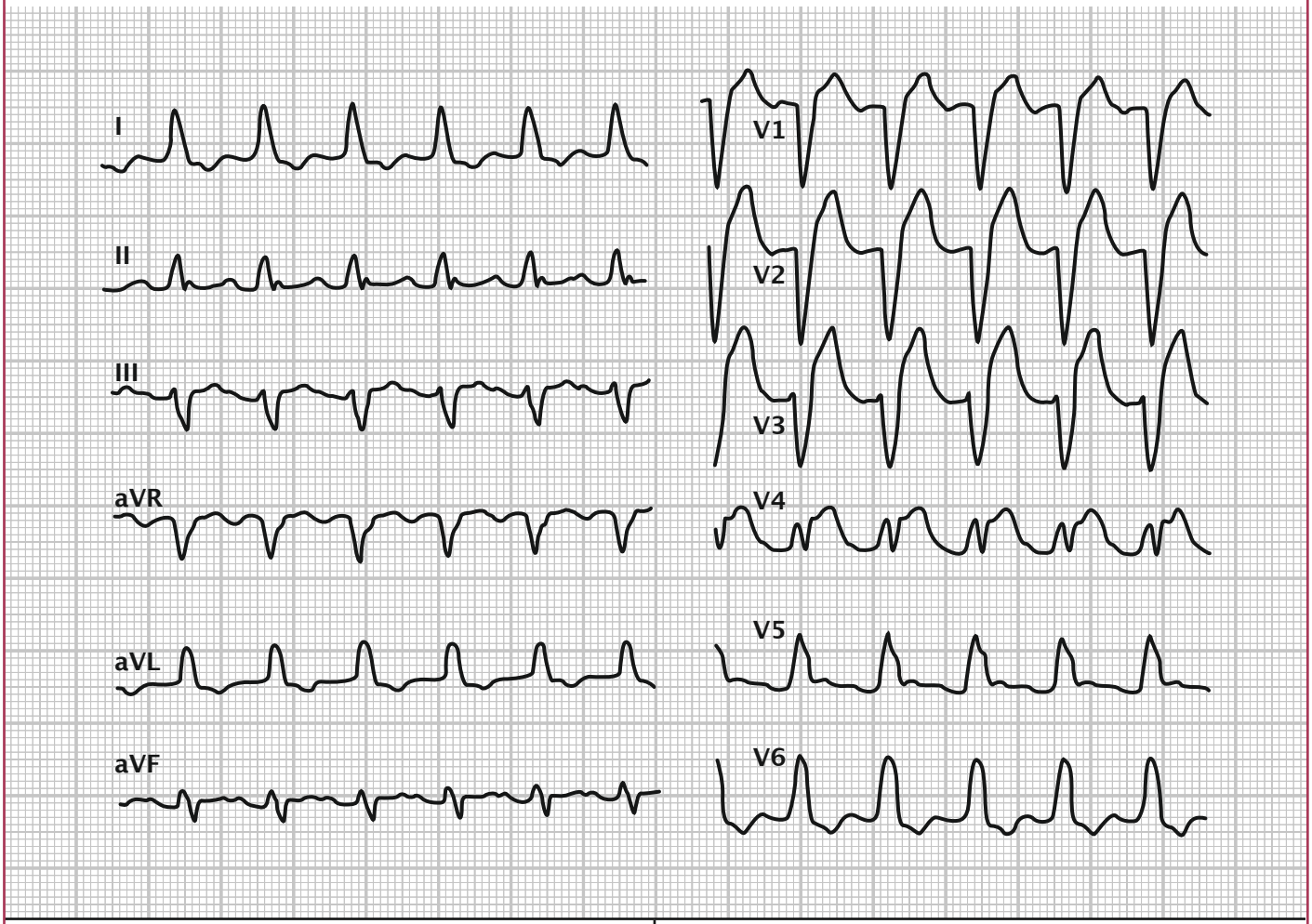
Level 2

QUIZ SECTION

Please estimate the heart rate, then try to determine if the cardiac activity is rhythmic or arrhythmic and if the QRS complexes are narrow or broad. Can you already make a rhythm diagnosis?

P
QRS
T

ECG 1



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Are you able to make a rhythm diagnosis with your current knowledge?
If yes, which one?

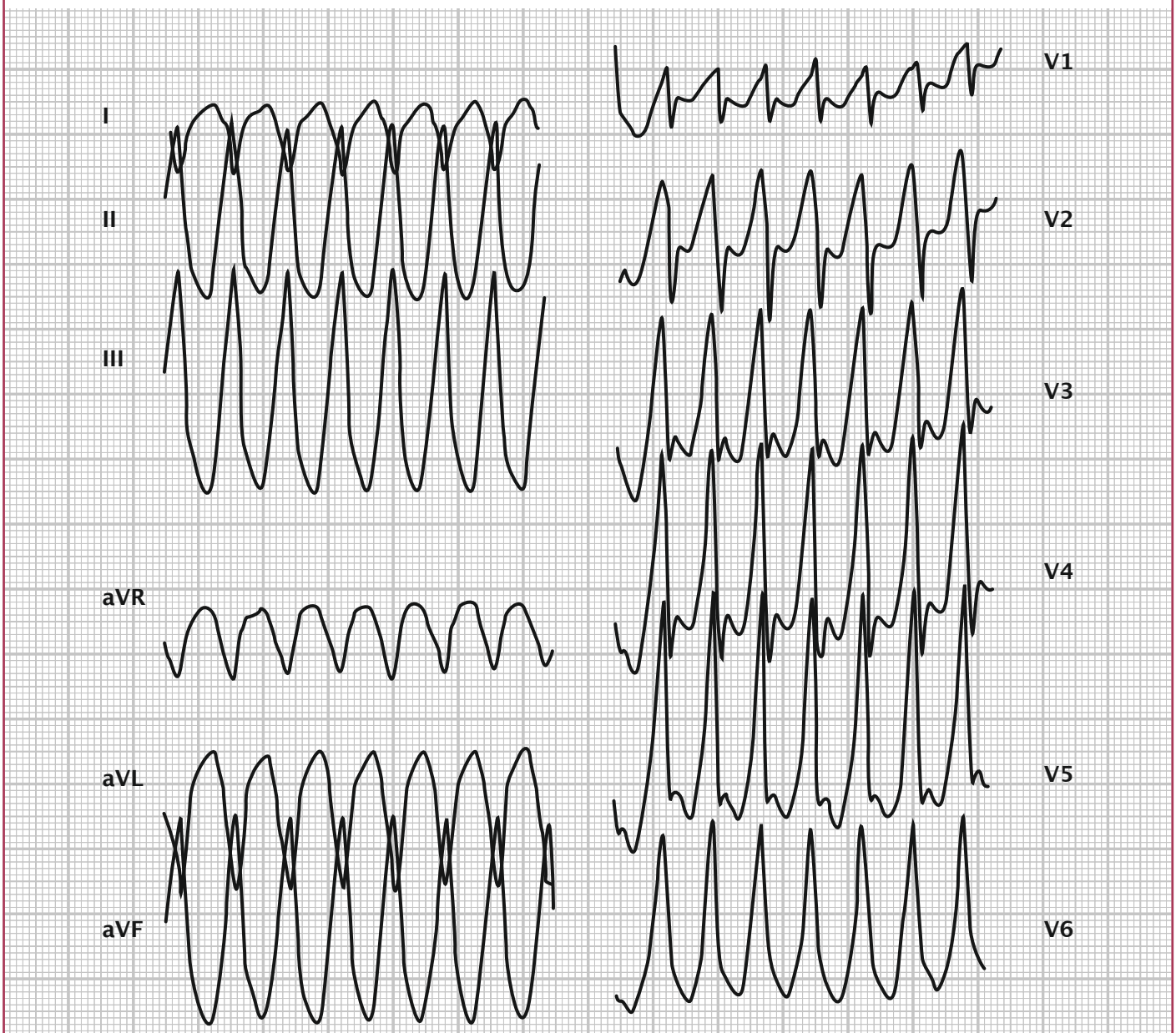
.....

P

QRS

T

ECG 2



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Are you able to make a rhythm diagnosis with your current knowledge?
If yes, which one?

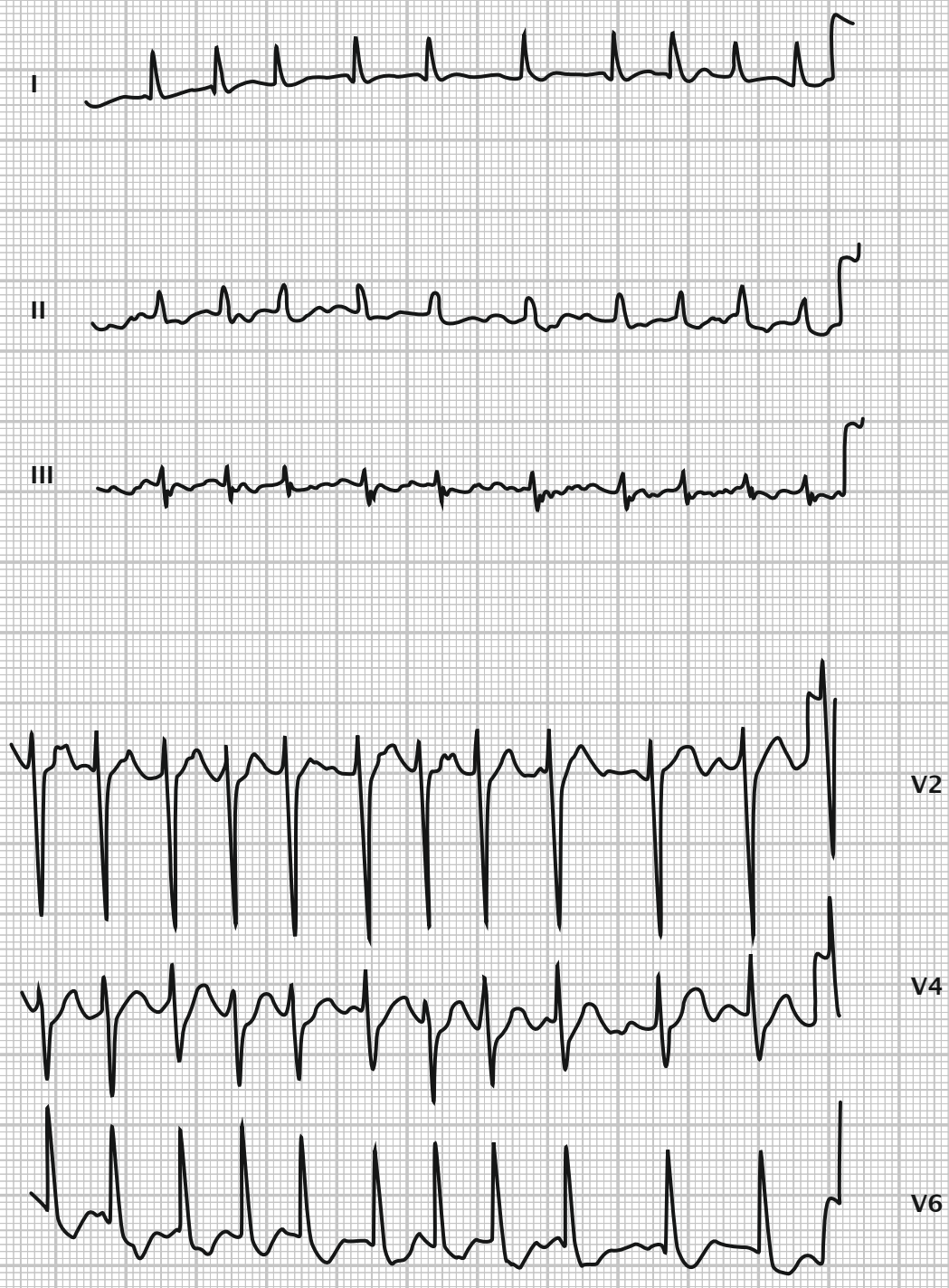
.....

P

QRS

T

ECG 3



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Are you able to make a rhythm diagnosis with your current knowledge?
If yes, which one?

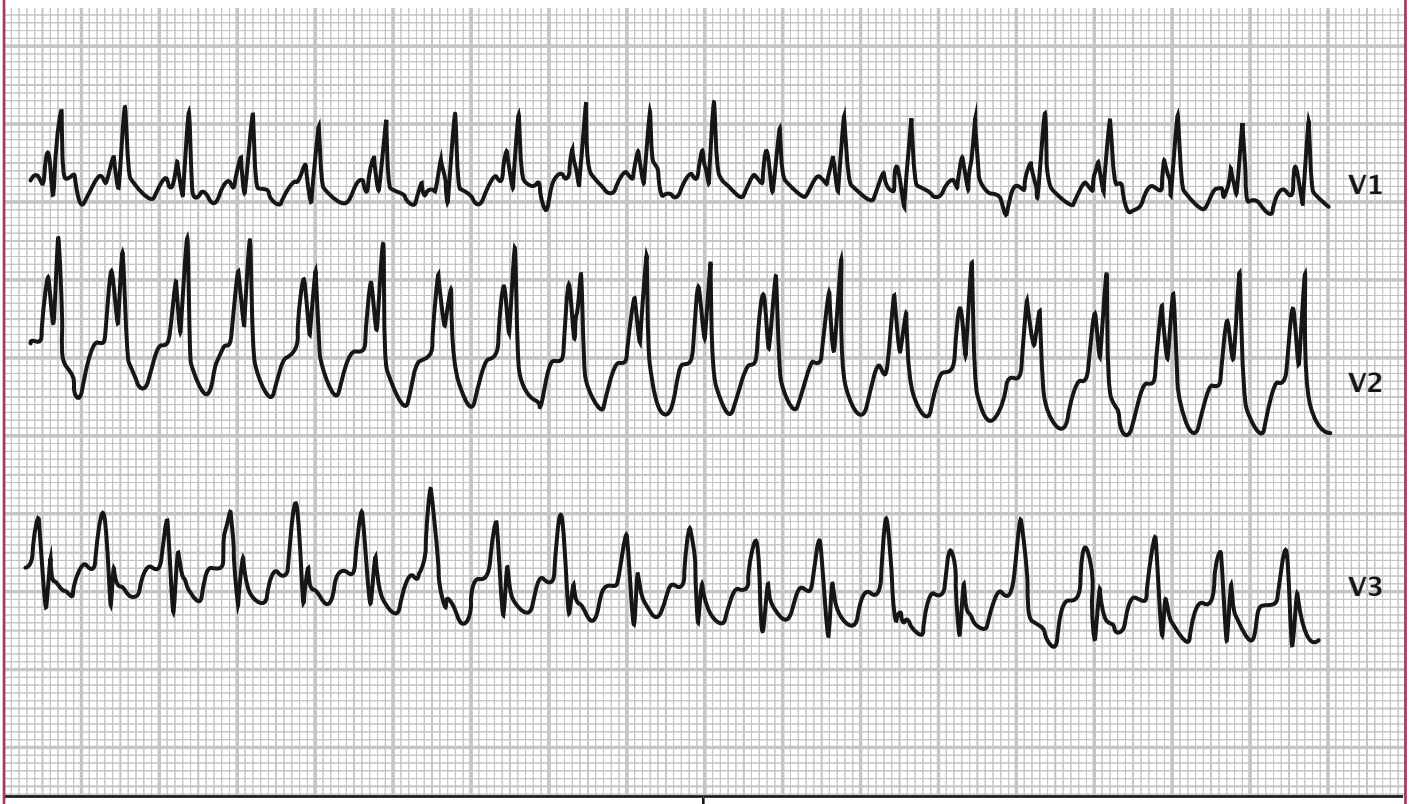
.....

P

QRS

T

ECG 4



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Are you able to make a rhythm diagnosis with your current knowledge?
If yes, which one?

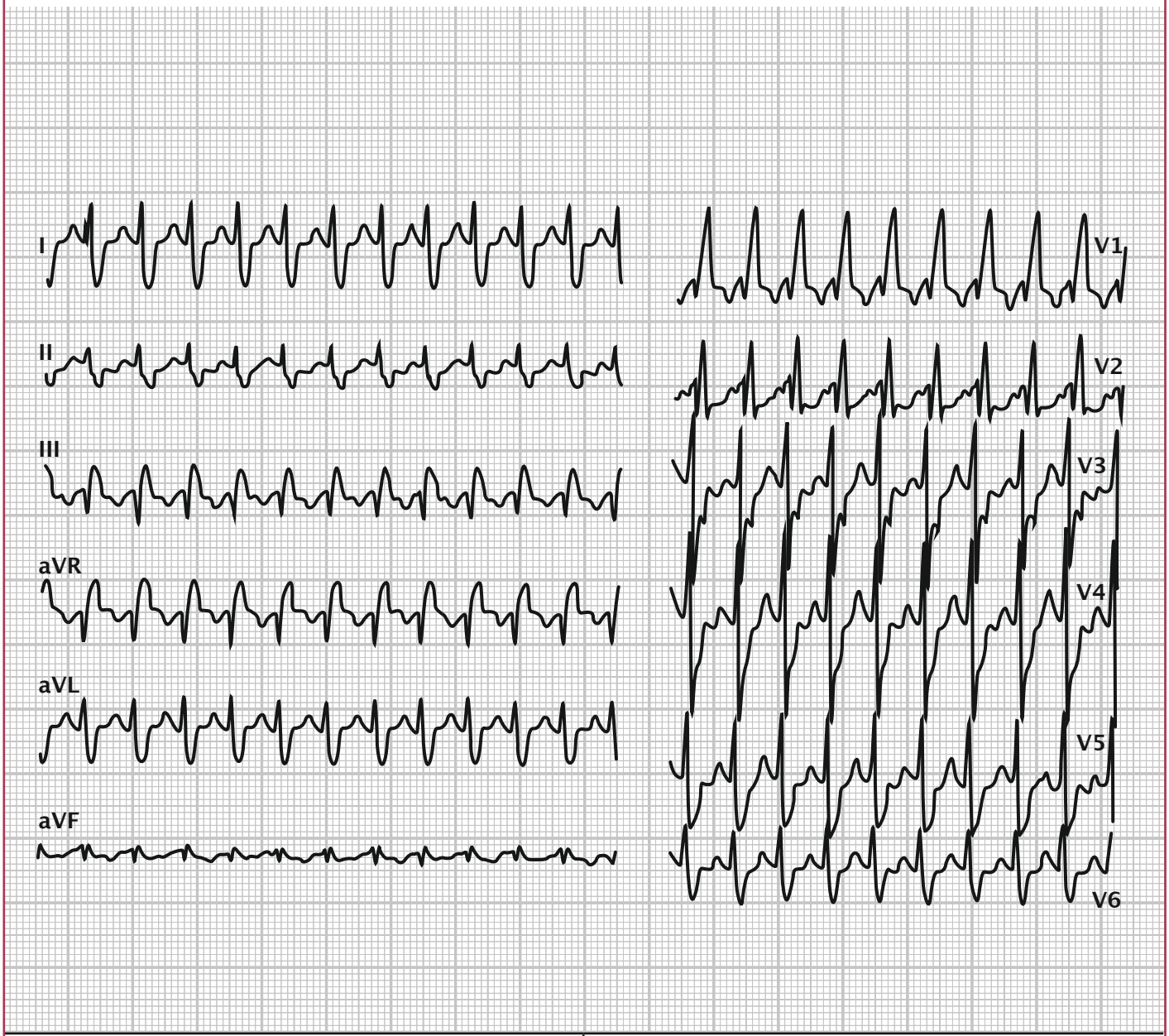
.....

P

QRS

T

ECG 5



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Are you able to make a rhythm diagnosis with your current knowledge?
If yes, which one?

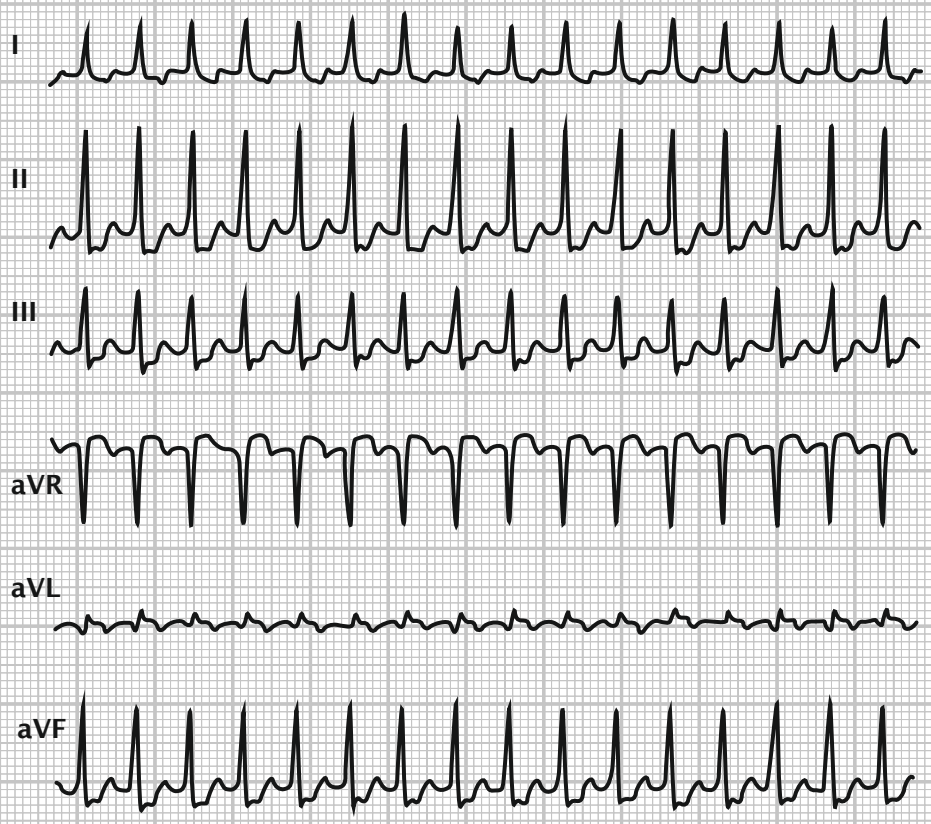
.....

P

QRS

T

ECG 6



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Are you able to make a rhythm diagnosis with your current knowledge?
If yes, which one?

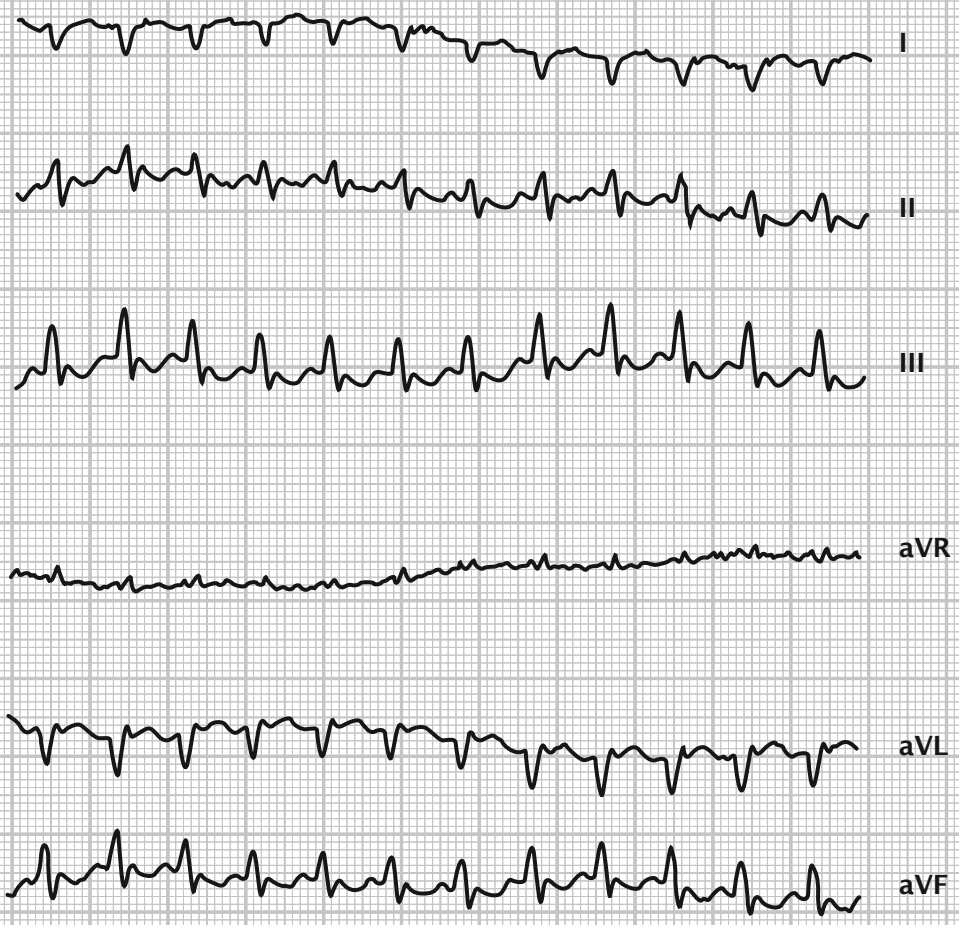
.....

P

QRS

T

ECG 7



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Are you able to make a rhythm diagnosis with your current knowledge?
If yes, which one?

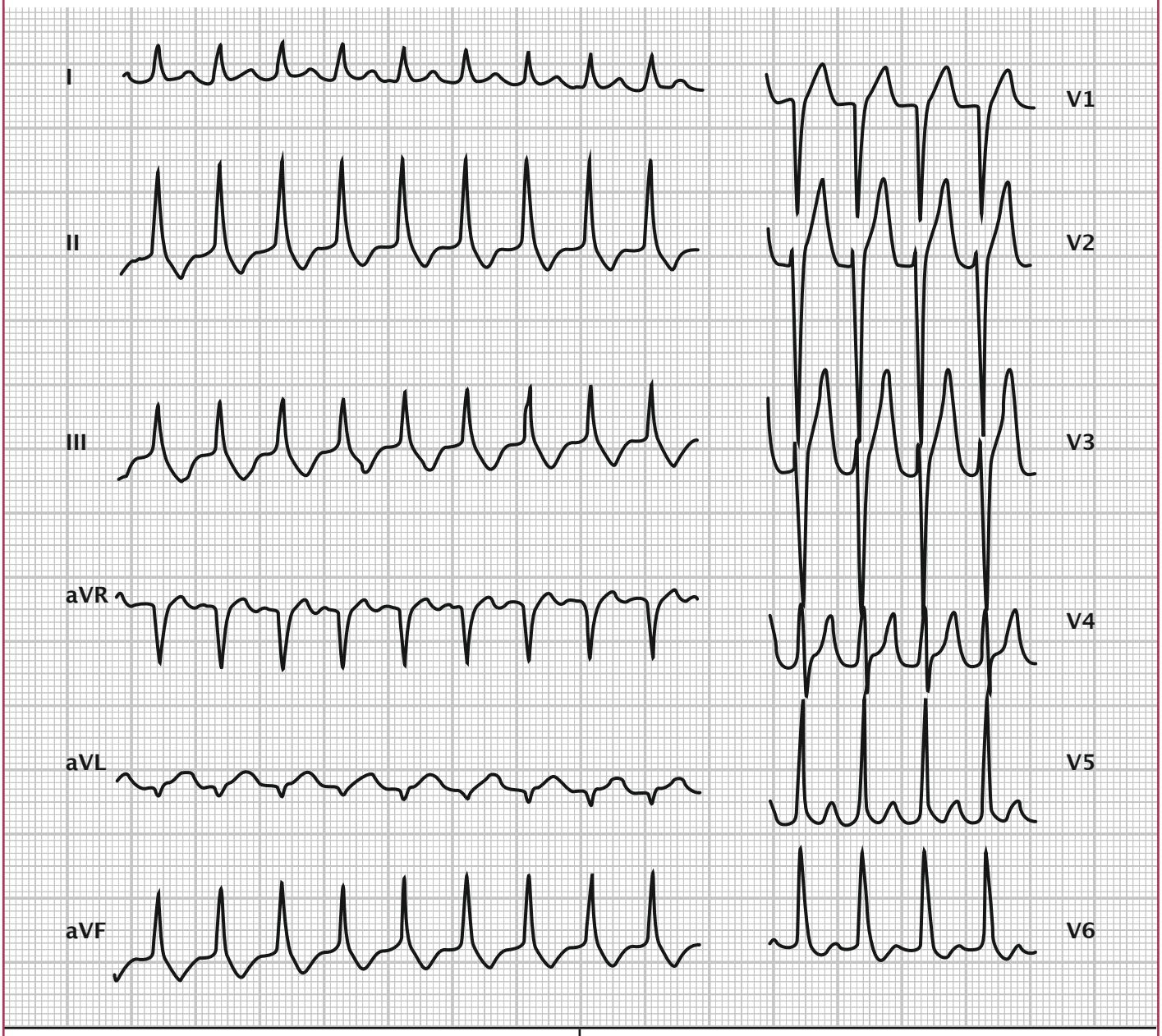
.....

P

QRS

T

ECG 8



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

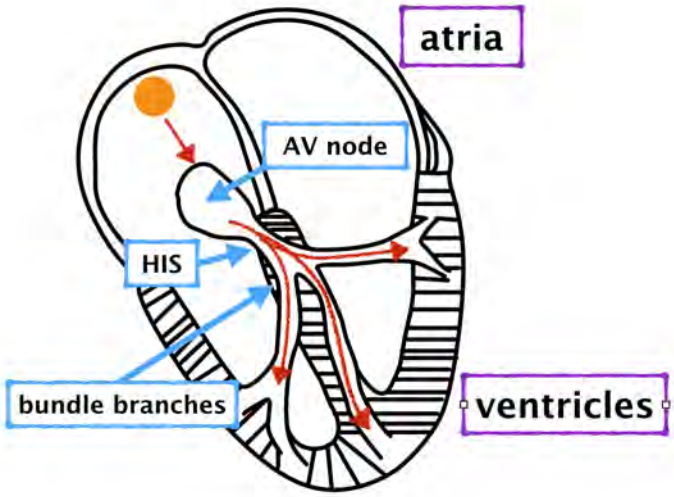
Are you able to make a rhythm diagnosis with your current knowledge?
If yes, which one?

.....

Level 3 : Narrow complex tachycardias = rapid + regular + narrow

In this chapter, you are going to learn about narrow complex tachycardias, what subtypes of tachycardias there are, and how to easily diagnose them. Please note that we are talking about regular tachycardias here (i.e., the R-to-R intervals are constant).

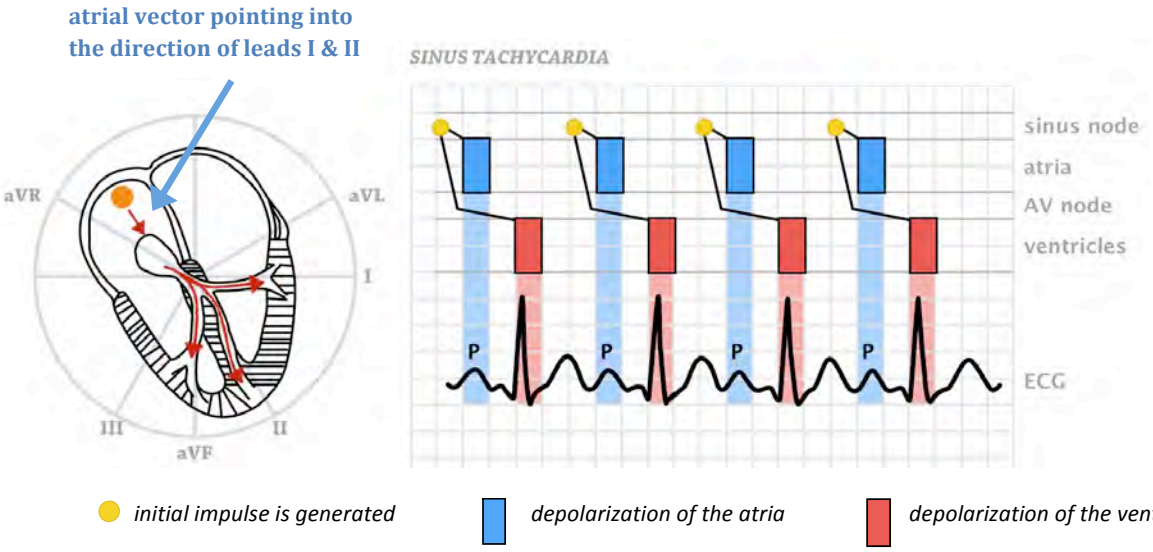
We've already learned that the QRS complex will be narrow if the impulse originates in the atria, takes its course through the AV node, the bundle of HIS, the bundle branches, and the Purkinje fibers. Of course this also applies to tachycardias.



The cardiac conduction system. Under normal circumstances, the impulse is generated in the sinus node, and travels through the AV node and the bundle of HIS and into the bundle branches and the Purkinje fibers (not shown), from where it depolarizes the ventricles.

Sinus tachycardias and atrial tachycardias

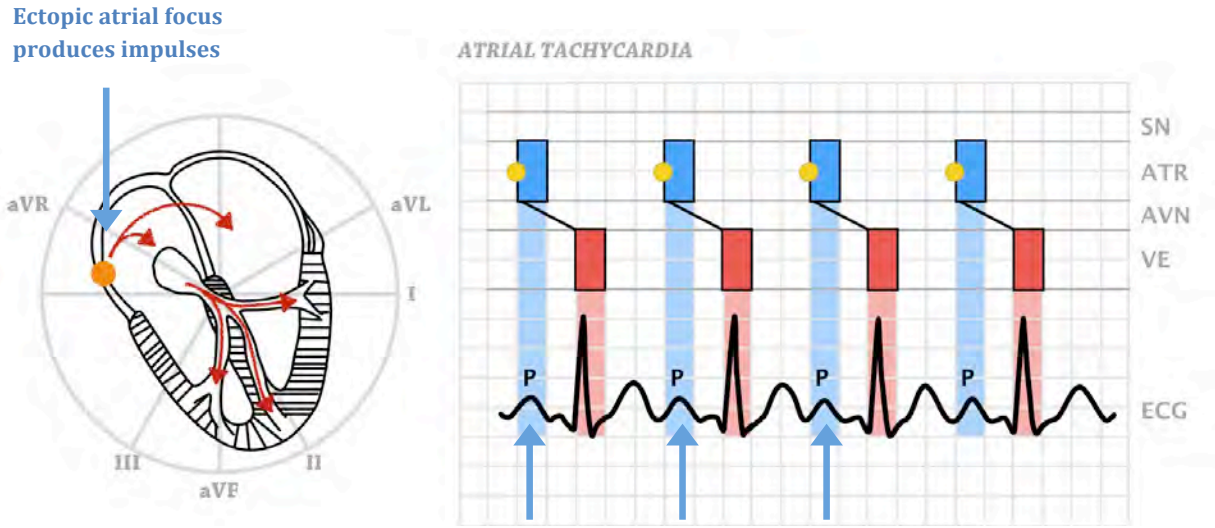
Let's look at an example of **sinus tachycardia** in a patient without bundle branch block:



There are a few things that you should note in the above ladder diagram:

- The QRS complexes are narrow.
- P waves are positive in leads I and II, because the atrial vector points in the direction of these leads.
- P waves precede QRS complexes.

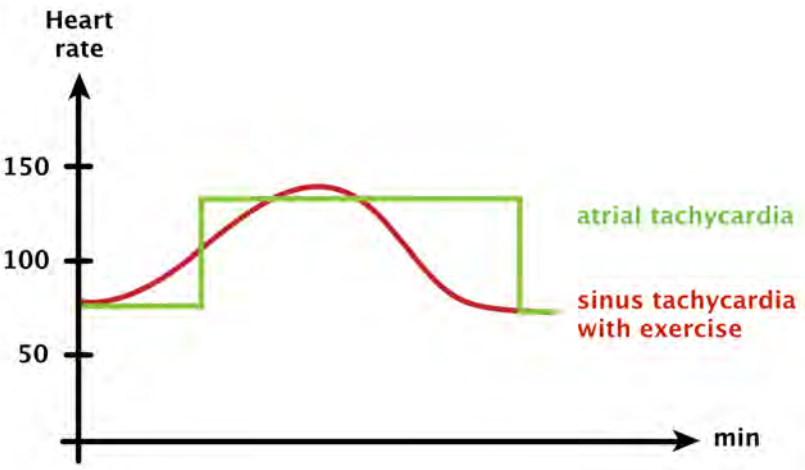
Now let's have a look at **atrial tachycardia** without bundle branch block, another common form of narrow complex tachycardia:



Note that in this case:

- The QRS complexes are narrow.
- P waves are slightly abnormal, but mostly positive in I and II.
- P waves precede QRS complexes.

How can you tell the difference between sinus tachycardia and atrial tachycardia from a clinical perspective? Well, sinus tachycardia is due to an underlying cause such as fever, drugs (e.g. atropin), or exertion. These underlying causes come and go gradually. Therefore, sinus tachycardia also comes and goes gradually. On the other hand, atrial tachycardia is a disorder in and of itself; it comes and goes abruptly, as you can see in the following graph.



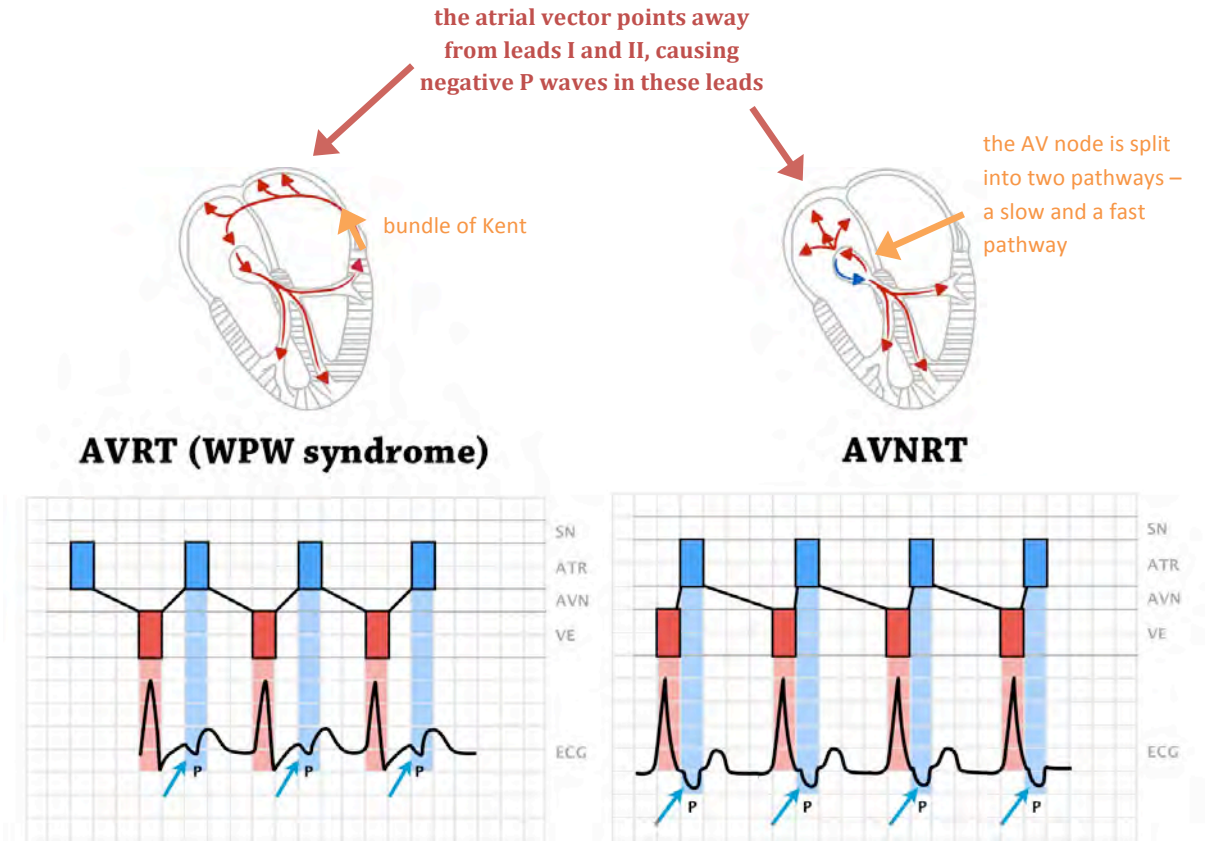
Reentrant tachycardias

In some cases, the atrial impulse not only depolarizes the ventricles but also finds its way back up to the atria again via an additional conduction bundle. Back in the atria it causes another wave of depolarization with a P wave, then travels down through the AV node where it depolarizes the ventricles, again producing yet another QRS complex, and so forth.

Because the atria are depolarized retrogradely, P waves will be negative in leads II, III, and aVF, and positive in lead aVR. This type of tachycardia is called **reentry tachycardia** or **circus movement tachycardia**.

Let's have a look at the two most common types of reentry tachycardias:

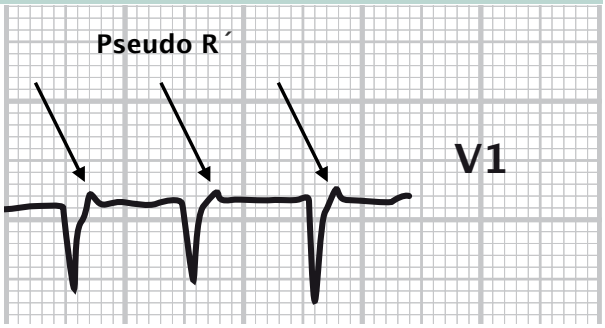
1. **AV reentrant tachycardia (AVRT) in patients with WPW syndrome**: In the case of AVRT, the impulse travels down to the ventricles through the AV node and back to the atria through the so-called bundle of Kent. Compared to AVNRT, the impulse takes longer before it reaches the atria again. Therefore, the retrograde (i.e., negative) P wave will be found further away from the QRS complex than in AVNRT, in close proximity to the T wave.
2. **AV nodal reentrant tachycardia (AVNRT)**: This is a tachycardia using two distinct pathways within the AV node. The impulse travels down the so-called fast pathway and returns to the atria using the slow pathway immediately thereafter. Therefore, the retrograde P wave will be found immediately after the QRS complex or even inside the QRS complex.



In AVRT, the impulse takes longer before it returns back to the atria. The retrograde P wave will thus be located further away from the QRS complex than in AVNRT.

In AVNRT, the impulse returns to the atria earlier than in AVRT. The P wave will be located closer to the QRS complex. Sometimes the negative retrograde P wave is even hidden within the final part of the QRS complex.

Here's a trick for spotting retrograde P waves that are "hidden" within the QRS complex in AVNRT: Look for a notch at the end of QRS in V1. This type of notch is also called "pseudo R prime."



Note that the retrograde P wave is positive in V1, whereas it is negative in I and II.

So in summary, these are the causes for regular narrow complex tachycardias:

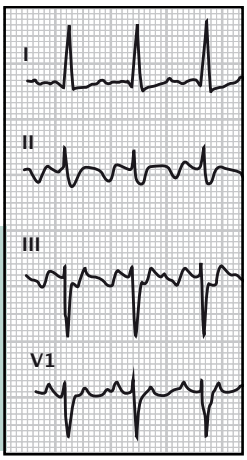
- Sinus tachycardia
- Atrial tachycardia
- AV nodal reentrat tachycardia (AVNRT)
- AV reentrant tachycardia (AVRT) in WPW

And here's a table that will help you differentiate between these types of tachycardias:

	Sinus tachycardia	Atrial tachycardia	AVNRT	AVRT (WPW)
P wave direction (I,II)	*positive*	*positive*	*negative*	*negative*
P wave location	*before QRS*	*before QRS*	*after / inside QRS*	*after QRS*
Distance QRS to P wave	...	...	*short*	*long*

Please note that P waves can also be negative in atrial tachycardia. However, most of the time they are positive with a slightly different morphology than sinus P waves.

There's one more instance when the rhythm will also be rapid, regular, and narrow, and that's atrial flutter with constant 2:1 conduction. However, here we would also expect to see flutter waves in leads II, III, and aVF.



Atrial flutter

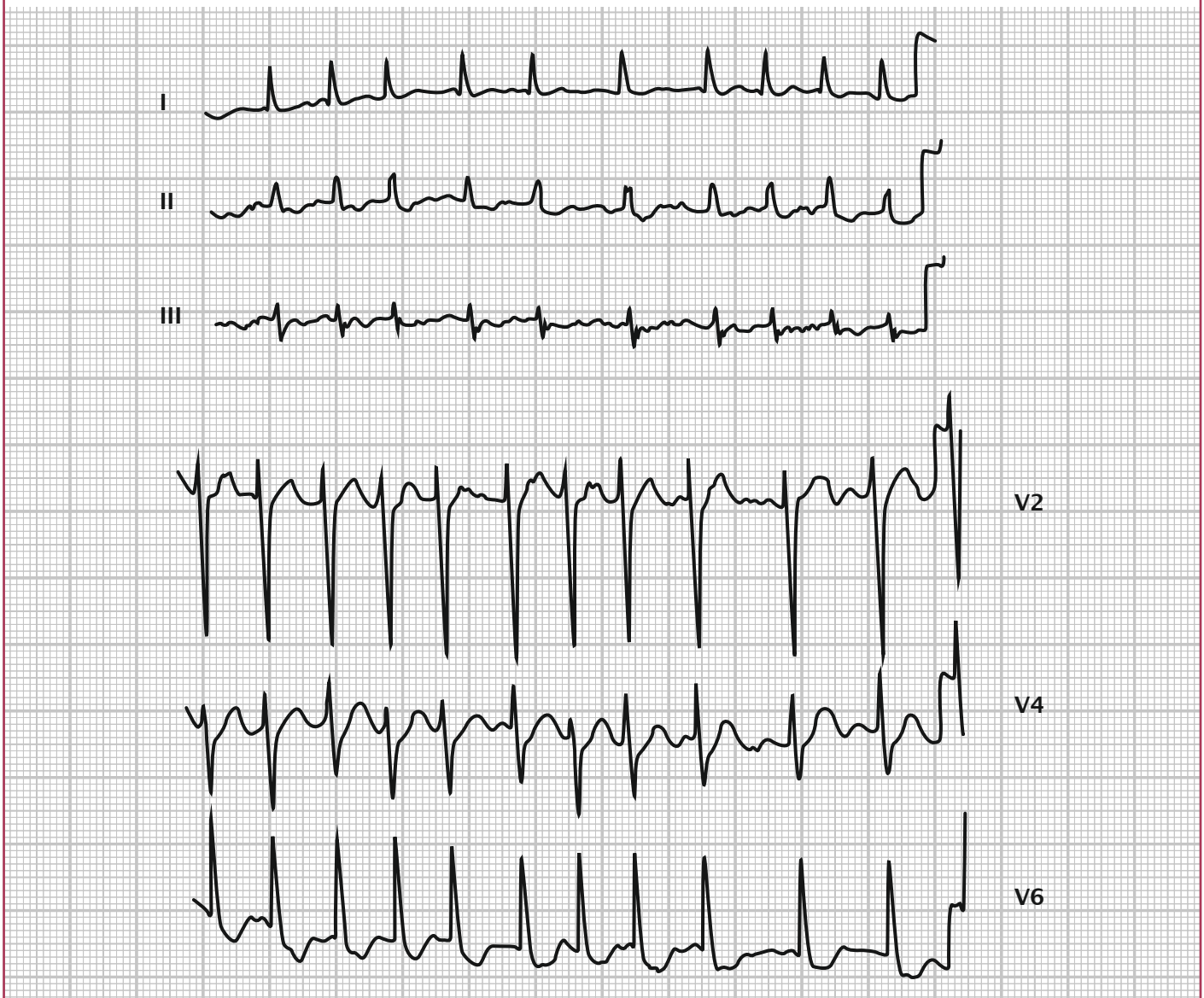
Level 3

QUIZ SECTION

Please estimate the heart rate, then try to determine if the cardiac activity is rhythmic or arrhythmic and if the QRS complexes are narrow or broad. Can you already make a rhythm diagnosis?

P
QRS
T

ECG 1



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Diagnosis:

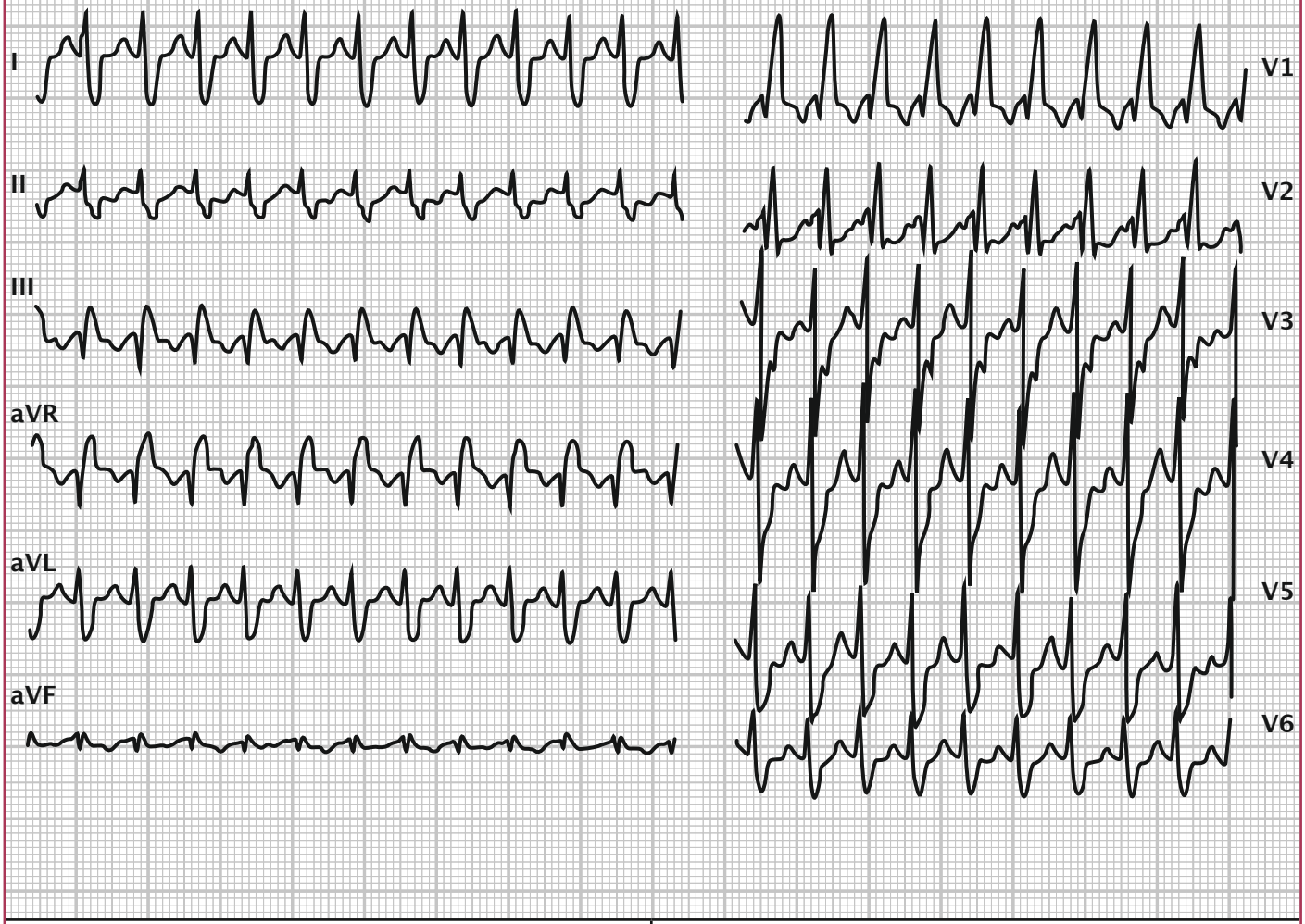
- ☐ sinus tachycardia
- ☐ atrial tachcardia
- ☐ AVNRT or AVRT
- ☐ ventricular tachycardia
- ☐ other: .....

P

QRS

T

ECG 2



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Diagnosis:

☐ sinus tachycardia

☐ atrial tachcardia

☐ AVNRT or AVRT

☐ ventricular tachycardia

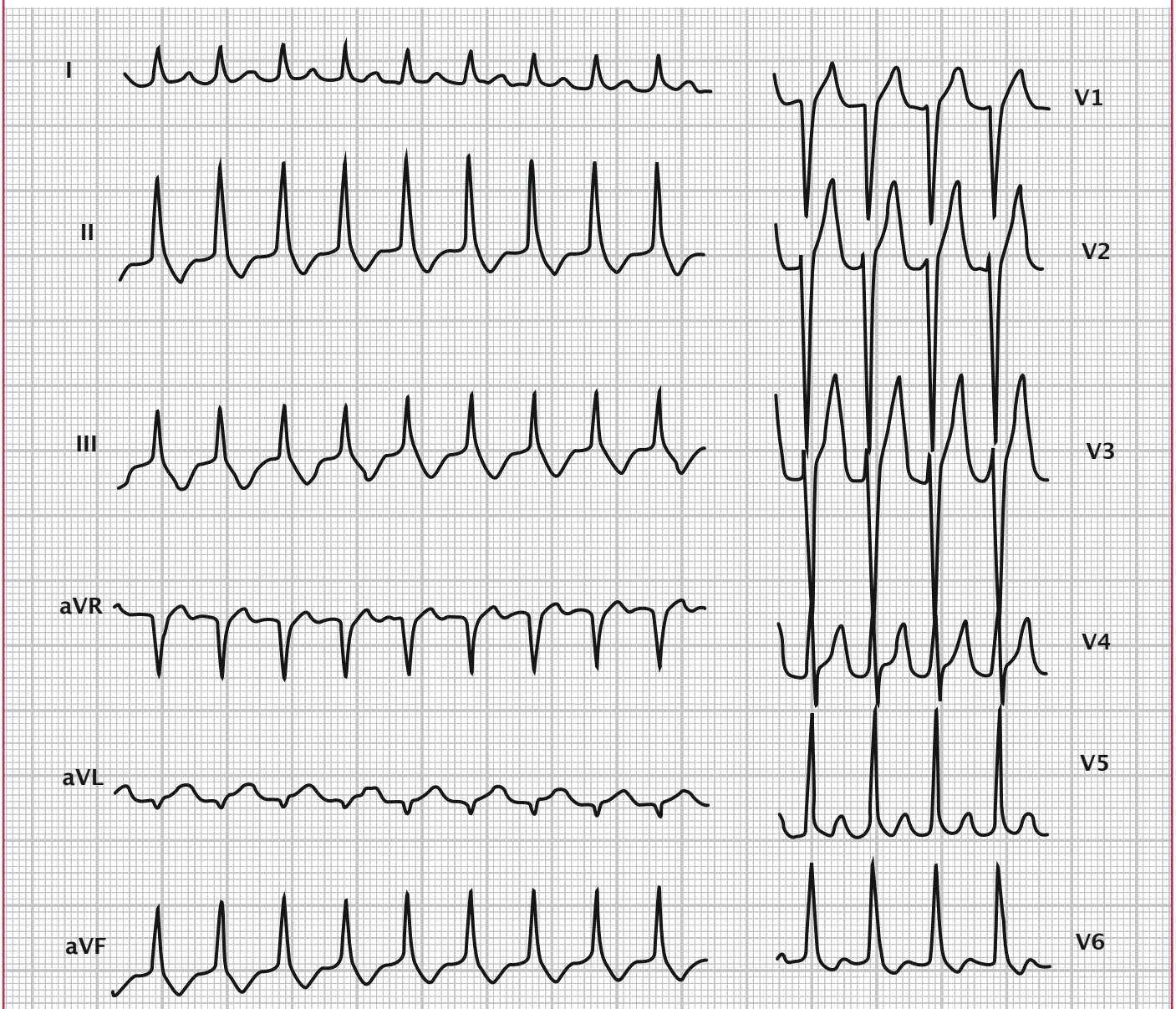
☐ other: .....

P

QRS

T

ECG 3



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Diagnosis:

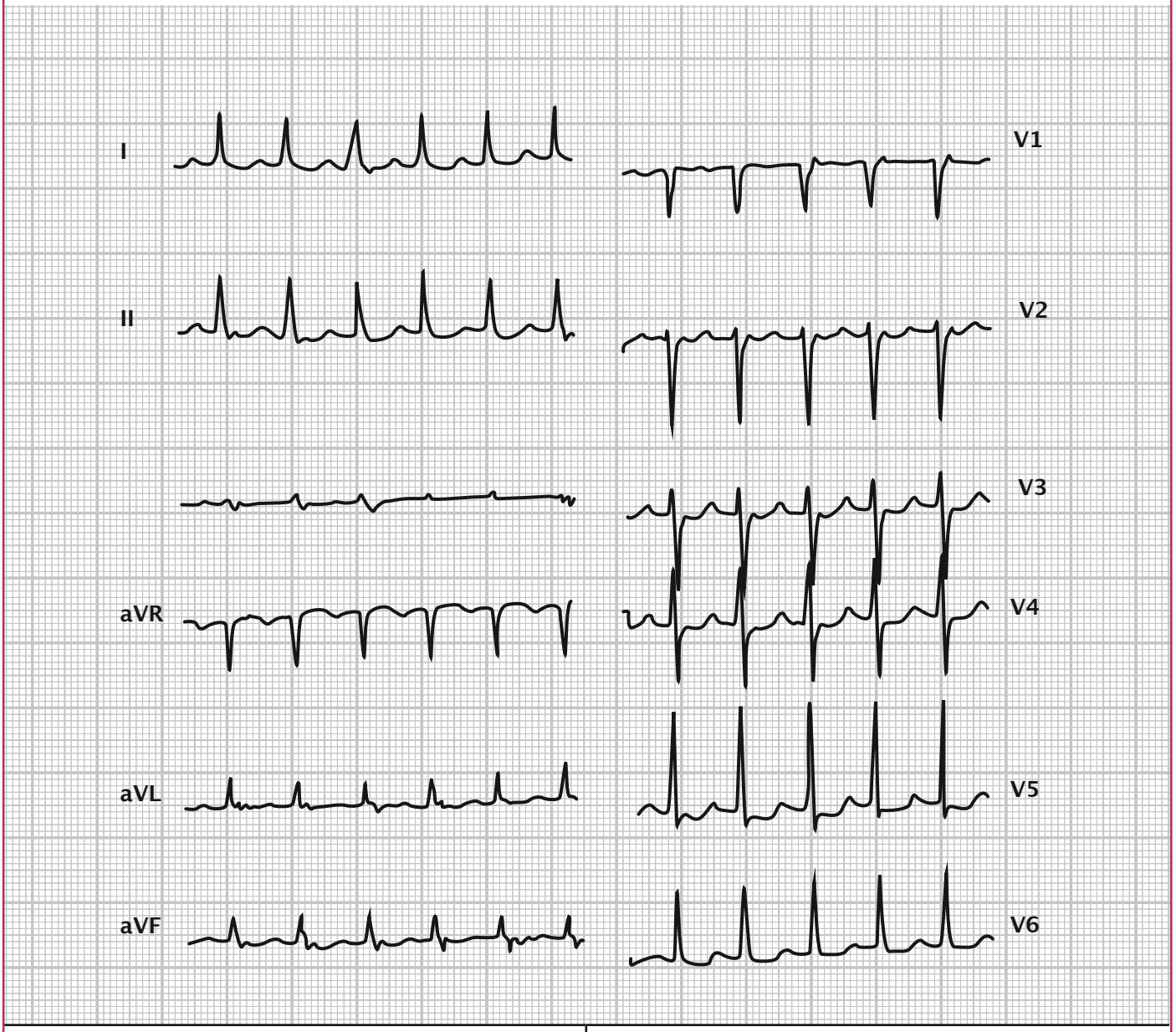
- ☐ sinus tachycardia
- ☐ atrial tachcardia
- ☐ AVNRT or AVRT
- ☐ ventricular tachycardia
- ☐ other: .....

P

QRS

T

ECG 4



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Diagnosis:

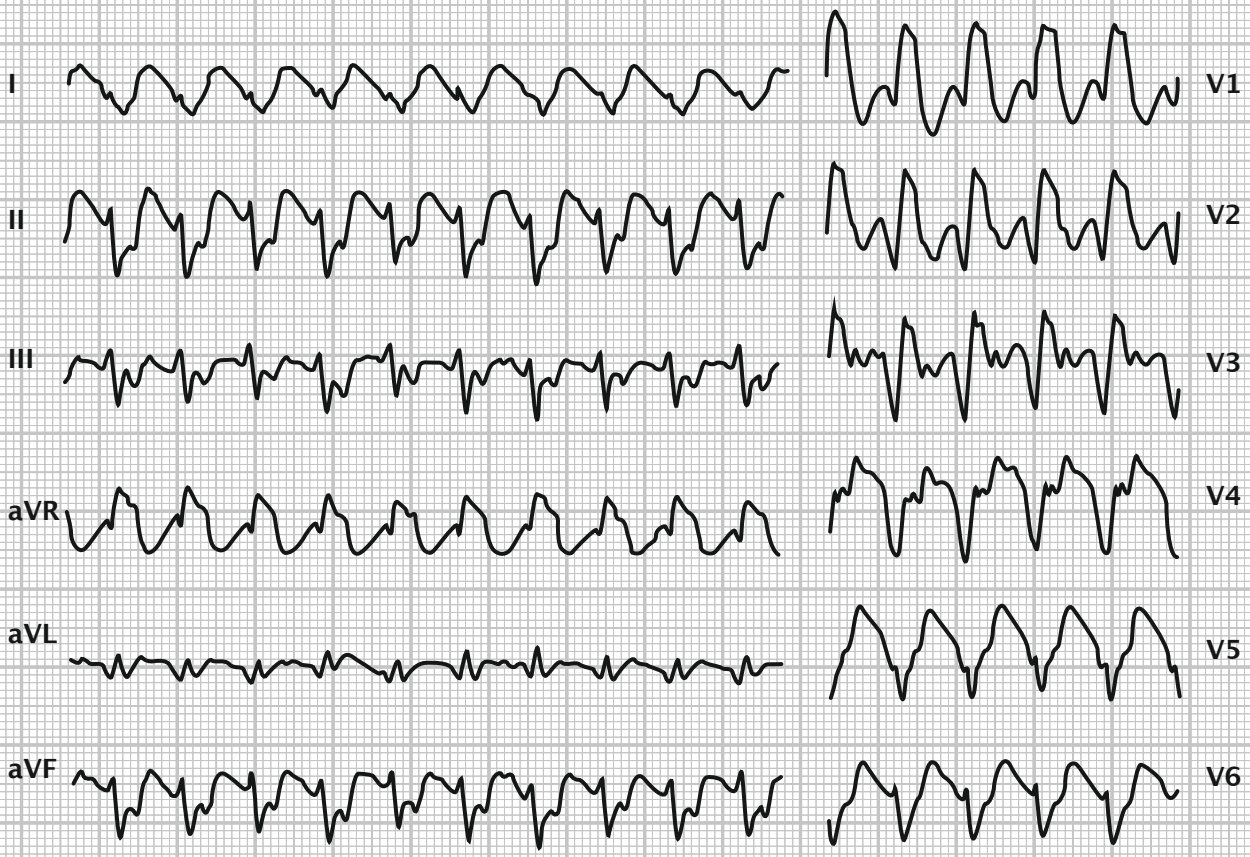
- ☐ sinus tachycardia
- ☐ atrial tachcardia
- ☐ AVNRT or AVRT
- ☐ ventricular tachycardia
- ☐ other: .....

P

QRS

T

ECG 5



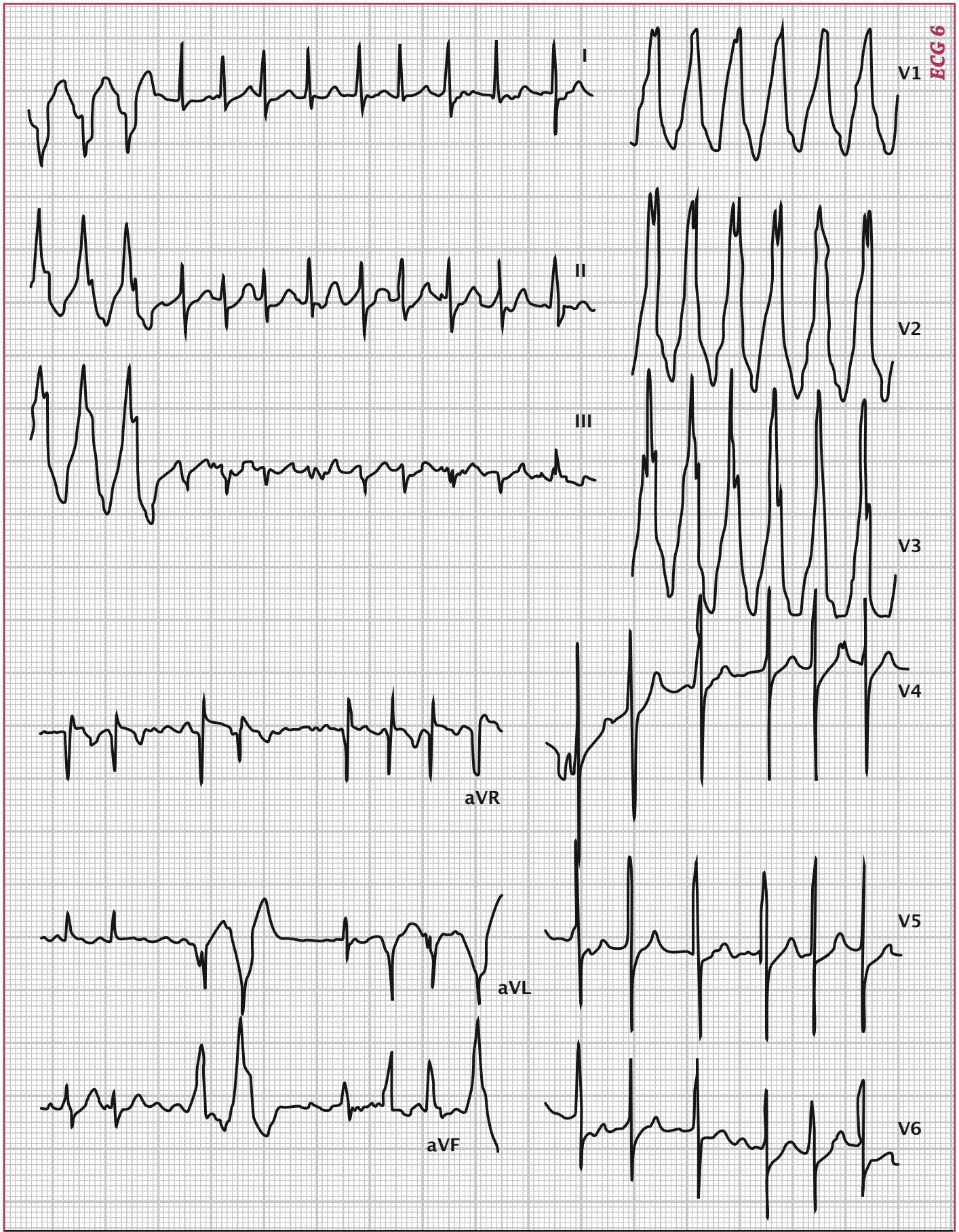
heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Diagnosis:

- ☐ sinus tachycardia
- ☐ atrial tachcardia
- ☐ AVNRT or AVRT
- ☐ ventricular tachycardia
- ☐ other: .....



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Diagnosis:

☐ sinus tachycardia ☐ AVNRT or AVRT

☐ atrial tachcardia ☐ ventricular tachycardia

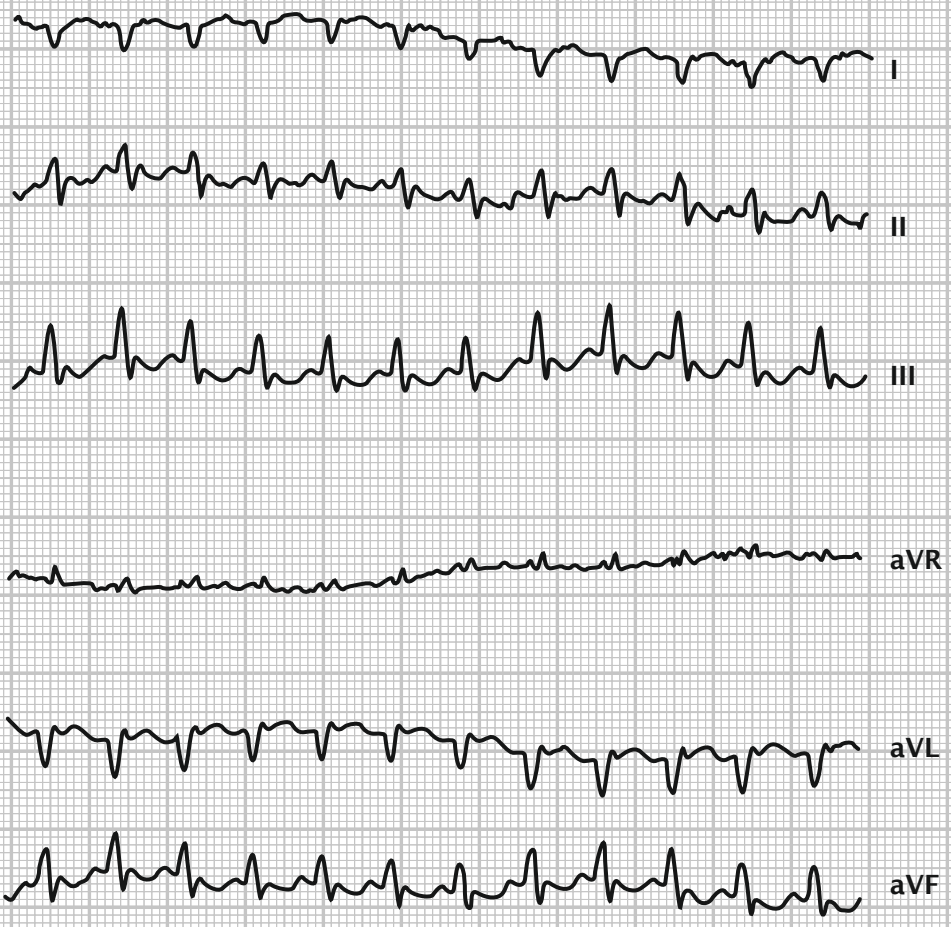
☐ other: .....

P

QRS

T

ECG 7



heart rate ..... / min

rhythmic ☐ arrhythmic ☐

narrow QRS ☐ broad QRS ☐

Diagnosis:

- ☐ sinus tachycardia
- ☐ atrial tachcardia
- ☐ AVNRT or AVRT
- ☐ ventricular tachycardia
- ☐ other: .....

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)

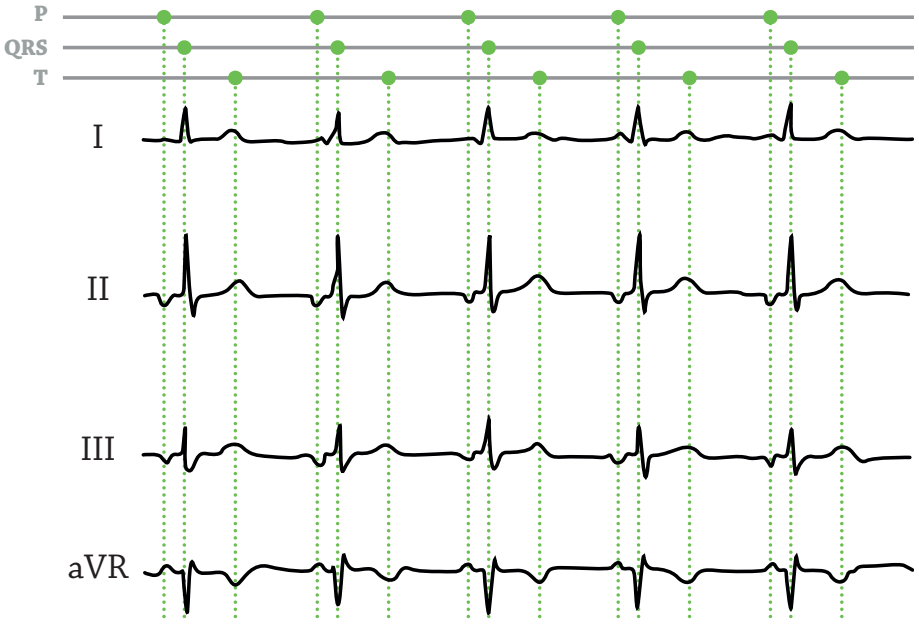
Steps 4 and 5 of the cheat sheet: when P waves are not normal

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.

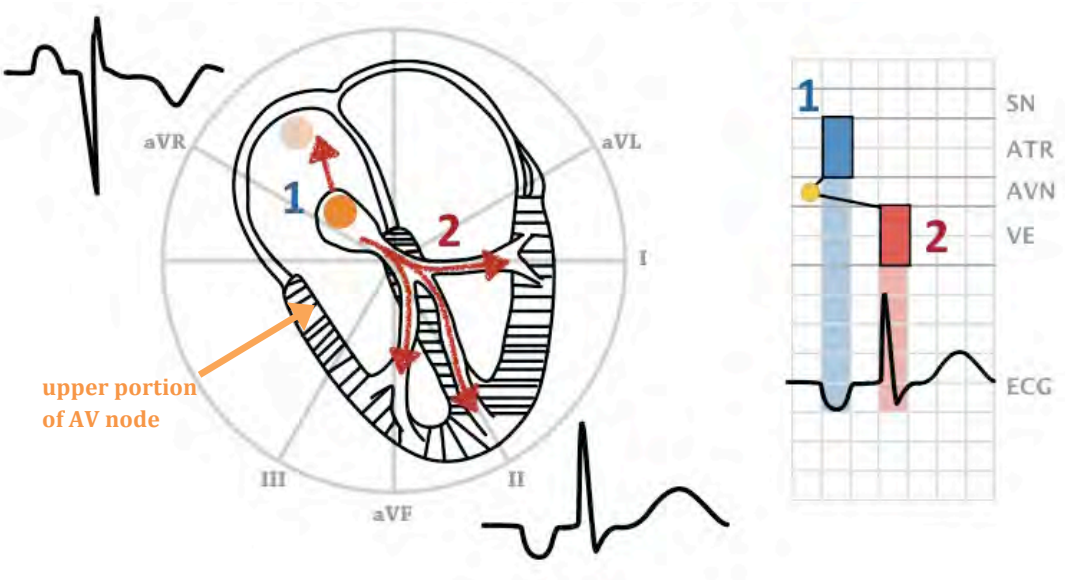
Let's jump right into a couple of examples.

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.

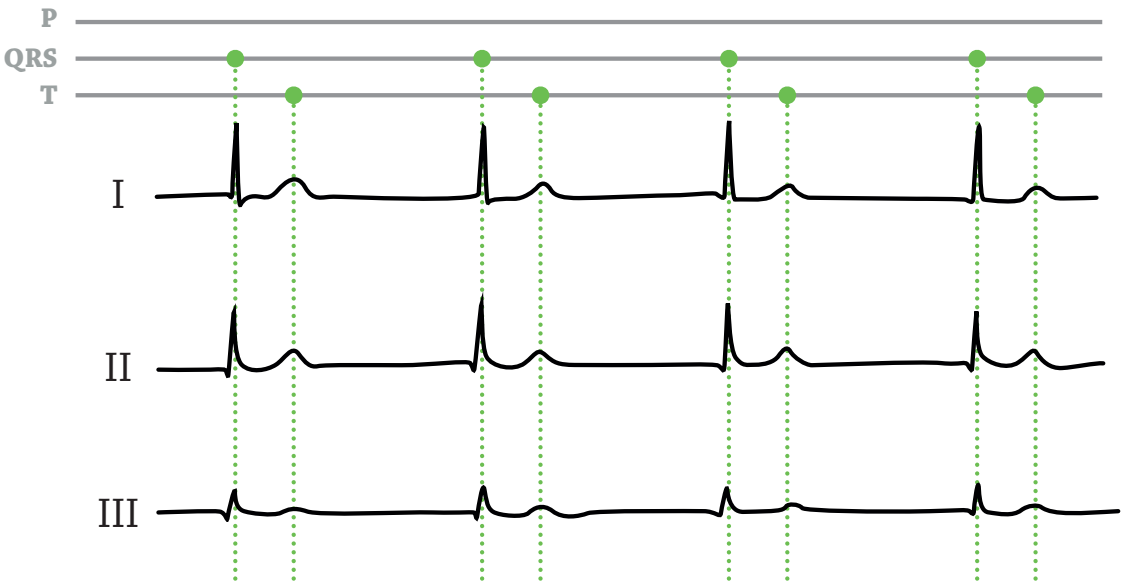
UPPER JUNCTIONAL RHYTHM



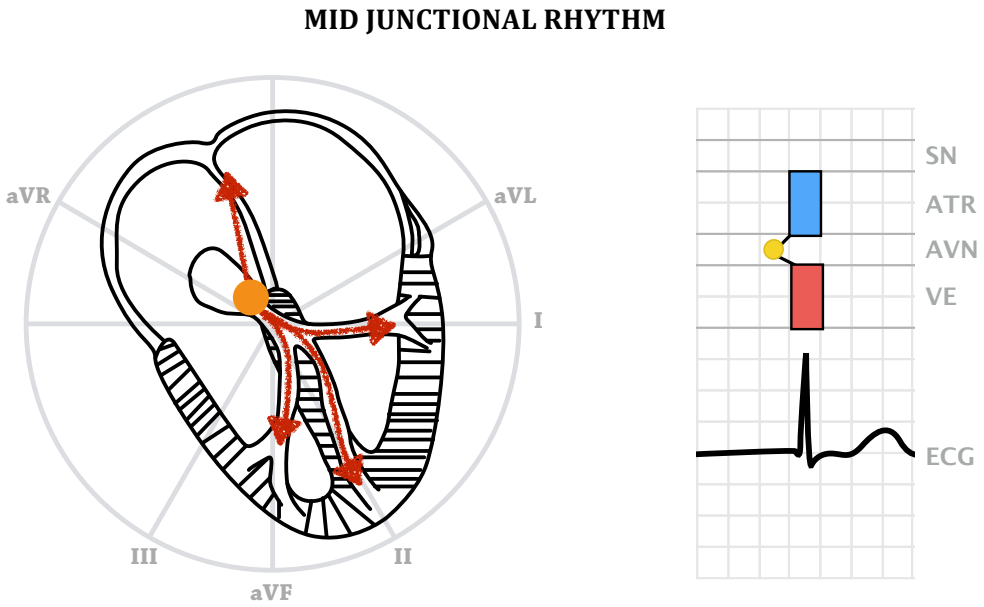
In upper junctional rhythm, depolarization starts in the upper portion of the AV node, then travels up towards lead aVR and away from leads II & III, causing a positive P wave in aVR and negative P waves in II and III (1). Subsequently, the impulse travels down into the ventricles through the normal 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



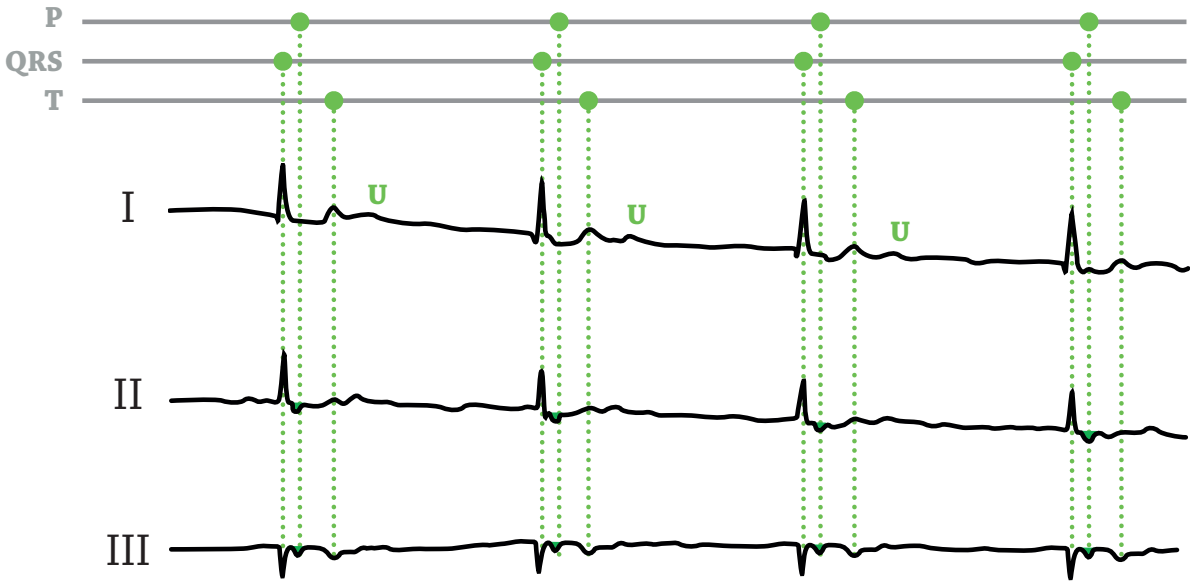
This is an ECG without any P waves. However, the QRS complexes appear regular. Regular QRS complexes in combination with absent P waves are typical for a **mid junctional rhythm** (i.e., it originates from the mid-portions of the AV node).



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.

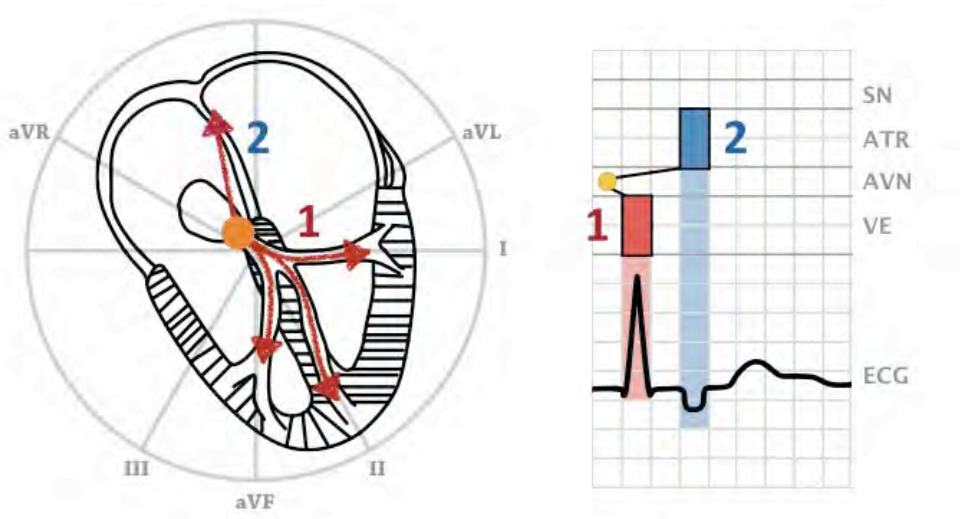
Now take a look at the next case...

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.

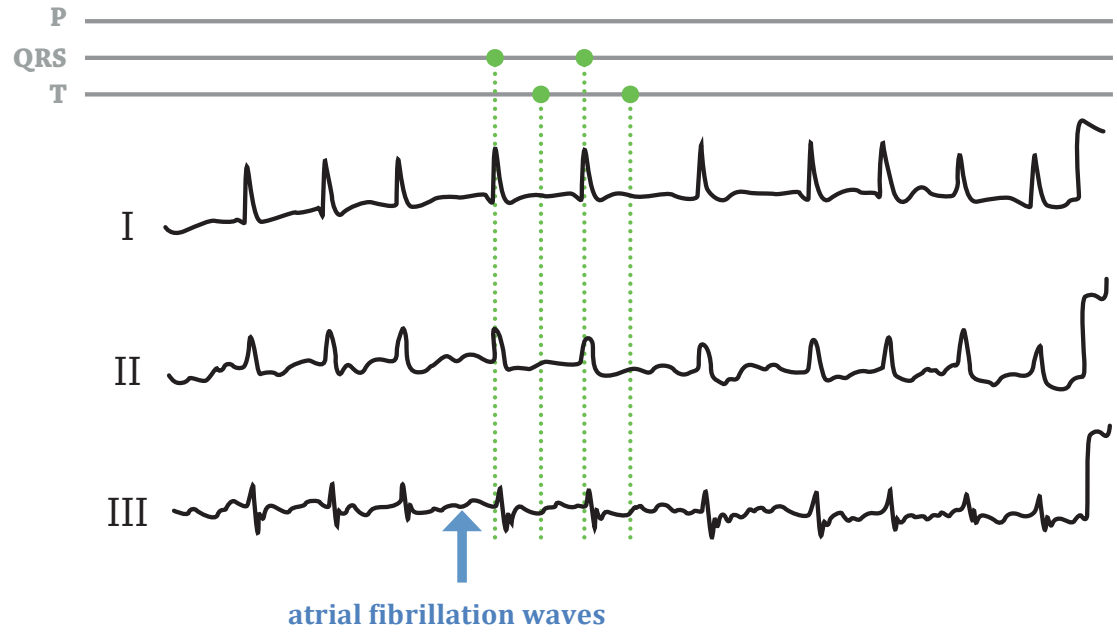
LOWER JUNCTIONAL RHYTHM



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



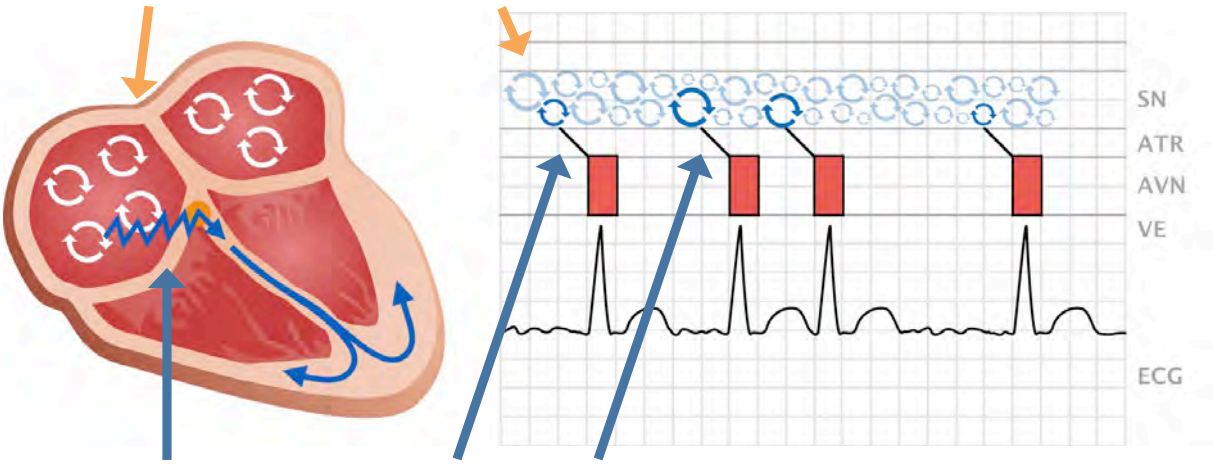
In this example, it's difficult to decide whether P waves are present or not. Several waves are present which could be P waves based on their morphology, but they look quite different from one another. Actually, there is a lot of variability on this ECG:

- 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

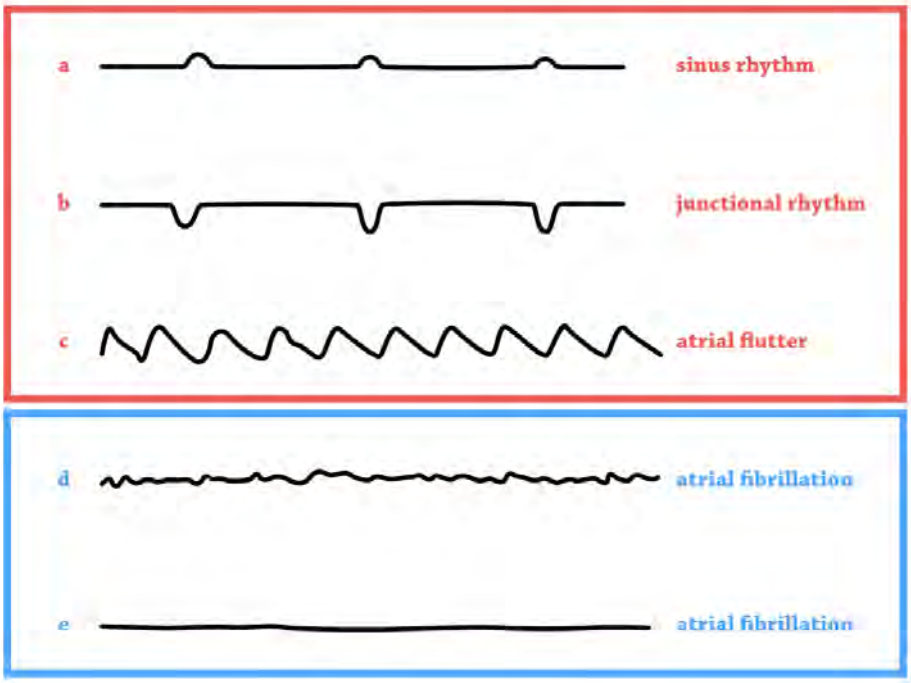


Thanks to the filter function of the AV node, not every impulse will be conducted down into the ventricles.

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

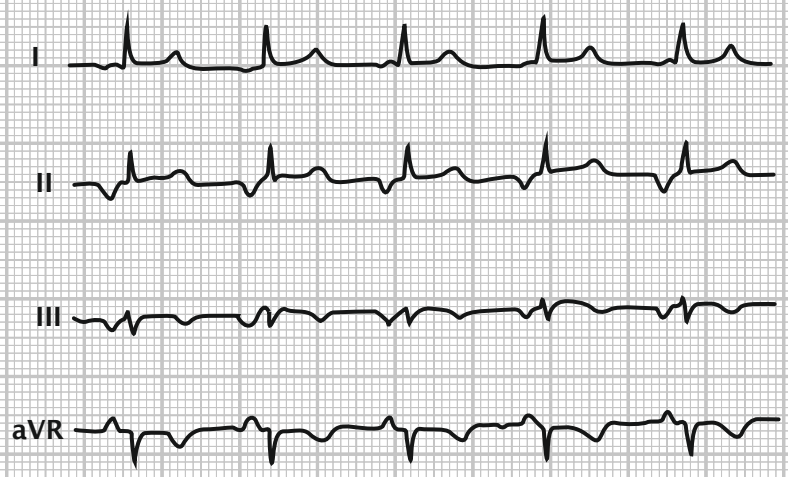
Level 4

QUIZ SECTION

Can you come up with the right diagnosis? Please also determine the heart rate and write down any additional comments.

P
QRS
T

ECG 1



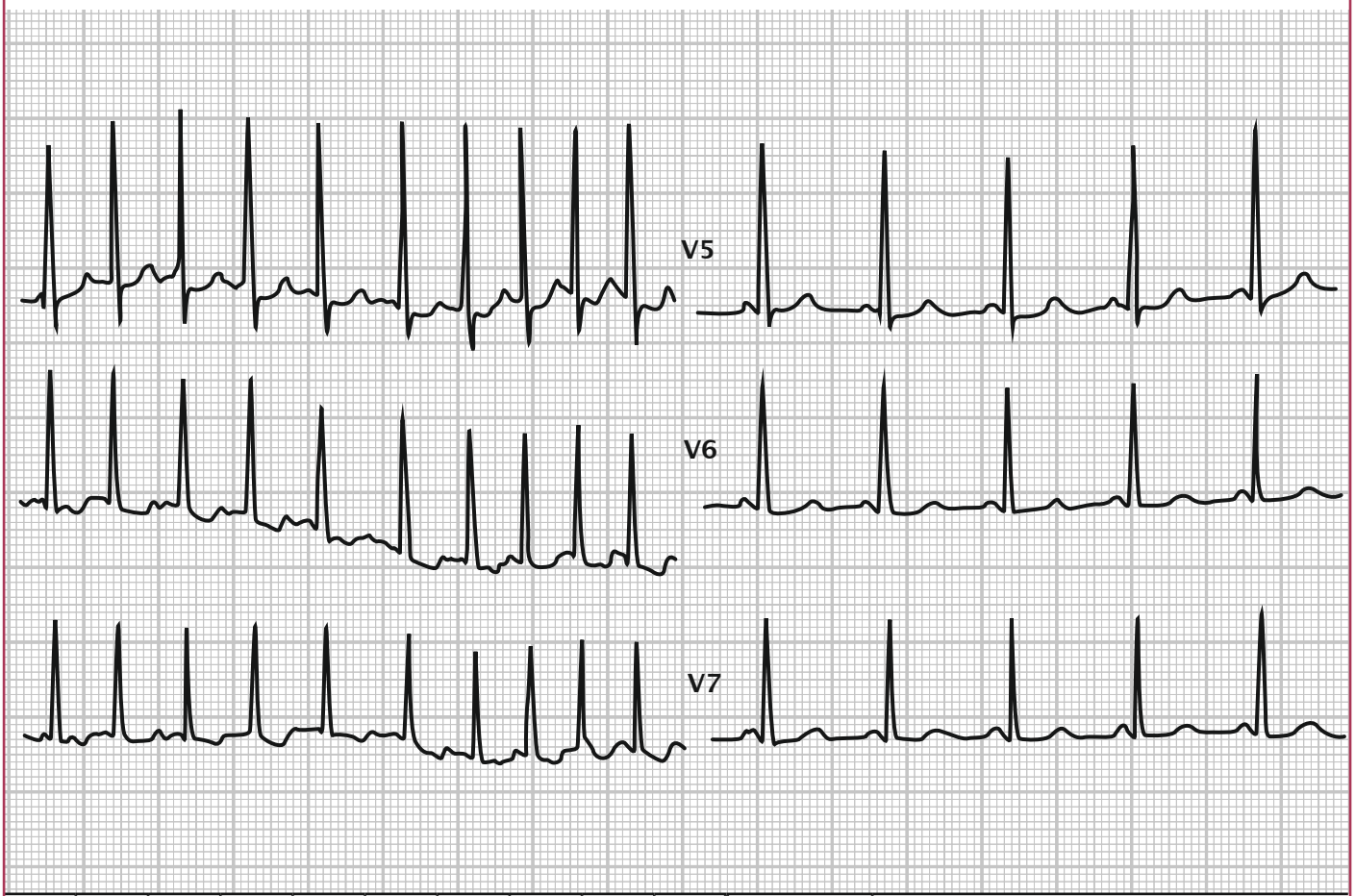
sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial flutter	atrial fibrillation	upper junctional rhythm	mid junctional rhythm	lower junctional rhythm	pacemaker	heart rate	additional comments

P

QRS

T

ECG 2



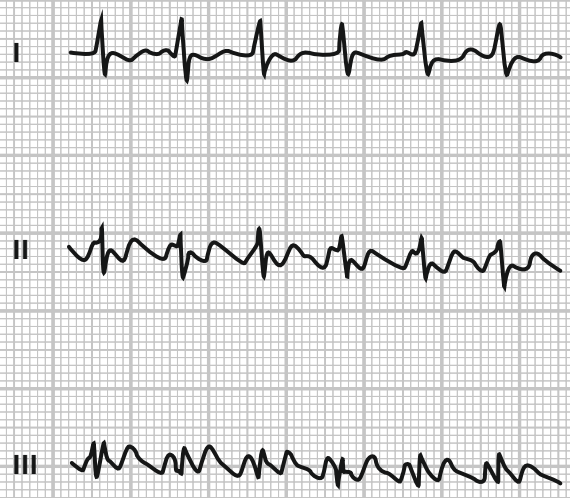
sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial flutter	atrial fibrillation	upper junctional rhythm	mid junctional rhythm	lower junctional rhythm	pacemaker	heart rate	additional comments

P

QRS

T

ECG 3



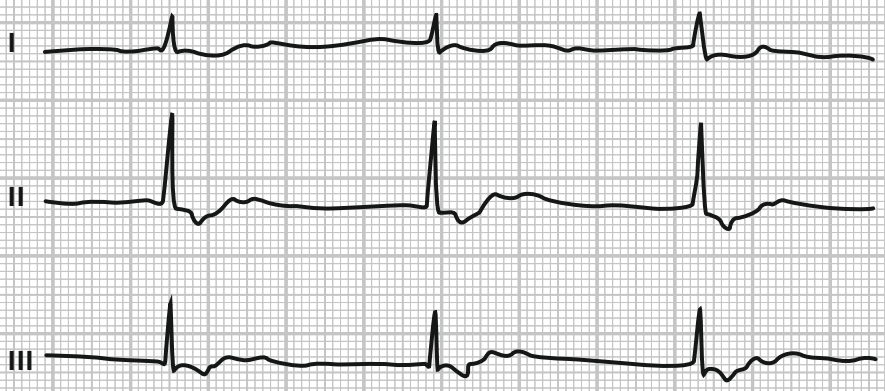
sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial flutter	atrial fibrillation	upper junctional rhythm	mid junctional rhythm	lower junctional rhythm	pacemaker	heart rate	additional comments

P

QRS

T

ECG 4



sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial flutter	atrial fibrillation	upper junctional rhythm	mid junctional rhythm	lower junctional rhythm	pacemaker	heart rate	additional comments

P

QRS

T

ECG 5

sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial flutter	atrial fibrillation	upper junctional rhythm	mid junctional rhythm	lower junctional rhythm	pacemaker	heart rate	additional comments

P

QRS

T

ECG 6

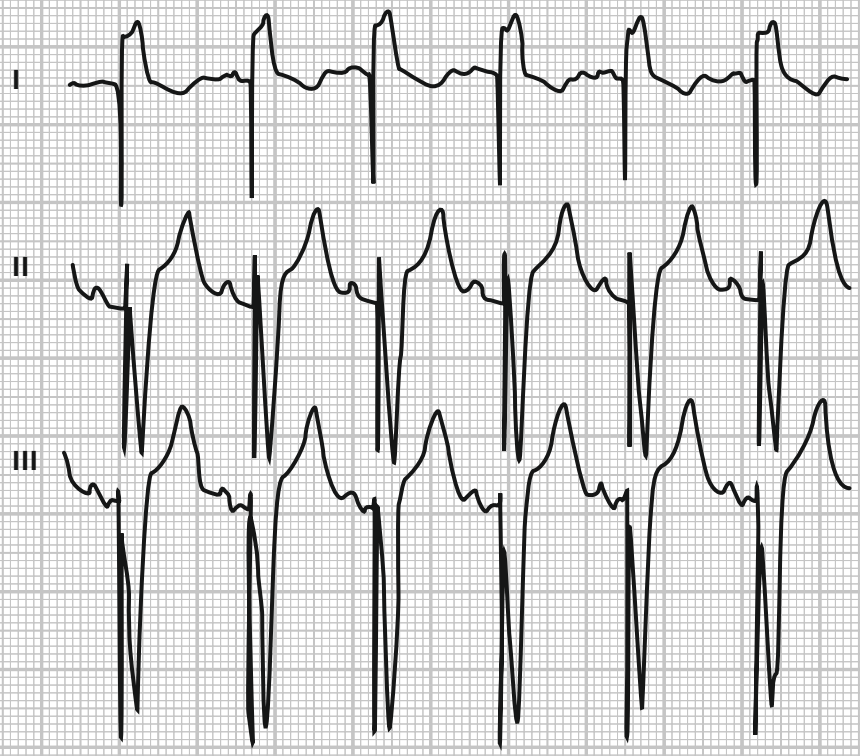
sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial flutter	atrial fibrillation	upper junctional rhythm	mid junctional rhythm	lower junctional rhythm	pacemaker	heart rate	additional comments

P

QRS

T

ECG 7



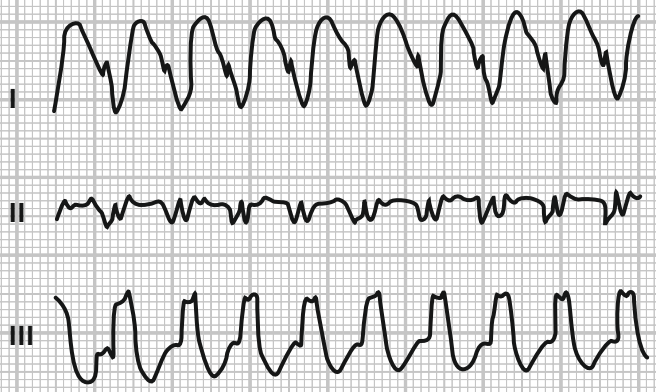
sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial flutter	atrial fibrillation	upper junctional rhythm	mid junctional rhythm	lower junctional rhythm	pacemaker	heart rate	additional comments

P

QRS

T

ECG 8



sinus rhythm	ventricular fibrillation	ventricular tachycardia	ventricular flutter	atrial flutter	atrial fibrillation	upper junctional rhythm	mid junctional rhythm	lower junctional rhythm	pacemaker	heart rate	additional comments

Level 5: Too many P waves

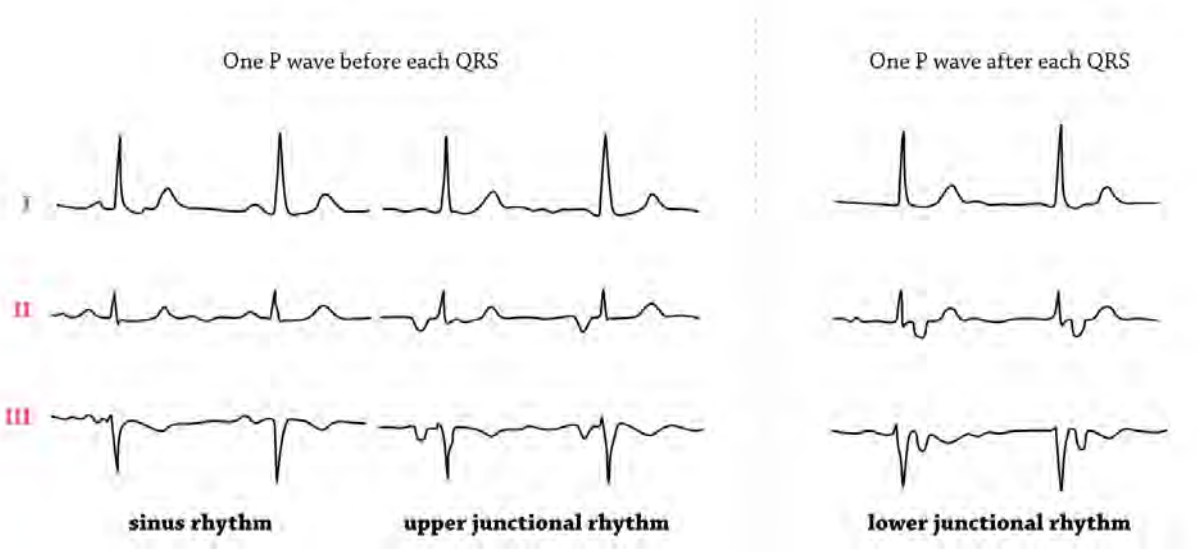
If you still haven't reached a diagnosis, it's time to move on to step 6 of the Rhythm Cheat Sheet and **count the number of P waves and QRS complexes**.

initial question			answer		additional question	rhythm diagnosis
	6	Are there too many P waves?	N	Y	PR constant?	2nd deg. AVB Mobitz type II
					PR varying QRS regular	3rd deg. AV block
					PR varying QRS irregular	2nd deg. AVB Mobitz type I

Step 6 of the cheat sheet: too many P waves

Before we give you some practical tips on how to count the P waves, let's review what we have learned before.

In the previous chapters, there used to be a constant relationship between P waves and QRS complexes. Most of the time there was one P wave for each QRS complex, even if the rhythm was not sinus rhythm. Let's check out three examples:



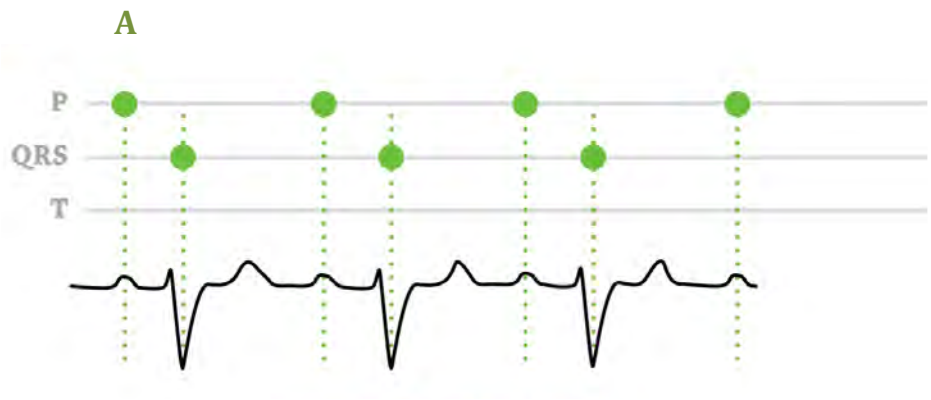
In the two cases to the left of the dotted line, there's one P wave preceding each QRS complex. In the example on the right, there is one P wave following each QRS complex. Most of these P waves look abnormal but their numbers match those of the QRS complexes.

In this and the upcoming chapter, we are going to focus on situations where these numbers don't match.

When the number of P waves exceeds the number of QRS complexes, this means that conduction from the atria to the ventricles is not working properly. This is a situation that we call "high degree AV block." Let's start with two practical tips on counting the P waves.

Tip #1: Make sure that the rhythm strip is long enough

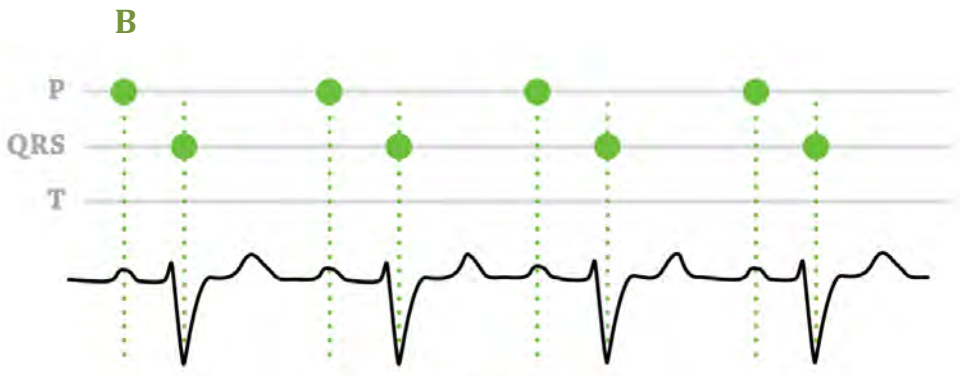
Take a look at ECG A below. There are four P waves but only three QRS complexes. Does this mean that the number of P waves exceeds the number of QRS complexes?



ECG strip that's too short

No it doesn't. The simple answer is that the QRS complex following P wave #4 was cut off. So the rhythm strip is too short in order to count the P waves and QRS complexes properly.

Here's the ECG with all the QRS complexes:

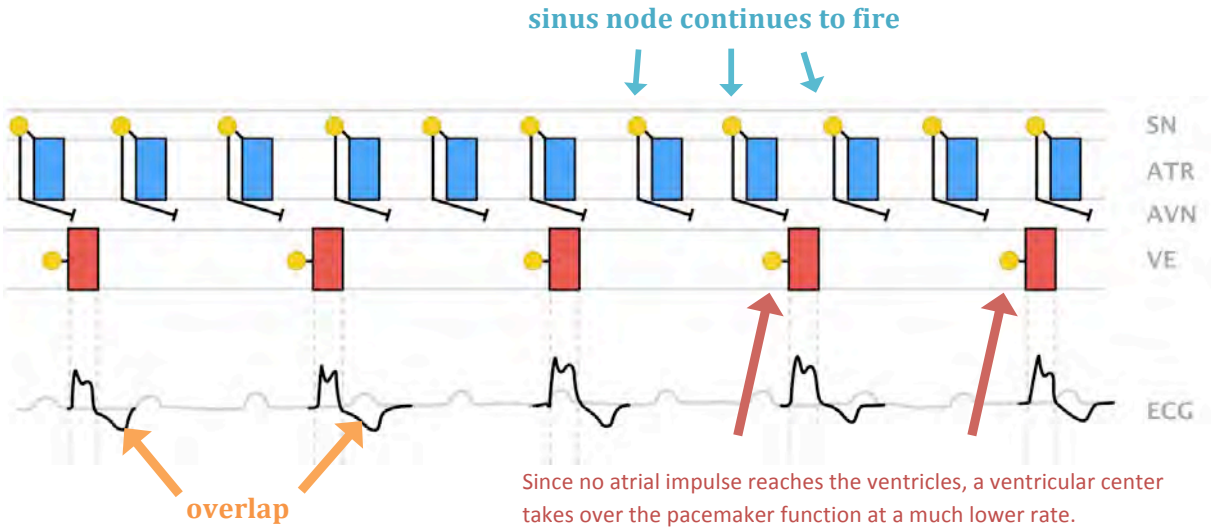


correct ECG strip

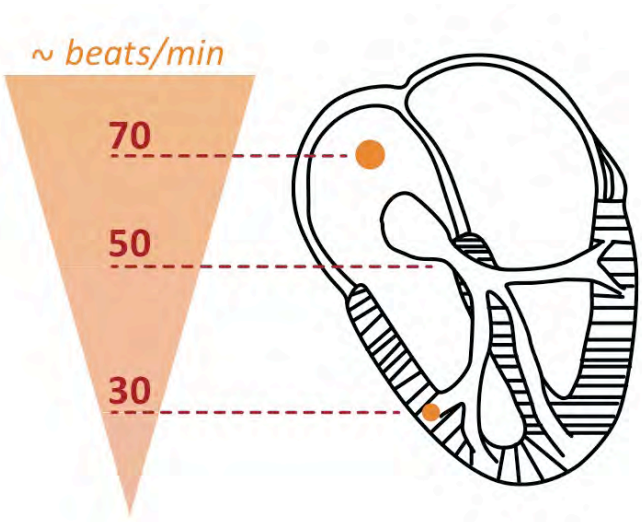
Tip #2: Use the "paper and pen method" to identify P waves

When AV conduction is completely blocked (third degree AV block), no atrial impulse can travel down into the ventricles. In this case, three things will happen:

1. The atrial pacemaker (usually the sinus node) continues to fire at a regular rate.
2. A ventricular pacemaker center takes over in order to keep the circulation going. Like every myocardial pacemaker, this one will fire at regular intervals, but we must keep in mind that the stimulation rate gradually decreases as we descend from the sinus node (approximately 70 beats per minute) to the AV node (approximately 50 bpm) and into the ventricles (approximately 25 to 40 bpm).
3. The atrial and ventricular pacemaker centers are completely independent of one another; therefore, P waves and QRS complexes can occur at the same time.



Both atrial and ventricular pacemakers discharge at their own individual and regular intervals. But since they are completely independent of one another, P waves, QRS complexes, and T waves sometimes overlap, which makes counting the P waves much harder than normal.



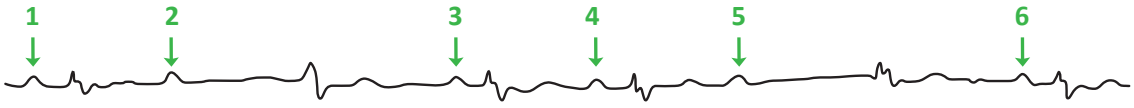
Here's a trick for finding all the P waves, even the hidden ones. Just remember:

- P waves can sometimes be hidden within the QRS complexes.
- P waves occur at constant intervals (i.e., their rate is regular).
- Using one P wave and the P-to-P interval, you'll be able to find all other P waves on the ECG strip—even the hidden ones.

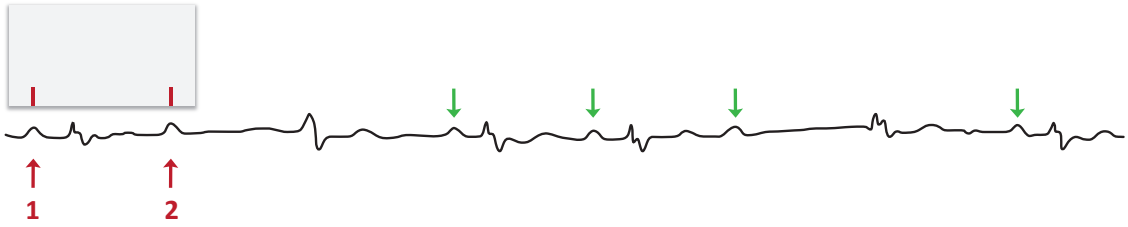
All you have to do is to take a piece of **paper and a pen** and mark the shortest P-to-P interval on the ECG strip. Then use this interval to find all the other P waves. Also mark those areas on the ECG where no clear P waves can be seen. Remember, they might just be hidden.

Here's an example:

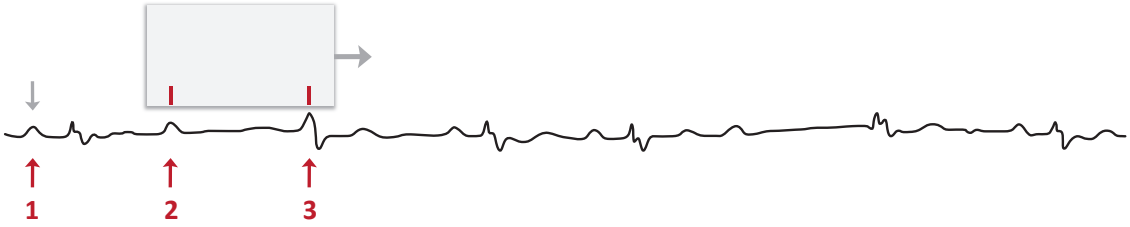
At first you'll count six P waves:



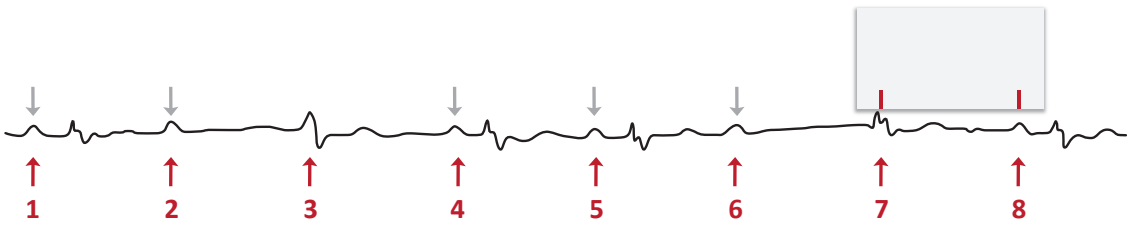
Take a piece of paper, and mark the shortest P-to-P interval:



Moving the paper further along the ECG will help you find all the other P waves:



You see, you have managed to identify all eight P waves!



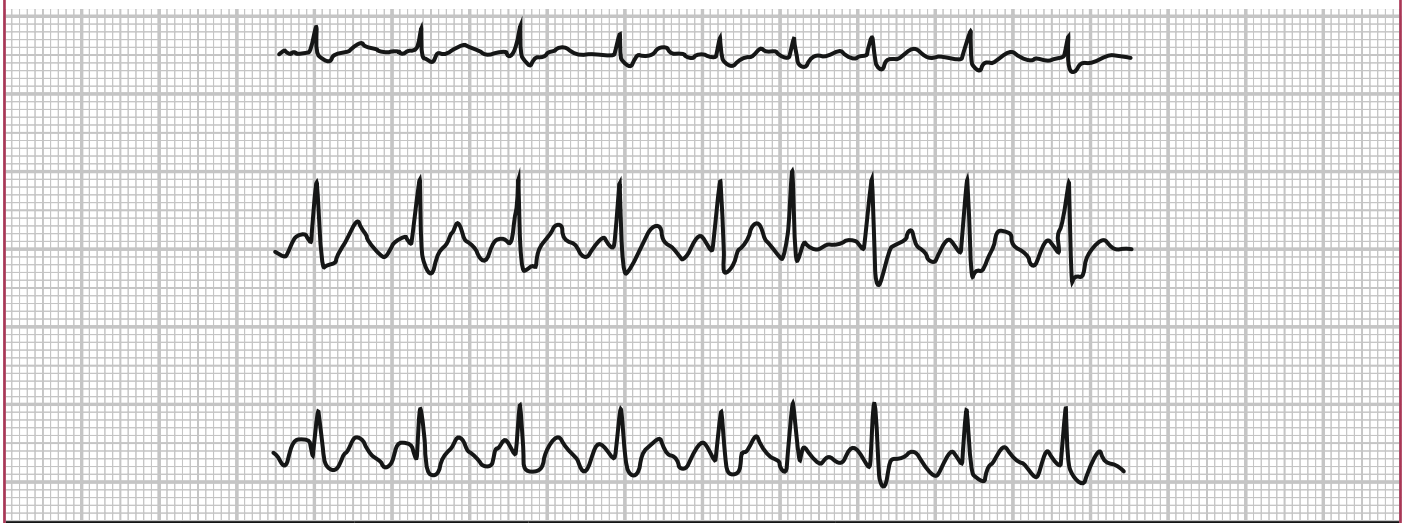
Level 5

QUIZ SECTION

Please count the number of P waves and QRS complexes on the following ECG tracings. Is there a mismatch? Can you identify the patients with high degree AV block? Also, what's the rhythm?

P
QRS
T

ECG 1



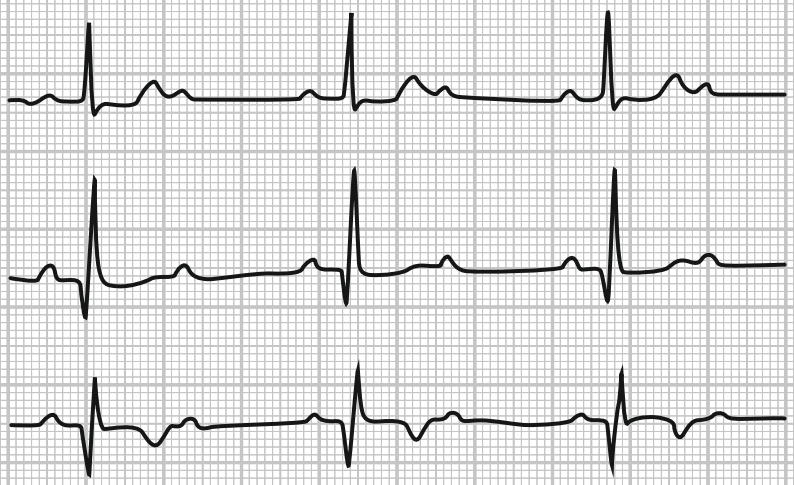
Number of p waves:	Number of QRS complexes:	Are you able to make a rhythm diagnosis with your current knowledge? **yes no**	If yes, which rhythm is present?	High degree AV block? **yes no**

P

QRS

T

ECG 2



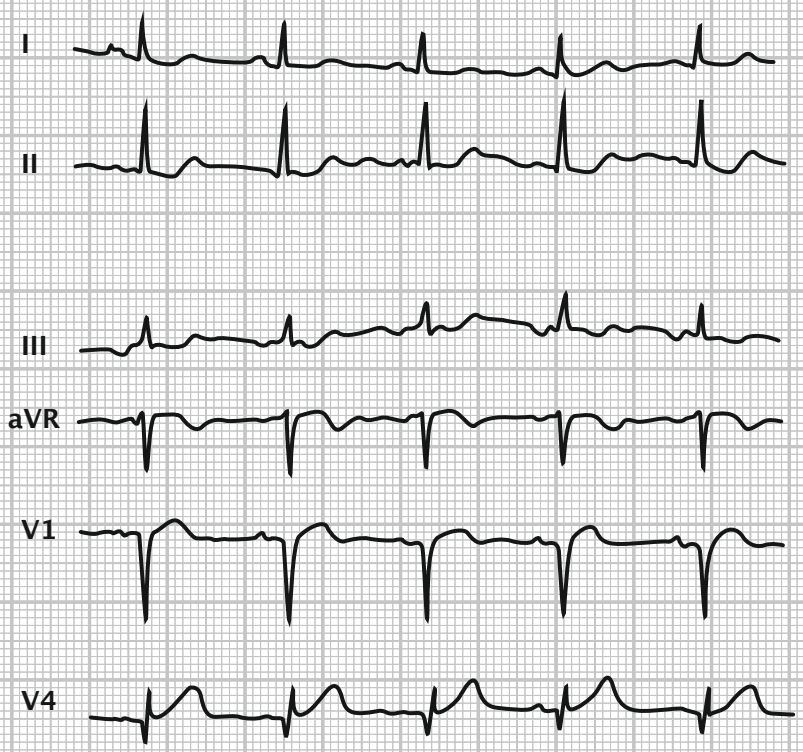
Number of p waves:	Number of QRS complexes:	Are you able to make a rhythm diagnosis with your current knowledge? **yes** **no**	If yes, which rhythm is present?	High degree AV block? **yes** **no**

P

QRS

T

ECG 3



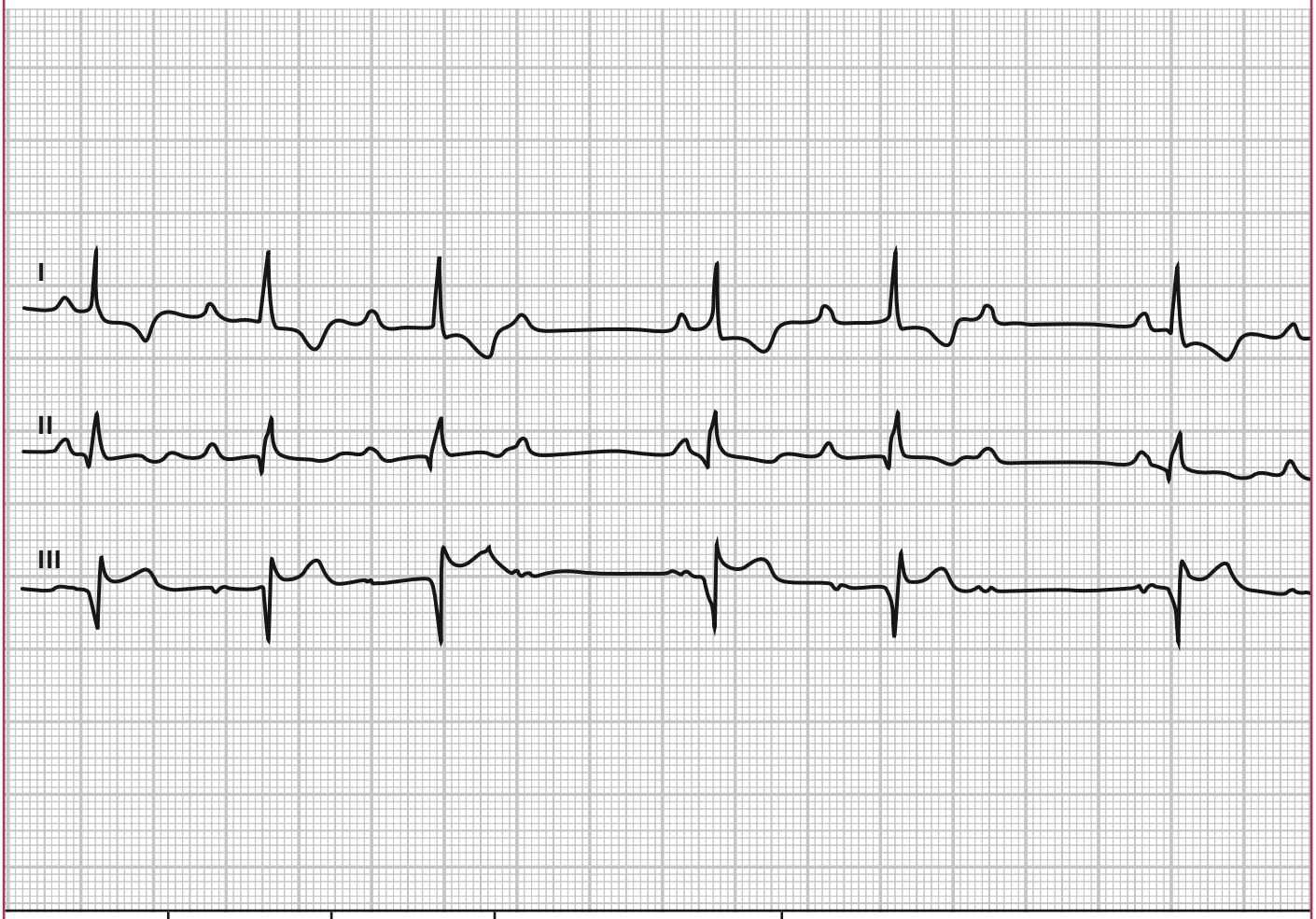
Number of p waves:	Number of QRS complexes:	Are you able to make a rhythm diagnosis with your current knowledge? **yes** **no**	If yes, which rhythm is present?	High degree AV block? **yes** **no**

ECG 4

P

QRS

T



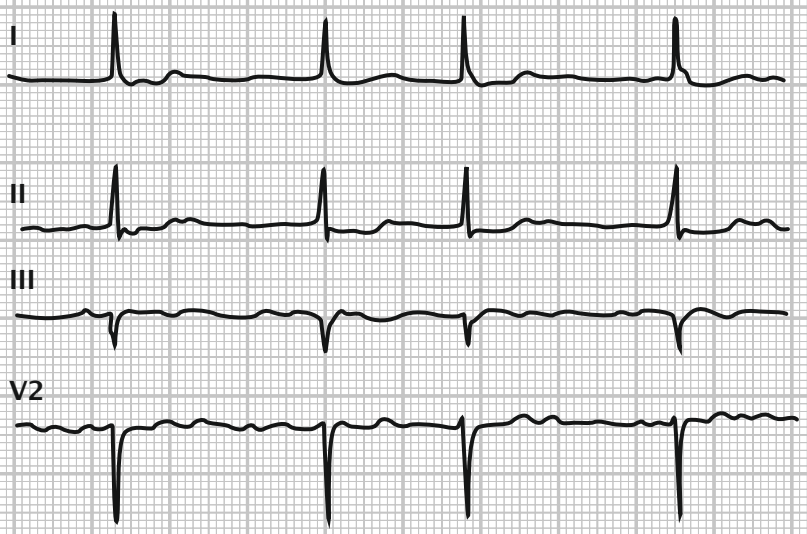
Number of p waves:	Number of QRS complexes:	Are you able to make a rhythm diagnosis with your current knowledge? **yes no**	If yes, which rhythm is present?	High degree AV block? **yes no**

P

QRS

T

ECG 5



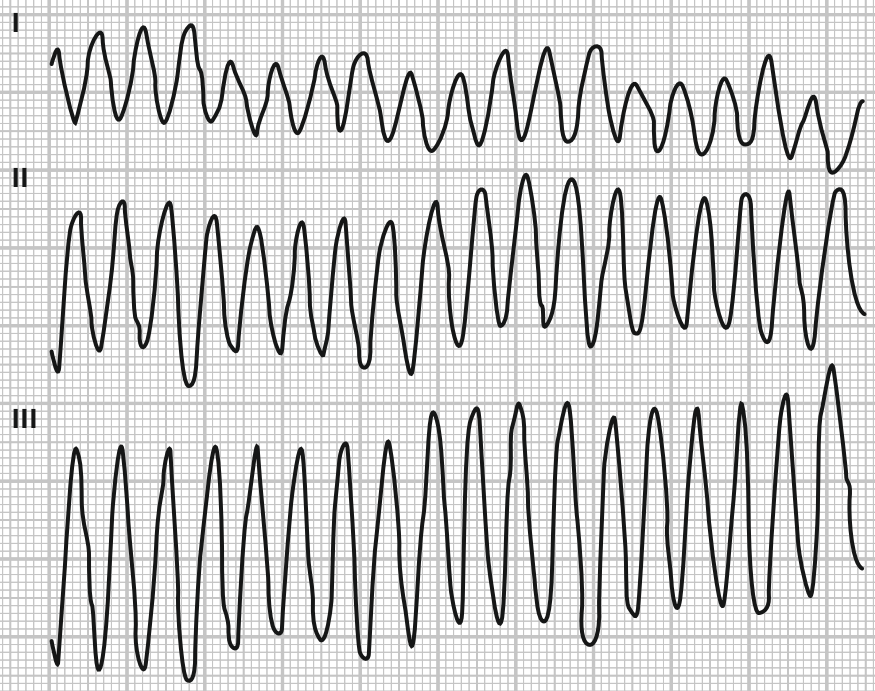
Number of p waves:	Number of QRS complexes:	Are you able to make a rhythm diagnosis with your current knowledge? **yes** **no**	If yes, which rhythm is present?	High degree AV block? **yes** **no**

P

QRS

T

ECG 6



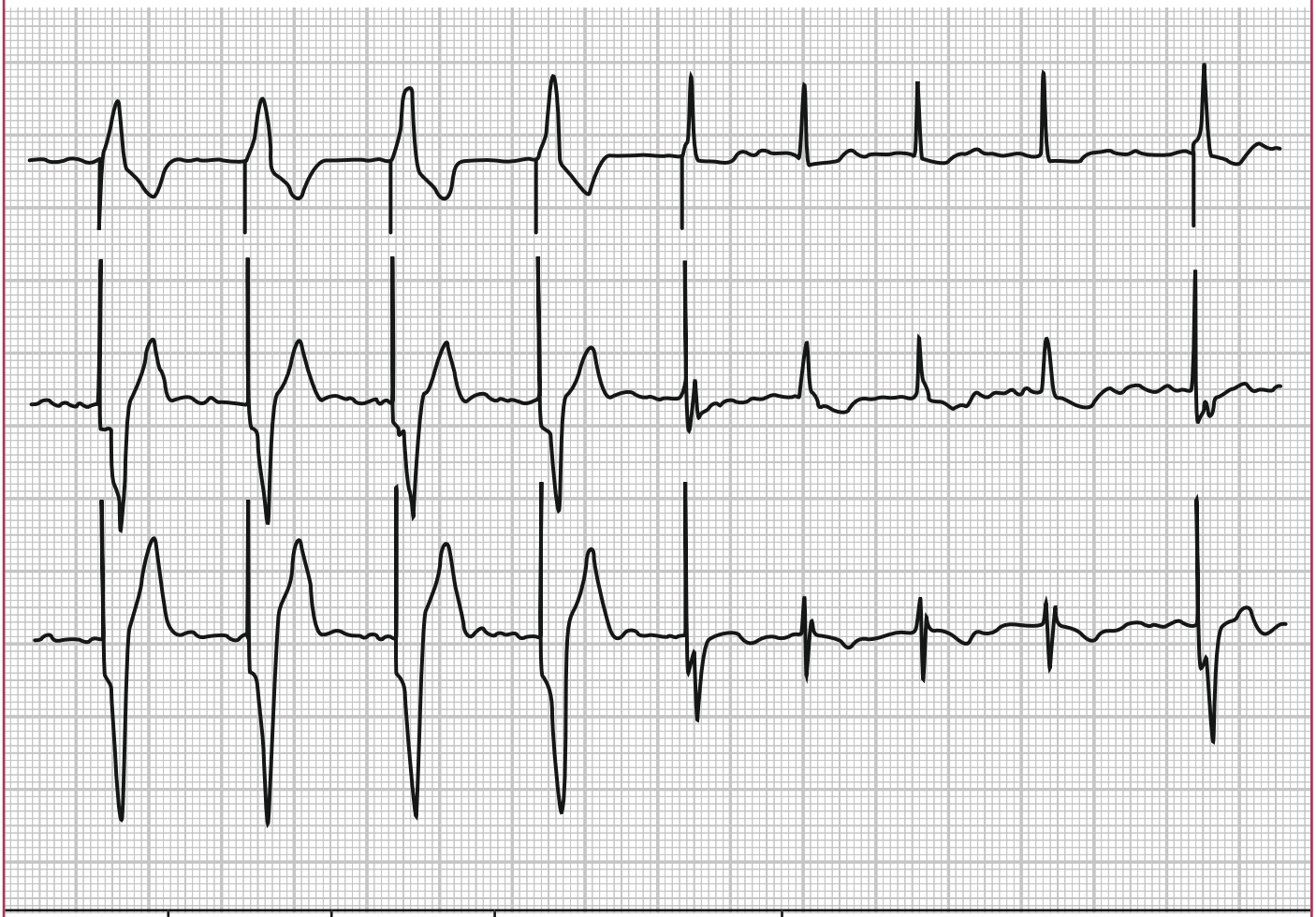
Number of p waves:	Number of QRS complexes:	Are you able to make a rhythm dia-gnosis with your current knowledge? **yes** **no**	If yes, which rhythm is present?	High degree AV block? **yes** **no**

P

QRS

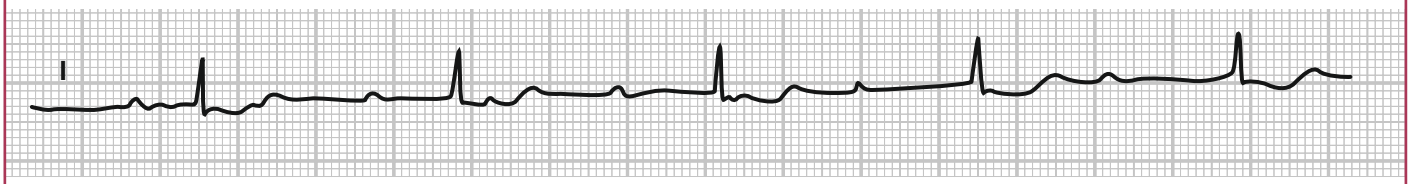
T

ECG 7

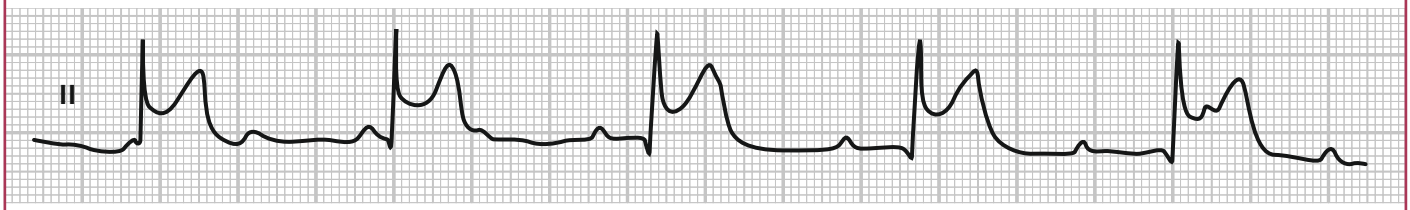


Number of p waves:	Number of QRS complexes:	Are you able to make a rhythm dia-gnosis with your current knowledge? **yes** **no**	If yes, which rhythm is present?	High degree AV block? **yes** **no**

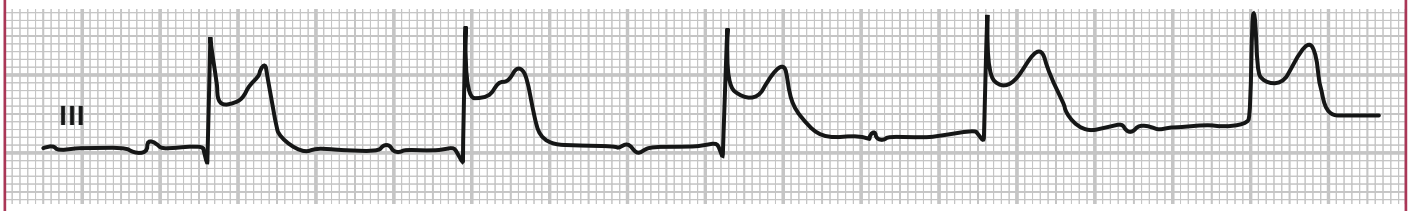
P
QRS
T



P
QRS
T



P
QRS
T



Number of p waves:	Number of QRS complexes:

Number of p waves:	Number of QRS complexes:

Number of p waves:	Number of QRS complexes:	Are you able to make a rhythm diagnosis with your current knowledge? **yes** **no**	If yes, which rhythm is present?	High degree AV block? **yes** **no**

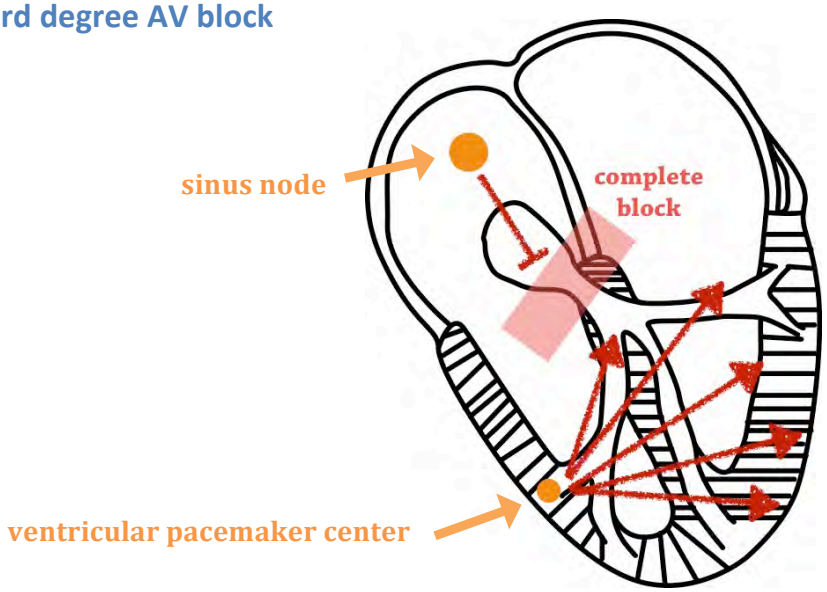
Level 6: High degree AV block—the mother of "too many P waves"

We already know that if there are more P waves than QRS complexes, high degree AV block is probably present. There are three forms of high degree AV block:

1. Second degree AV block Mobitz type I (or Wenckebach block)
2. Second degree AV block Mobitz type II
3. Third degree AV block

Let's start with the most extreme form of AV block…

Third degree AV block

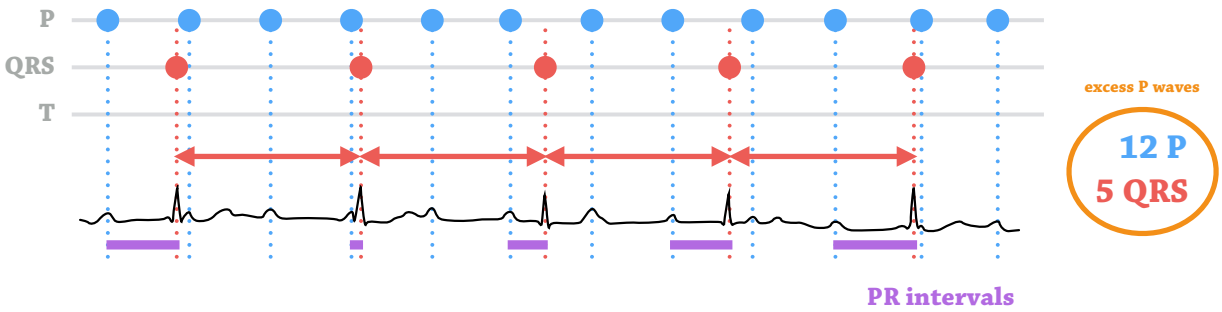


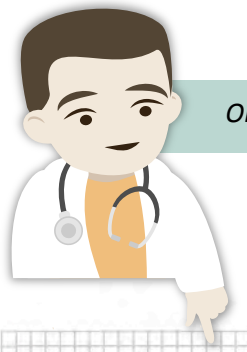
In third degree AV block, conduction through the AV node is completely blocked, and a ventricular center takes over the pacemaker function. Most of the time, the atria are beating in sinus rhythm. However, other rhythms can also be present in the atria, such as:

- Atrial fibrillation
- Atrial flutter
- Junctional rhythm
- Atrial tachycardia

There are **three key characteristics** in third degree AV block (in the most common situation that the atria are beating in sinus rhythm):

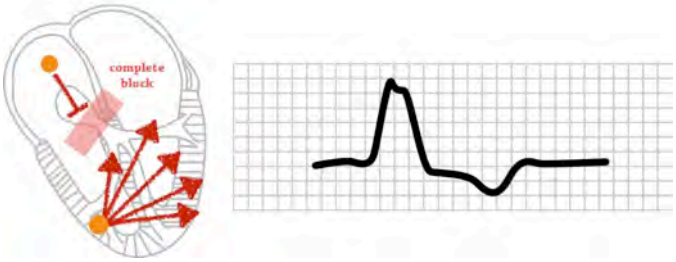
- **Excess of regular P waves:** The atrial pacemaker continues to fire regularly.
- **Variable PR intervals:** P waves and QRS complexes are completely independent of one another.
- **Regular QRS complexes:** The ventricular pacemaker fires at a regular but much slower rate.





One more thing about QRS morphology in 3rd degree AV block:

If the ventricular pacemaker is located close to the bundle of HIS, the impulses will be able to use the speedy pathways of the conduction system, and the resulting **QRS complexes will be narrow** (as is the case in the example above).



If the ventricular pacemaker is located further away from the conduction system, the impulse will have to take the non-speedy pathways and the resulting **QRS complexes will be broad.**

Now let's turn to situations when AV conduction is not completely blocked, which means that some atrial impulses will be able to travel down to the ventricles while others will be blocked. These types of blocks are called **second degree AV blocks**.

no AV block

second degree AV block

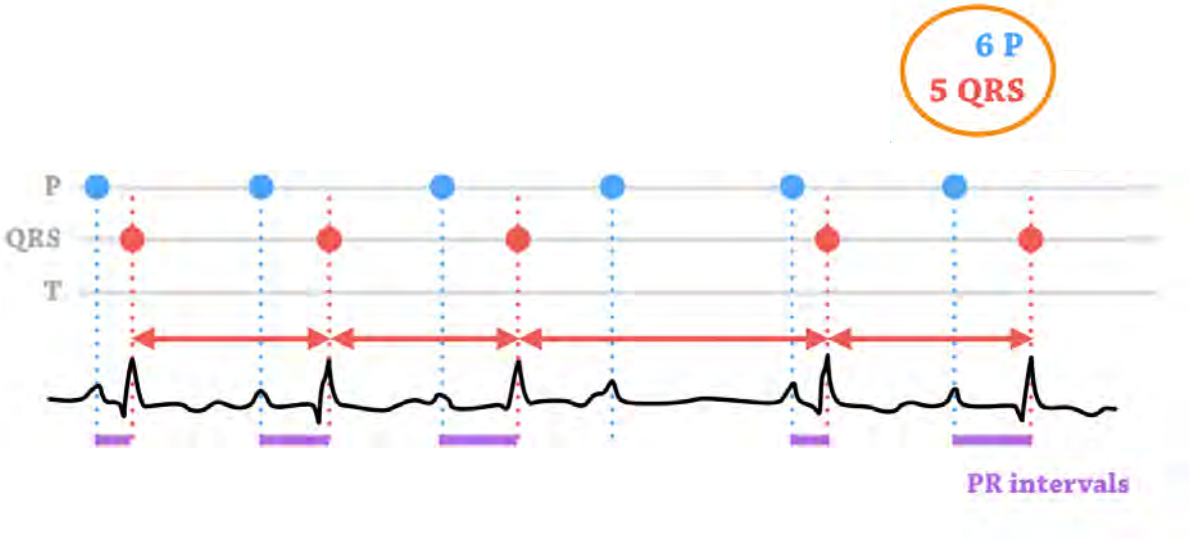
third degree AV block (complete AV block)

Second degree AV block Mobitz Type I (or Wenckebach block)

You could think of second degree AV block Mobitz type I as a progressive exhaustion of AV conduction; the PR interval progressively lengthens until one impulse is completely blocked (you can actually watch the decay of AV conduction).

The **key characteristics** of this type of AV block are:

- **Excess of regular P waves:** The atrial pacemaker continues to fire regularly.
- **Variable PR intervals:** The PR interval progressively lengthens.
- **Irregular QRS complexes:** Conduction of atrial impulses down to the ventricles is irregular, and the missing beat produces a longer pause; thus, QRS complexes are irregular.

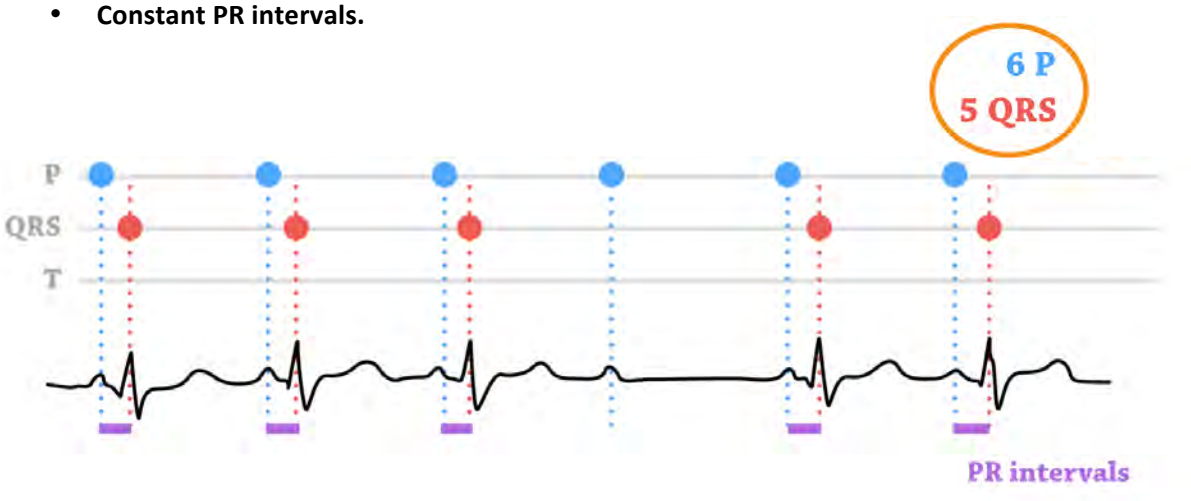


Second degree AV block Mobitz type II

Second degree AV block Mobitz type II is very similar to Mobitz type I with the exception that PR intervals remain constant. After a sequence of conducted beats, a QRS complex is dropped. QRS complexes appear at regular intervals except for the places where they are dropped.

Here are the **key characteristics** of second degree AV block Mobitz Type II:

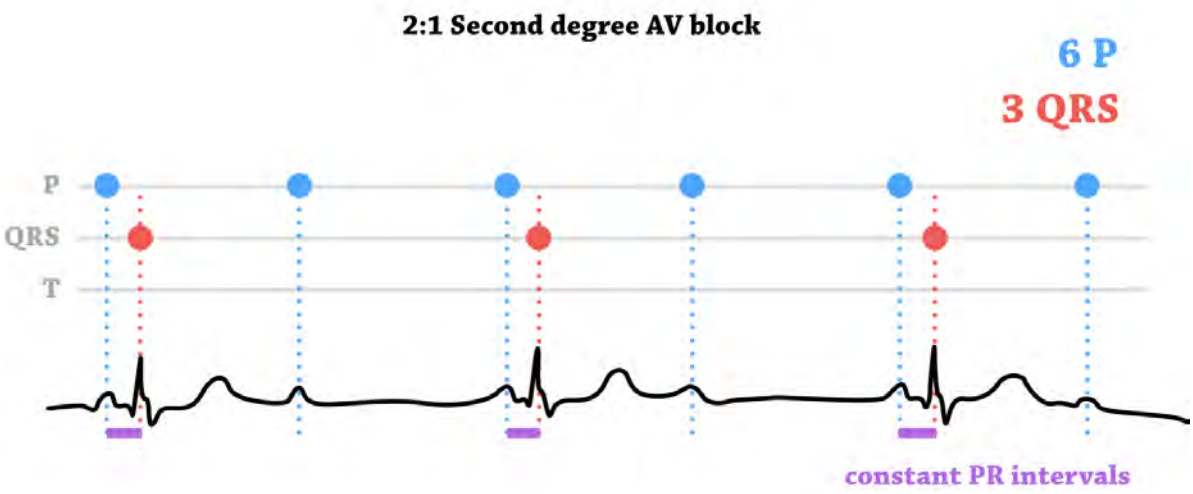
- **Excess of regular P waves**: The atrial pacemaker continues to fire regularly.
- **Constant PR intervals.**



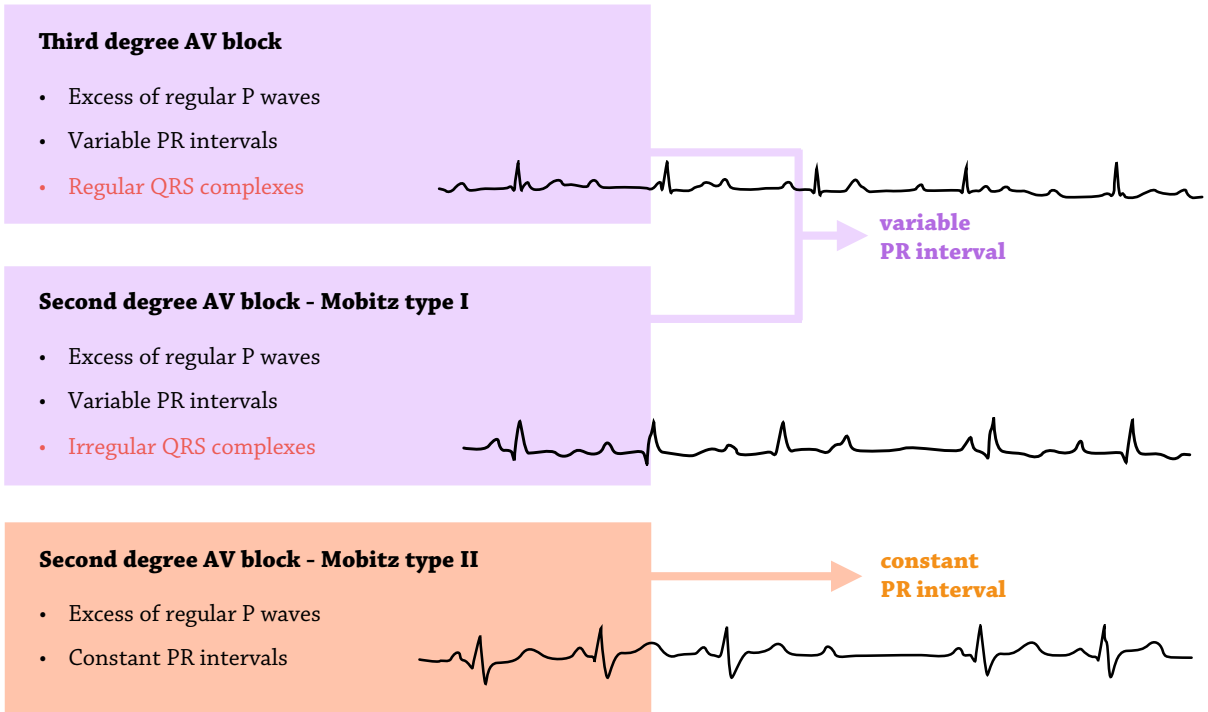
And finally, there is a special form of second degree AV block, which is really a hybrid between Mobitz I and Mobitz II.

2:1 AV block

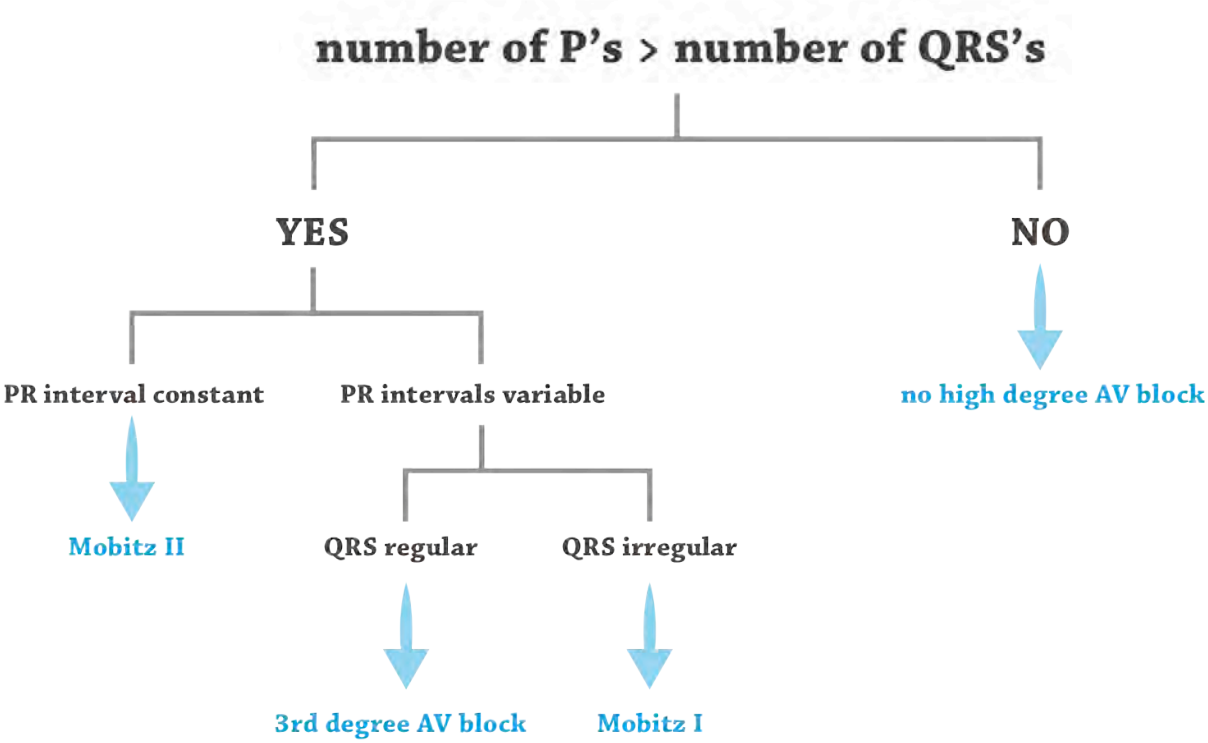
In 2:1 AV block every other P wave is blocked. There are twice as many P waves as QRS complexes. We cannot really tell if PR intervals become longer or not (i.e., if it's Mobitz I or Mobitz II) because there's only one PR interval before each dropped QRS! That's why this type of second degree AV block is referred to as 2:1 AV block.



Summarizing what we've learned about high degree AV blocks



Here's an algorithm that will help you discriminate between the different high degree AV blocks like a pro!



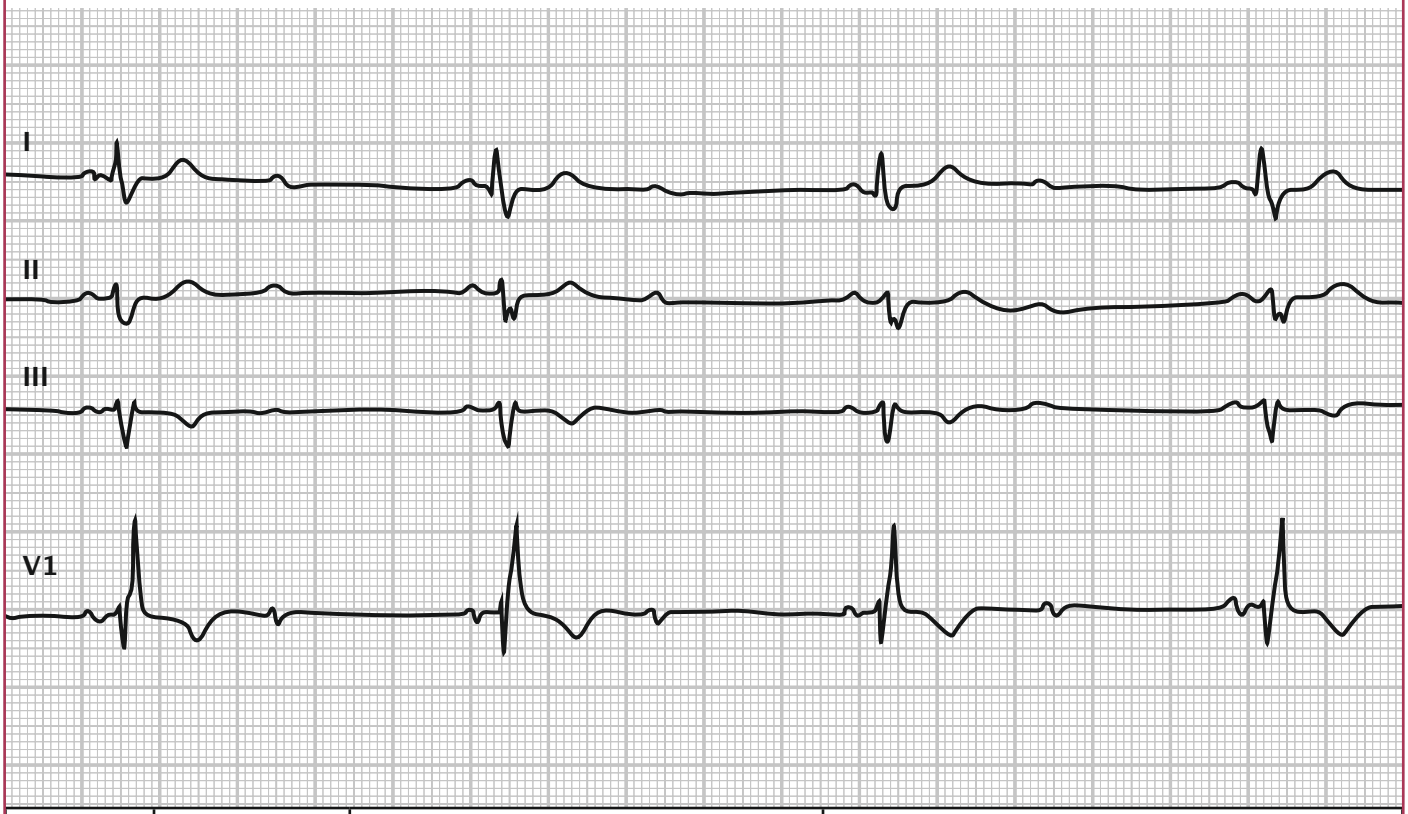
Level 6

QUIZ SECTION

Please answer the following questions and try to identify the cases with high degree AV block. Use our cookbook approach in order to identify any other problems.

P
QRS
T

ECG 1



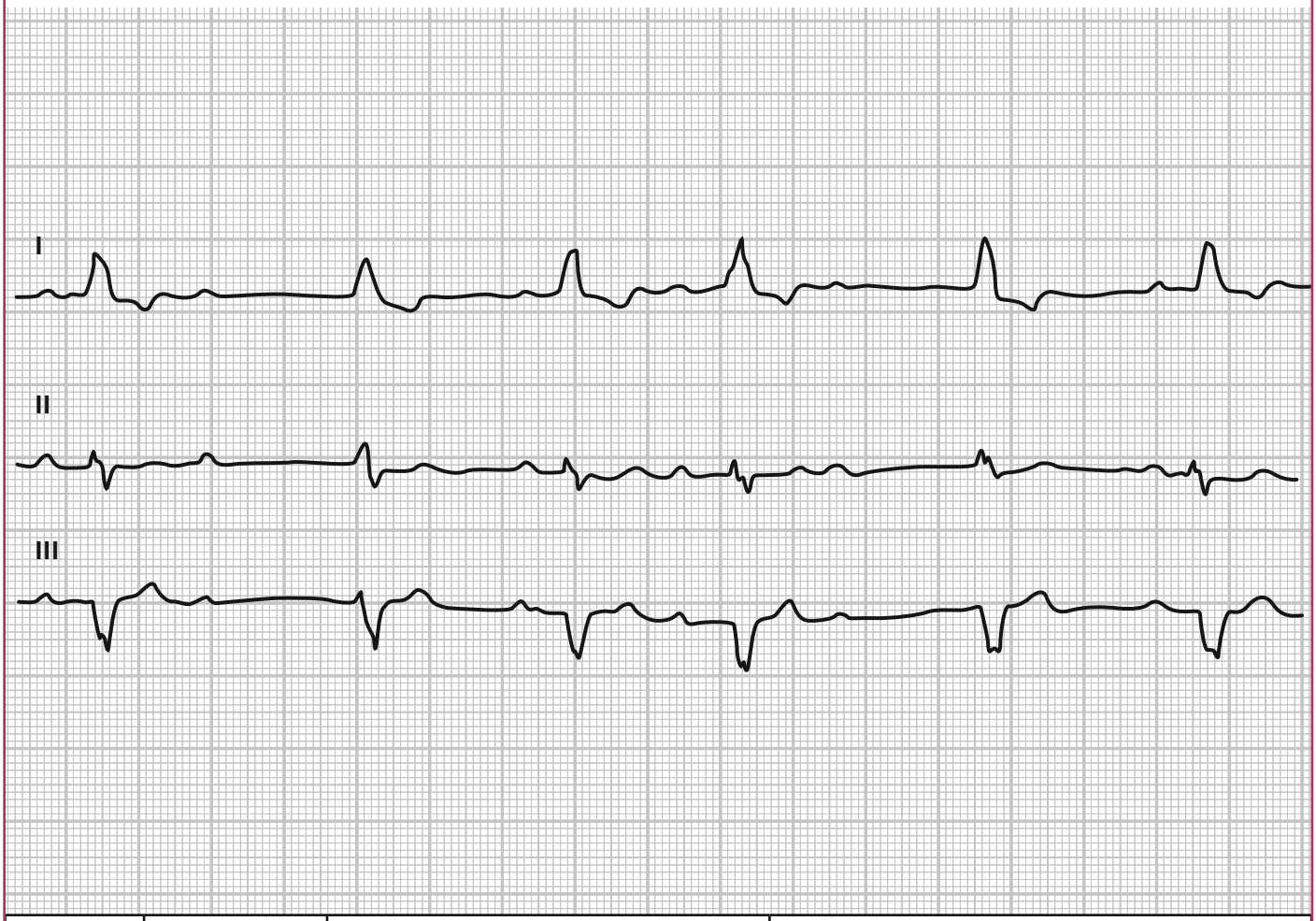
Number of P waves	Number of QRS complexes	Which rhythm diagnosis would you make?	What else can be found in this ECG according to our cookbook?
		What is the (average) heart rate?	

P

QRS

T

ECG 2



Number of P waves	Number of QRS complexes	Which rhythm diagnosis would you make?	What else can be found in this ECG according to our cookbook?
		What is the (average) heart rate?	

P

QRS

T

ECG 3

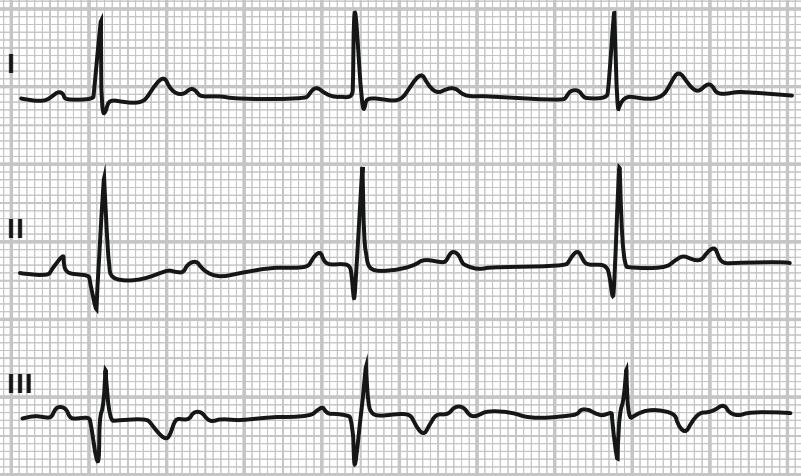
Number of P waves	Number of QRS complexes	Which rhythm diagnosis would you make?	What else can be found in this ECG according to our cookbook?
		What is the (average) heart rate?	

P

QRS

T

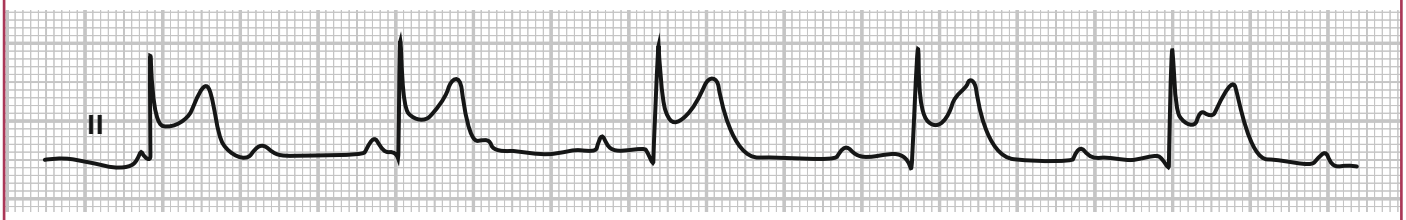
ECG 4



Number of P waves	Number of QRS complexes	Which rhythm diagnosis would you make?	What else can be found in this ECG according to our cookbook?
		What is the (average) heart rate?	

P
QRS
T

P
QRS
T



P
QRS
T

Number of P waves	Number of QRS complexes	Which rhythm diagnosis would you make?	What else can be found in this ECG according to our cookbook?
		What is the (average) heart rate?	

P

QRS

T

ECG 6

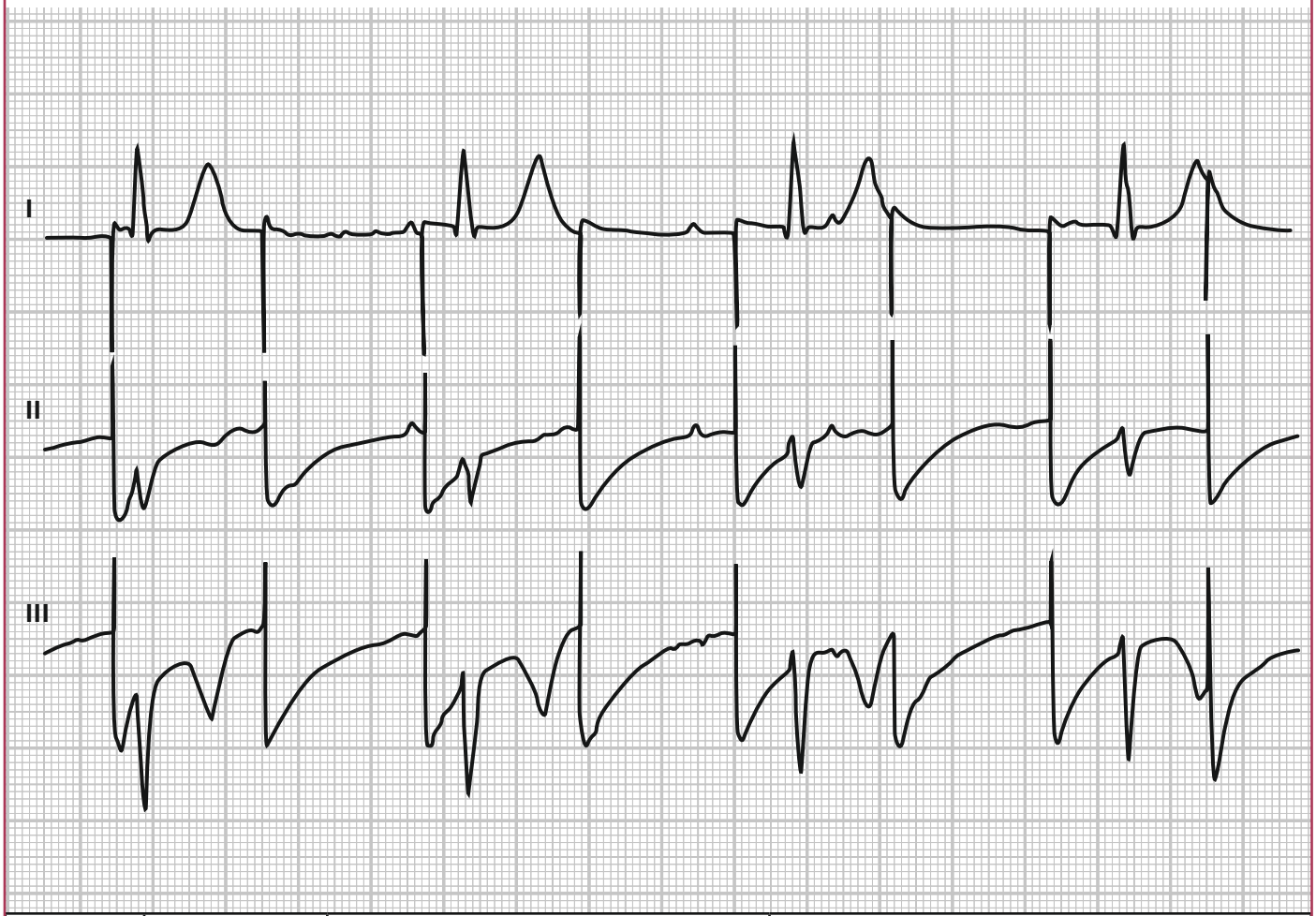
Number of P waves	Number of QRS complexes	Which rhythm diagnosis would you make?	What else can be found in this ECG according to our cookbook?
		What is the (average) heart rate?	

P

QRS

T

ECG 7



Number of P waves	Number of QRS complexes	Which rhythm diagnosis would you make?	What else can be found in this ECG according to our cookbook?
		What is the (average) heart rate?	

P

QRS

T

ECG 8

Number of P waves	Number of QRS complexes	Which rhythm diagnosis would you make?	What else can be found in this ECG according to our cookbook?
		What is the (average) heart rate?	

Level 7: The basic rhythm and its interruptions

When a certain rhythm is present for an extended period of time, we state in our ECG report that "The basic rhythm is …". You can fill in the blank of the preceding statement with one of the rhythms that we've already encountered:

Normal sinus rhythm

Atrial fibrillation

Atrial flutter

Broad complex tachycardia

Narrow complex tachycardia

Junctional rhythm

Second degree AV block

Third degree AV block

Artificial pacemaker

This chapter is a primer for steps 7 to 9 of the Rhythm Cheat Sheet. These steps are dealing with interruptions of the basic rhythm:

		initial question	answer		additional question	rhythm diagnosis
BASIC RHYTHM INTERRUPTED	7	Do you see a rhythm switch?	N	Y		Which ones?
	8	Do you see premature beats?	N	Y	preceding premature P?	Supraventricular premature beat (SPB)
					no preceding premature P?	Ventricular premature beat (VPB)
	9	Do you see a remarkable pause?	N	Y	following ventricular premature beat?	Compensatory pause
					after termination of TC?	Preautomatic pause
					"empty" pause	SA (sinoauricuar) block
					containing premature P?	Supraventricular premature beat + AV block
					terminated by a QRS with a different shape than the rest of the QRS complexes	Escape beat

Steps 7 to 9 of the Rhythm Cheat Sheet

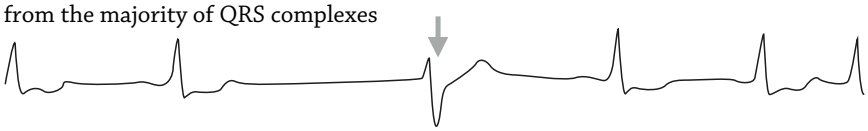
There are a few characteristic interruptions of the basic rhythm:

1. A change from one basic rhythm to another one = rhythm switch
e.g., From atrial fibrillation to sinus rhythm

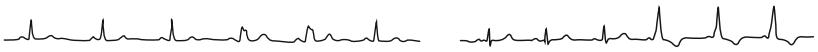
2. A QRS complex that comes too early
Extrasystoles, premature beats, or ectopic beats

3. Unexpected pauses

4. Escape beats
Unexpected beats terminating a pause - their shape is usually different from the majority of QRS complexes

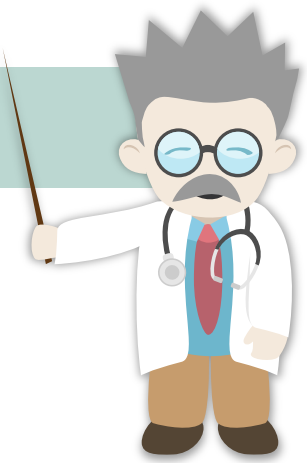


5. Intermittent bundle branch block or intermittent WPW syndrome



intermittent bundle branch block | intermittent WPW syndrome

In our algorithm to diagnose arrhythmias we must now go step by step and ask the following questions:



1. **Is there a basic rhythm, and if so, which one?** Steps 1 to 6 of your cheat sheet will help you identify the basic rhythm.
2. **Can we see a change of rhythms (rhythm switch)?** What rhythms can we see? Go through steps 1 to 6 of your cheat sheet until you have identified all the rhythms that can be seen on the ECG.
3. **Can we see unexpected beats interrupting our basic rhythm?** Are there premature beats or escape beats?
4. **Is the interval preceding the unexpected beat shorter (premature beat) or longer (escape beat) than the usual interval?**
5. **Can we see unexpected pauses?** In level 9 you'll learn more about pauses.
6. **Can we see a sudden change of QRS shape without a rhythm switch?** We might be dealing with intermittent bundle branch block or intermittent WPW syndrome.

Level 7

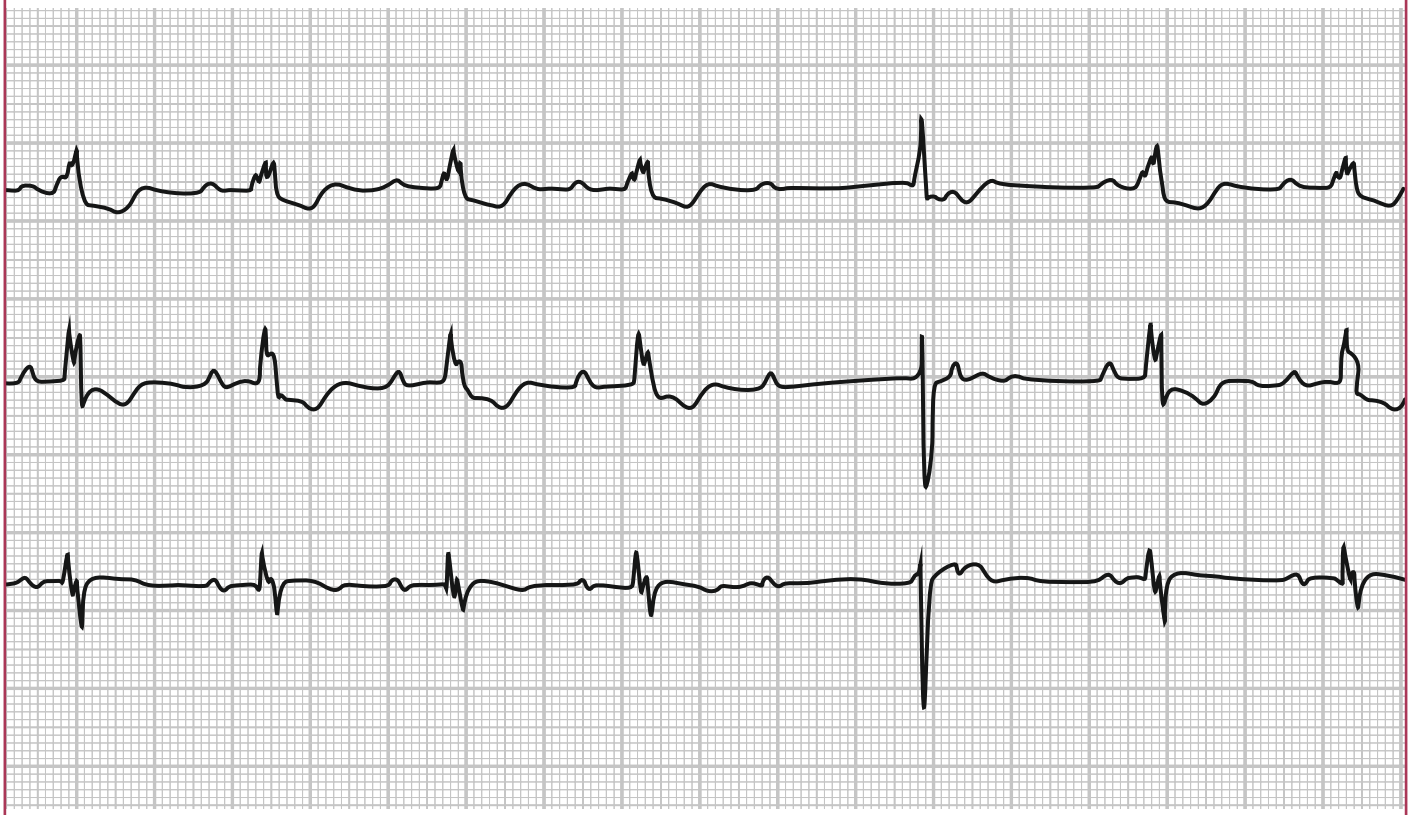
QUIZ SECTION

In the following exercises, you should ask yourself the three questions that we encountered in the introduction:

1. What's the basic rhythm? Is it normal?
2. Is the rhythm disturbed (by extra beats, pauses, etc.)
3. Is the rhythm replaced (is there a rhythm switch?)

P
QRS
T

ECG 1



1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

P

QRS

T

ECG 2

1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

P
QRS
T

ECG 3

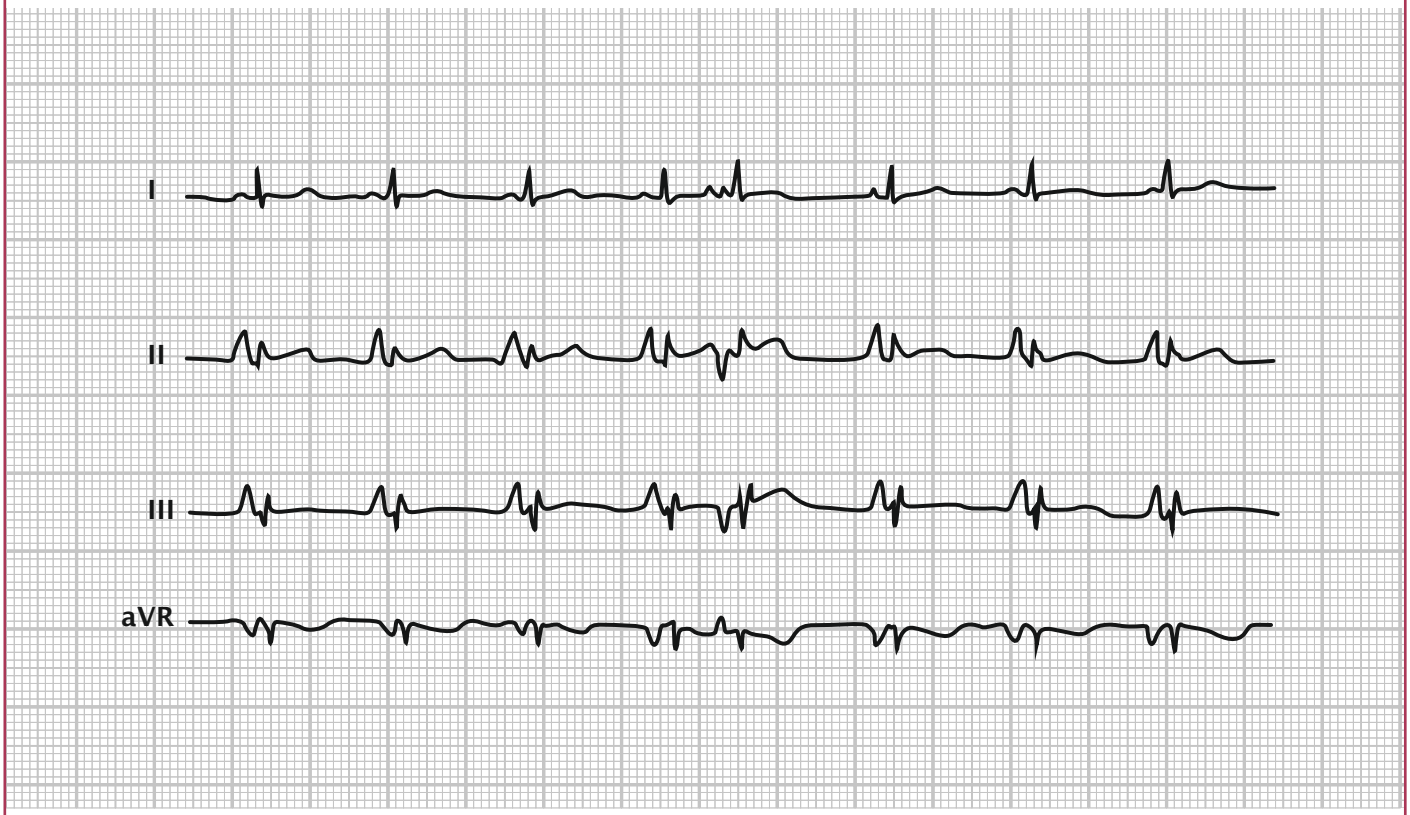
1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

P

QRS

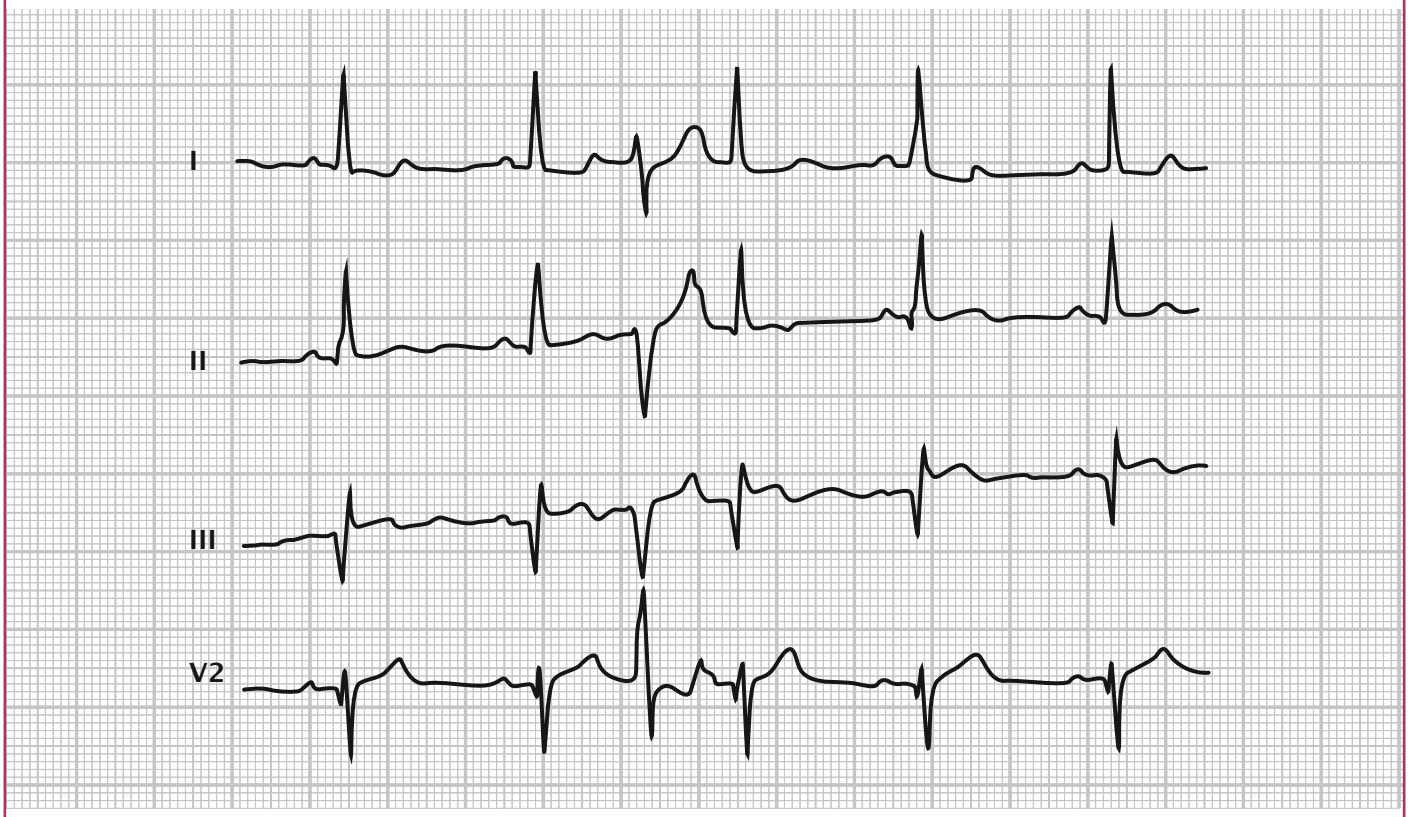
T

ECG 4



1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

P
QRS
T



1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

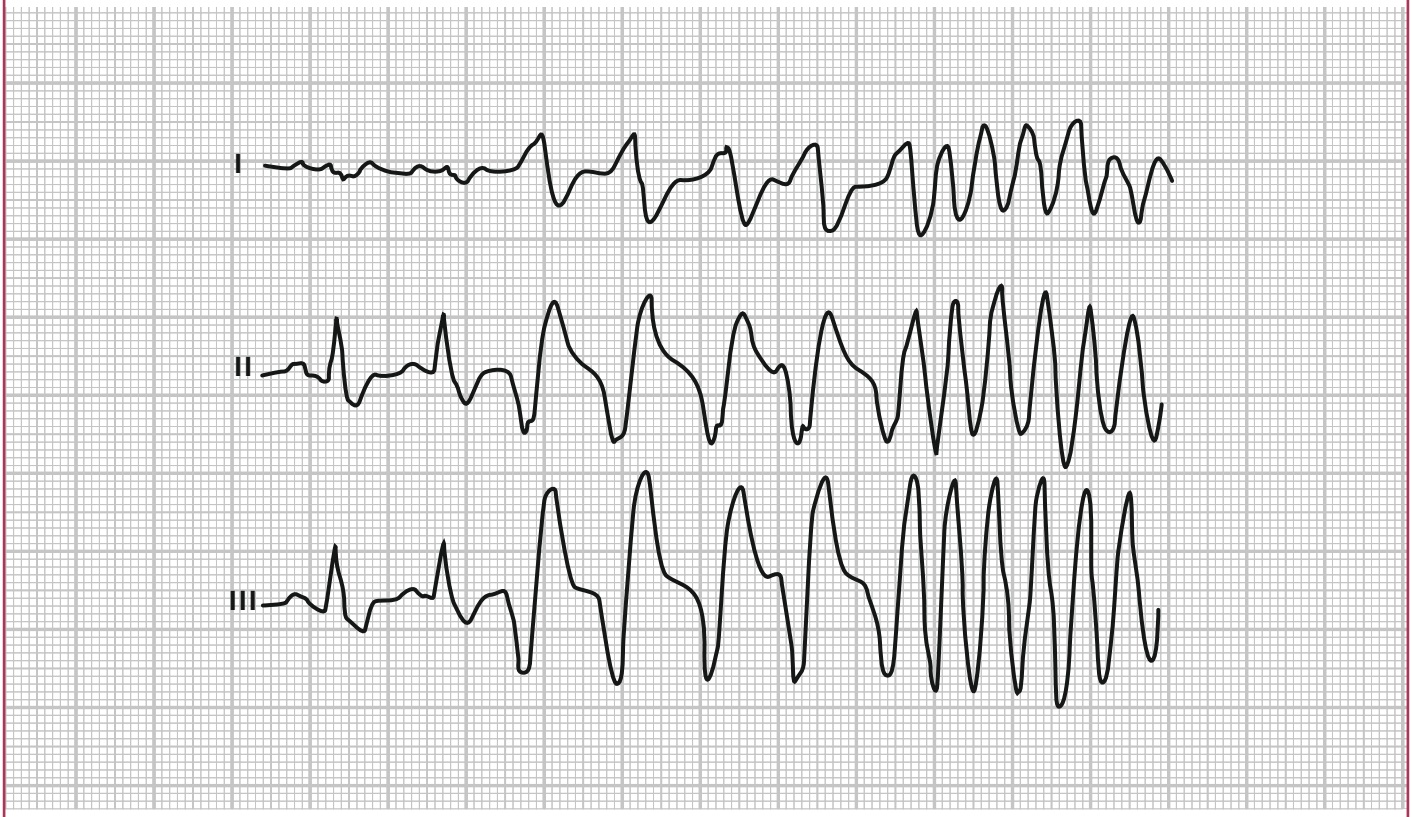
P
QRS
T

ECG 6

1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer** – **shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

P
QRS
T

ECG 7



1. Can you identify the basic rhythm? If yes, which one is present at the beginning of the tracing?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

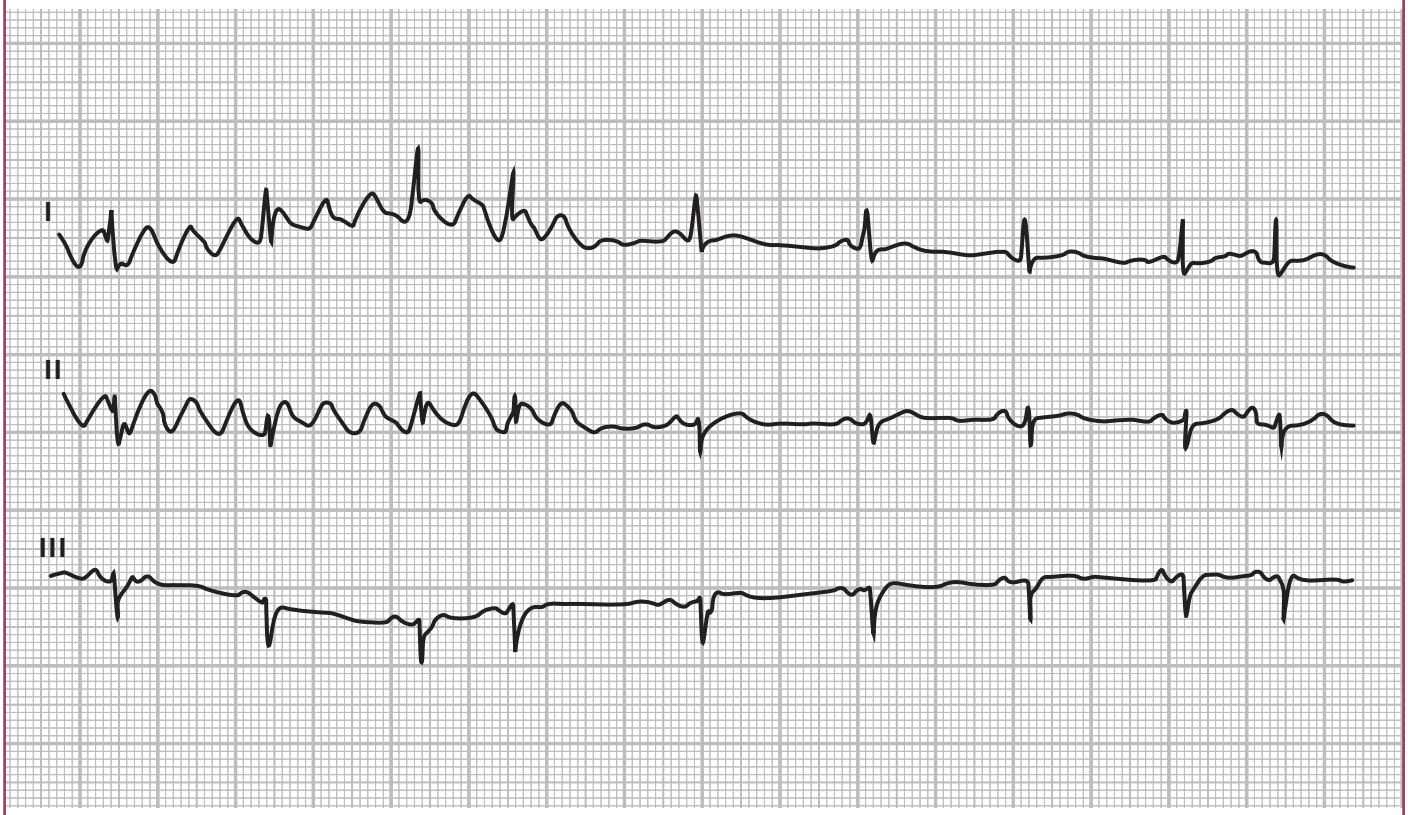
P
QRS
T

ECG 8

1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**
6. Is there a change in QRS morphology without a change in the rhythm?	**yes – no**

P
QRS
T

ECG 9



1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

P
QRS
T

ECG 10

1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer – shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

P
QRS
T

ECG 11

1. Can you identify the basic rhythm? If yes, which one?	**yes – no**
2. Is there a change in rhythm? If yes, which rhythms are present?	**yes – no**
3. Are there abnormal, "extra" beats?	**yes – no**
4. The interval before the extra beat is **longer** – **shorter** than the regular RR interval	
5. Are there any pauses that are uncommon or unusual in this type of rhythm problem?	**yes – no**

Level 8: Premature beats

Some of the unexpected beats that were introduced in the previous chapter can be categorized as **premature** or **ectopic beats**. The term “ectopic” describes their origin as coming from a region outside the sinus node. The term “premature” refers to the fact that they occur earlier than expected.

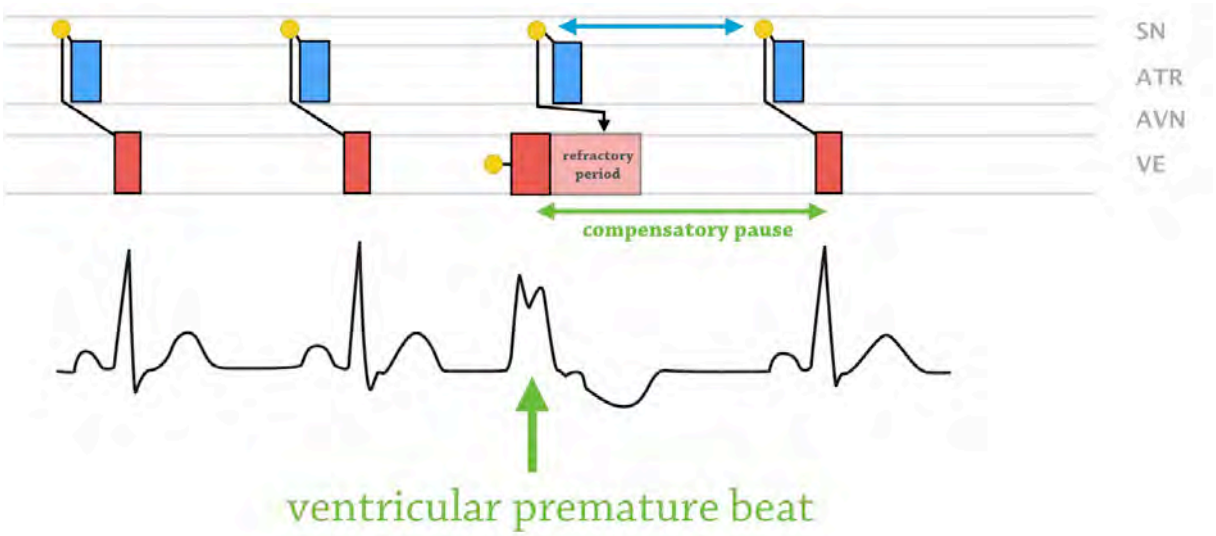
This ectopic pacemaker location can be anywhere in the heart. The resulting beat will have a very characteristic appearance depending on the location of its origin.

Ventricular premature beats

Here’s a **ventricular premature beat (VPB)** in action. Note two key characteristics:

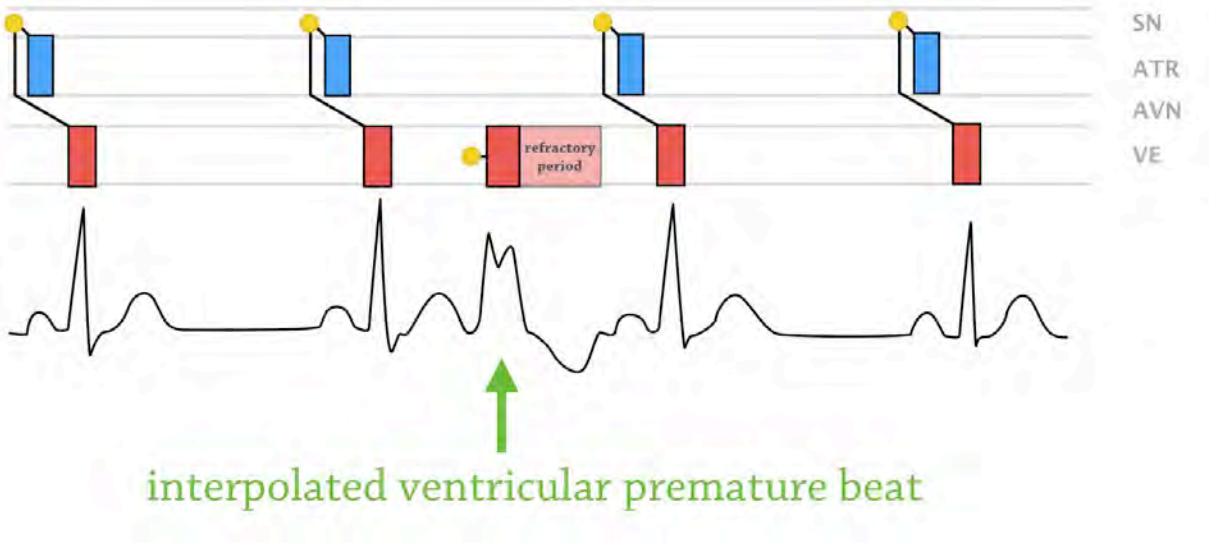
1. There’s no P wave preceding it.
2. The QRS is broad (≥ 0.12s in duration).

A premature broad QRS complex without a P wave preceding it is a clear sign of a VPB.



You should also note what’s happening in the atria: the sinus node continues to fire at its regular rate. However, the impulse number 3 reaches the ventricles at a point in time when they are still in their refractory period (of the VPB) and the respective P wave is hidden within the QRS or the ST segment. We have to wait until the next sinus interval is over (blue arrow) before the subsequent P wave is generated and conducted down into the ventricles. This is the reason why we see a **compensatory pause** following the VPB.

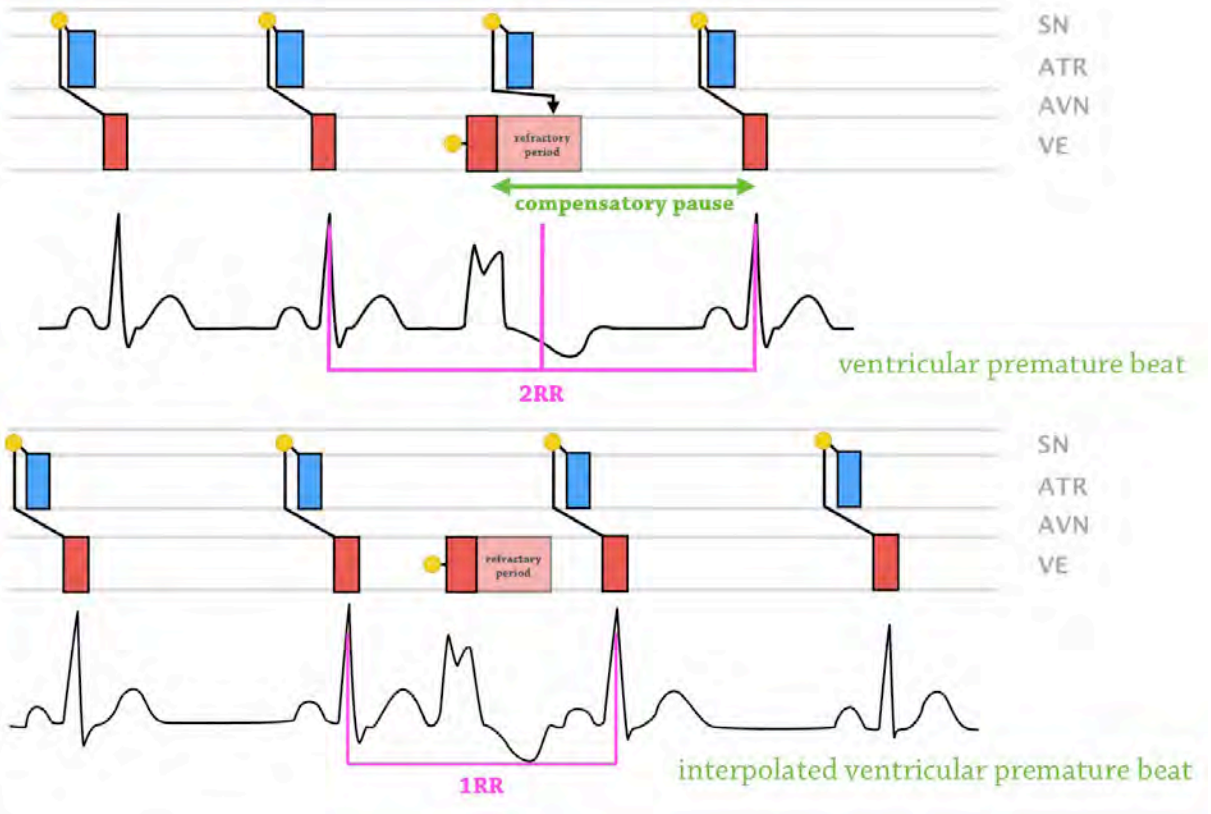
However there's also another kind of VPB in which this looks slightly different:



The refractory period of this VPB is already over before the next sinus impulse reaches the ventricles. Therefore, we do not see a compensatory pause following the premature QRS. This type of VPB is called an **interpolated ventricular premature beat**.

Differentiating between ventricular and supraventricular premature beats

There is one important measurement that will come in handy when we learn about supraventricular premature beats: the distance from the last normal QRS preceding the VPB to the next normal QRS following it.



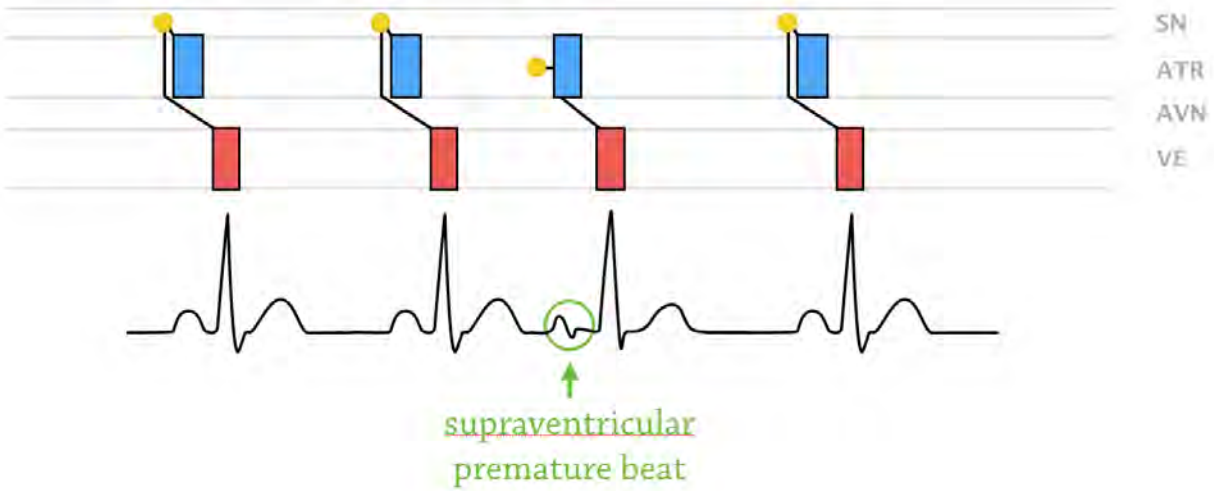
As you can see in the illustration above, the distance between the last normal QRS preceding the VPB and the next normal QRS following the VPB is either:

- Equal to **two normal R-to-R intervals,** in the case of **VPBs with a compensatory pause**.
  or
- Equal to **one normal R-to-R interval,** in the case of **interpolated VPBs**.

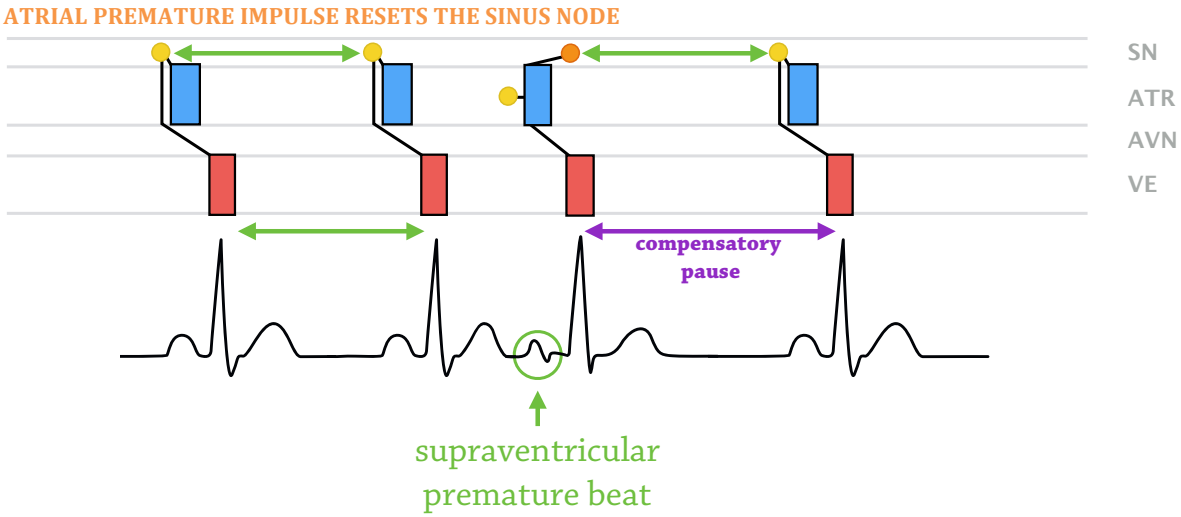
In the next section, you will learn how this measurement differs in supraventricular premature beats.

Supraventricular premature beats

Here's an example of a **supraventricular premature beat (SPB)**. Notice that the premature P wave looks different than the normal P waves because it's coming from a different region within the atria than the sinus node. The premature QRS on the other hand looks completely normal and narrow because the impulse is using the normal conduction pathways.



And what else is going on in the atria? Once the premature supraventricular impulse depolarizes the atria, it also "resets" the sinus node (orange dot). So the sinus node thinks that it has just discharged, and it will generate the next sinus impulse at the preset sinus interval (green arrows).

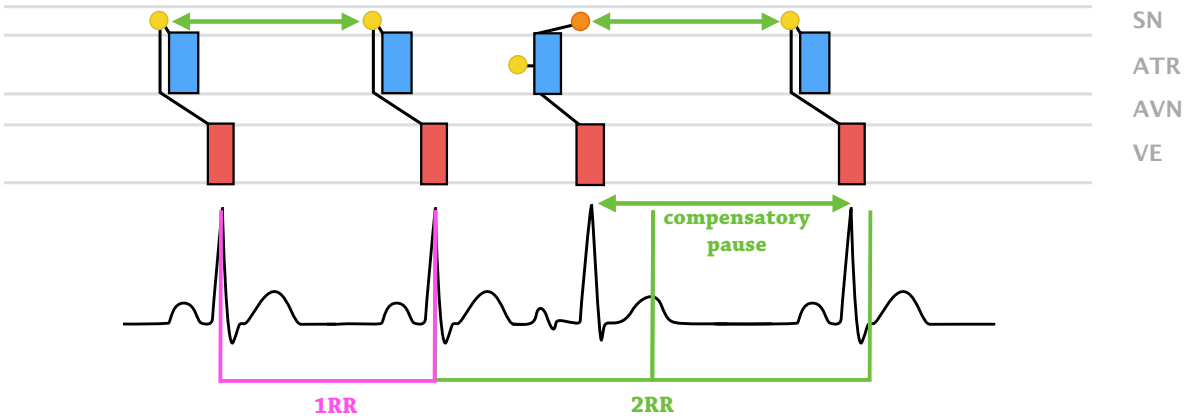


Practically all supraventricular premature beats are followed by a compensatory pause, sometimes clearly evident, sometimes very close to the R-to-R interval.

So remember these two key characteristics for identifying supraventricular premature beats:

1. They always have a premature P in front of their premature QRS.
2. The distance between the last normal QRS preceding the premature beat and the one following it is shorter than two normal R-to-R intervals.

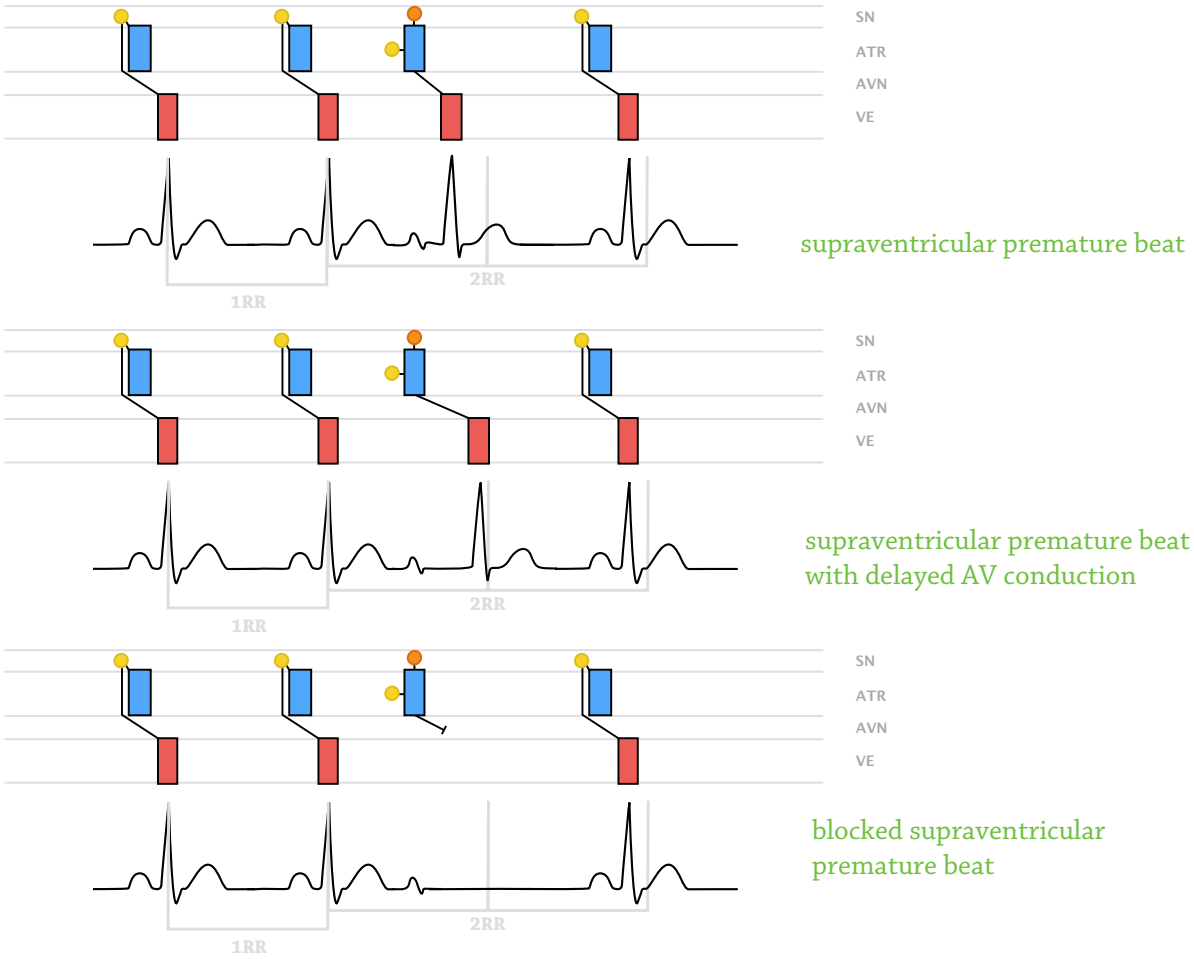
SUPRAVENTRICULAR PREMATURE BEAT



Note how the last beat (i.e., the normal QRS complex following the premature beat) comes in before the end of two normal RR intervals. In other words, the distance from the normal QRS preceding the premature beat to the normal QRS following it is shorter than two normal RR intervals.

Sometimes the premature atrial impulse reaches the AV node at a point in time at which it is still unable to conduct the impulse properly. When this happens, conduction down the AV node is either **delayed** or **completely blocked**. In the former, the PR interval will be prolonged, in the latter, the QRS complex will be completely blocked.

No matter if conduction through the AV node is normal or not, the distance between the normal QRS preceding the premature beat and the QRS following the premature beat is still less than two normal RR intervals.



So in summary, supraventricular premature beats are characterized by a premature P wave. **The QRS complex can**:

- Be narrow.
- Have a bundle branch block morphology.
- Be missing (as in blocked supraventricular premature beats).

The **PR interval can**:

- Be normal.
- Be prolonged.

Level 8

QUIZ SECTION

Just as in the previous level, please ask yourself these three questions:

1. What's the basic rhythm? Is it normal?

2. Is the rhythm disturbed (by extra beats, pauses, etc.)

3. Is the rhythm replaced (is there a rhythm switch?)

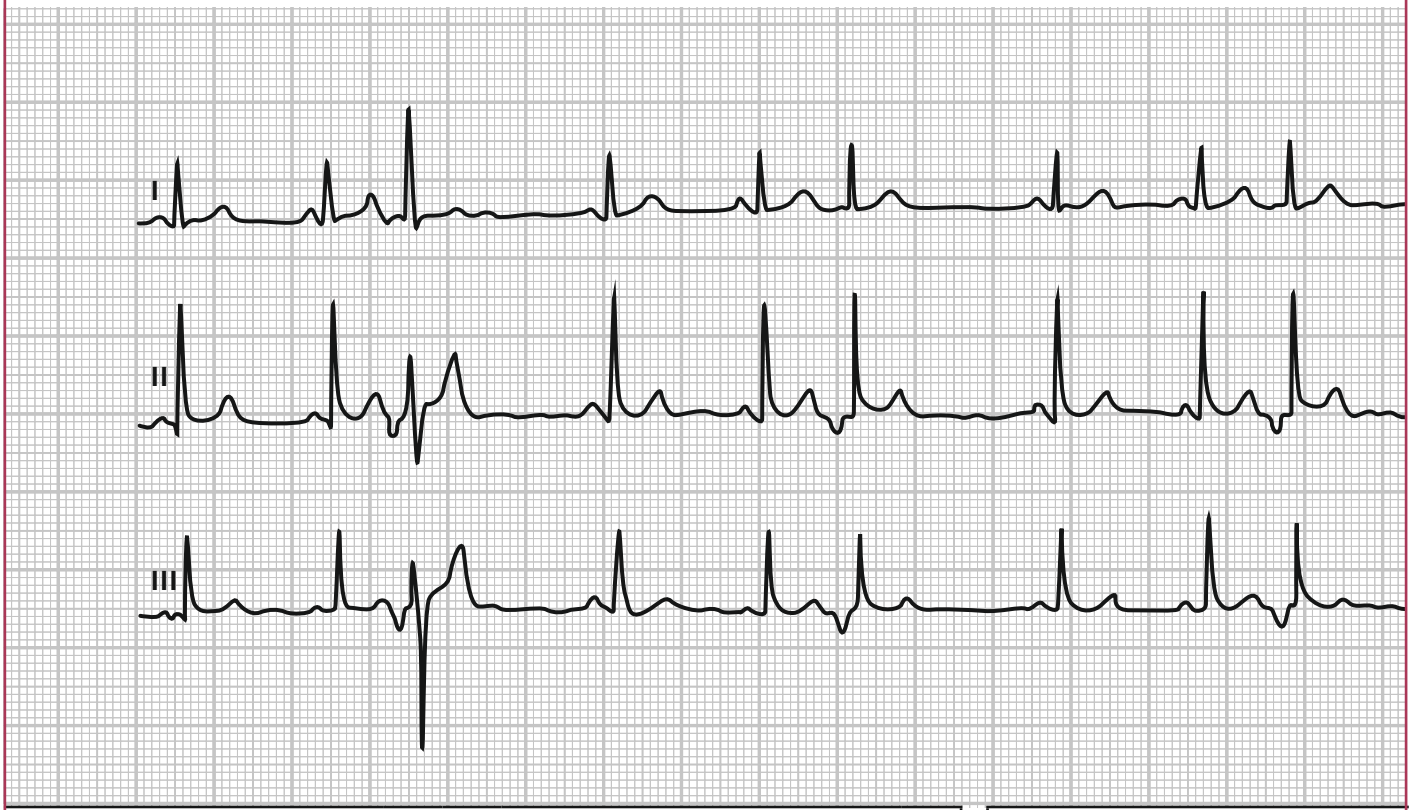
If you think that a supraventricular premature beat (SVPB) or a ventricular premature beat (VPB) is present, please specify the type of beat, then see if conduction from the atria to the ventricles as well as conduction within the ventricles is normal or not.

P

QRS

T

ECG 1



Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

↓

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

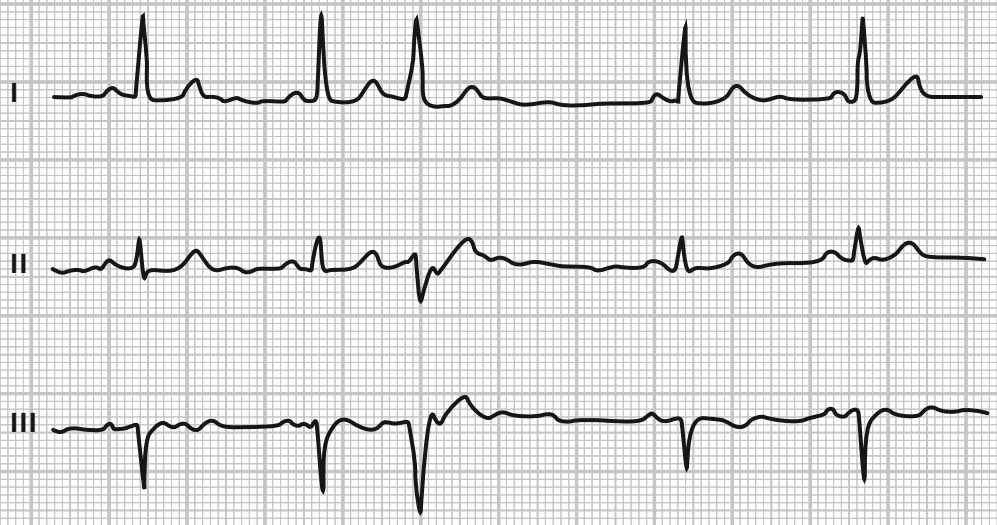
VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 2



Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

↓

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 3

Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

↓

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

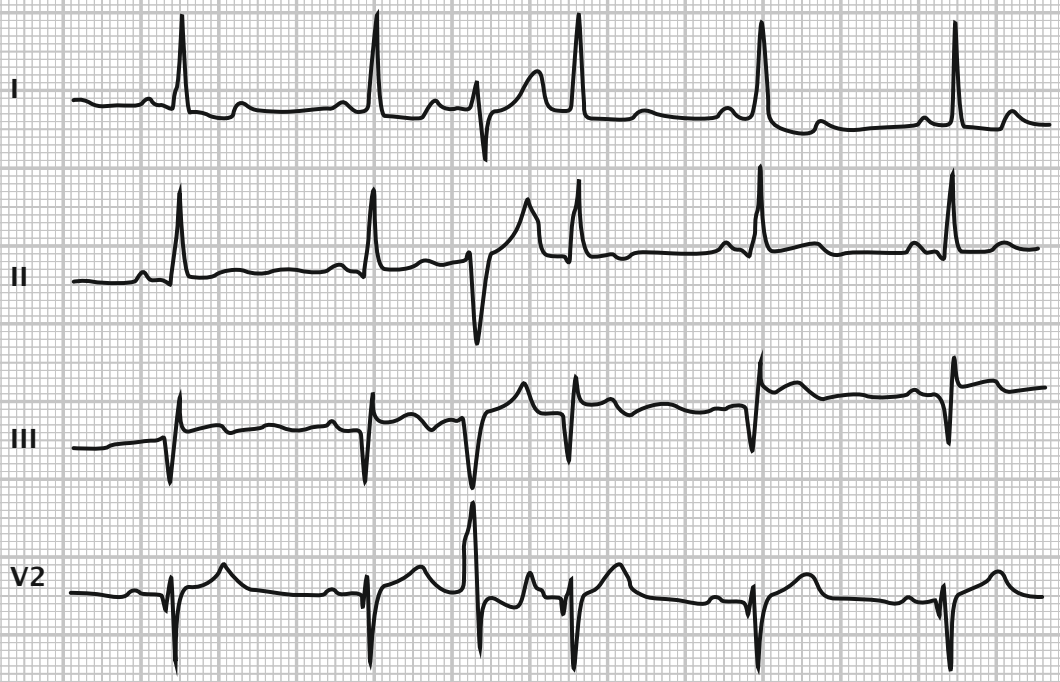
VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 4



Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

⬇

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 5

Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

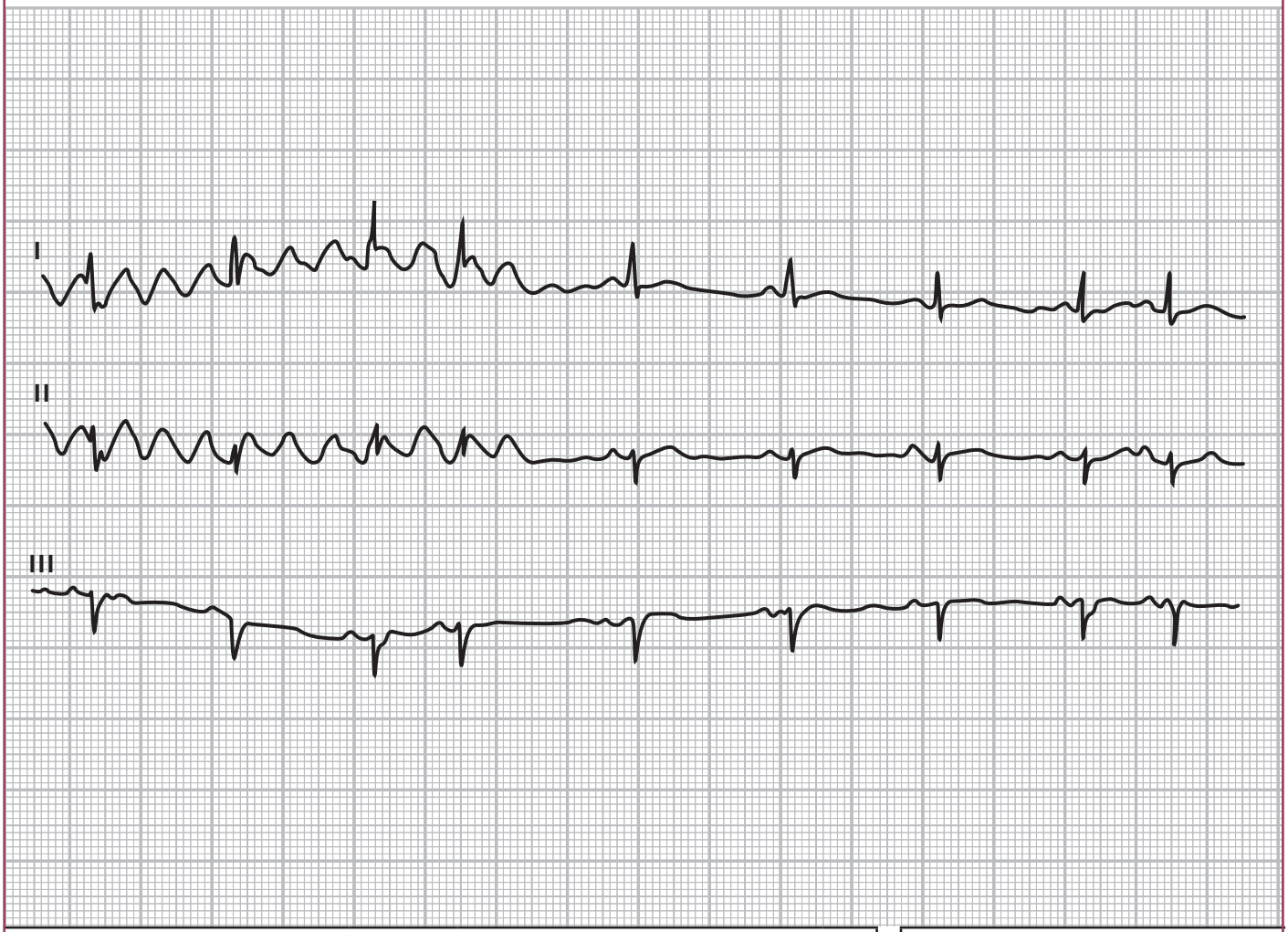
VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 6



Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

↓

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

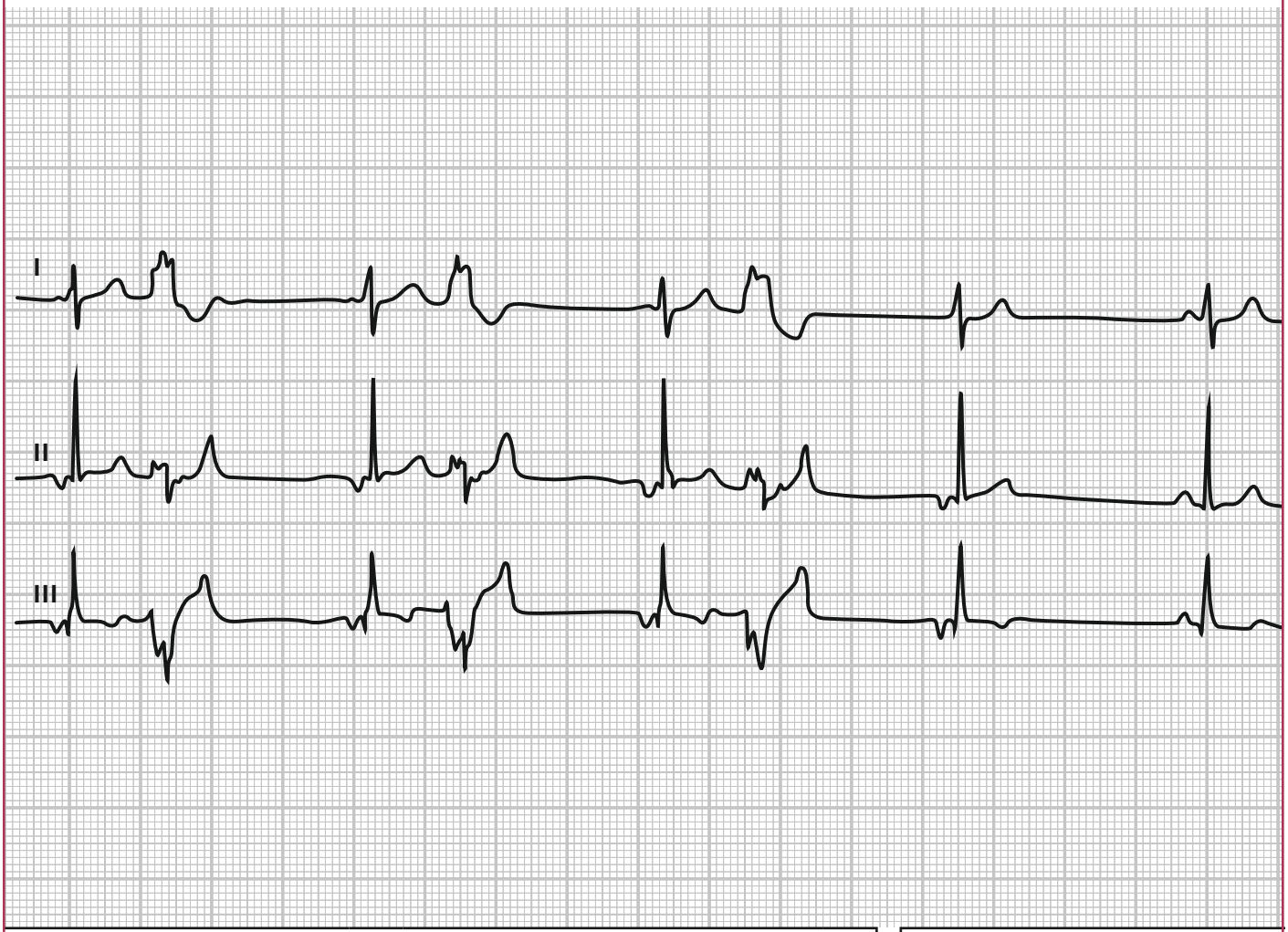
VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 7



Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

↓

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

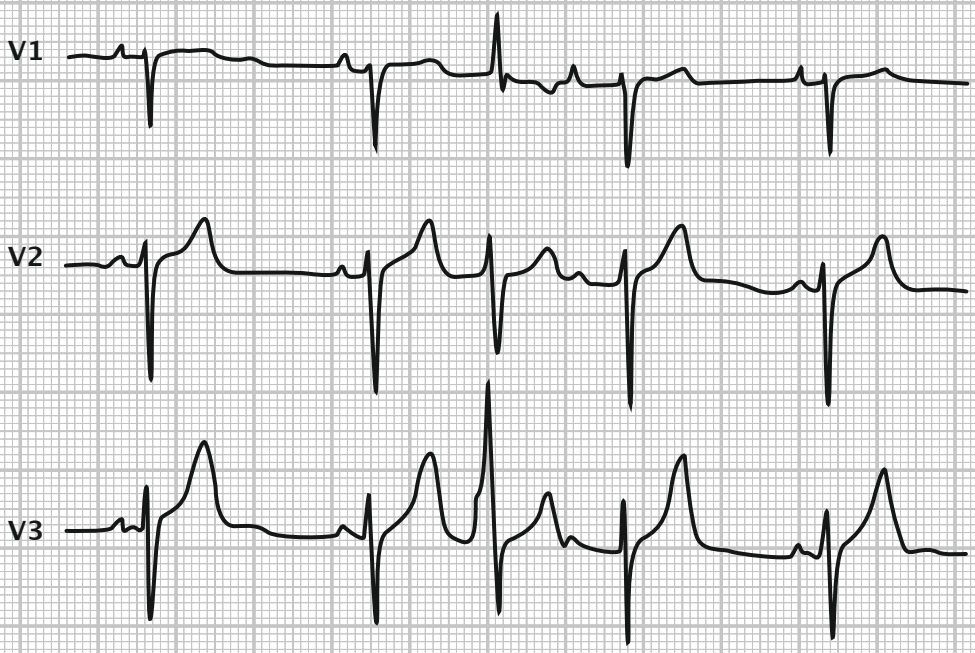
VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 8



Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

⬇

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

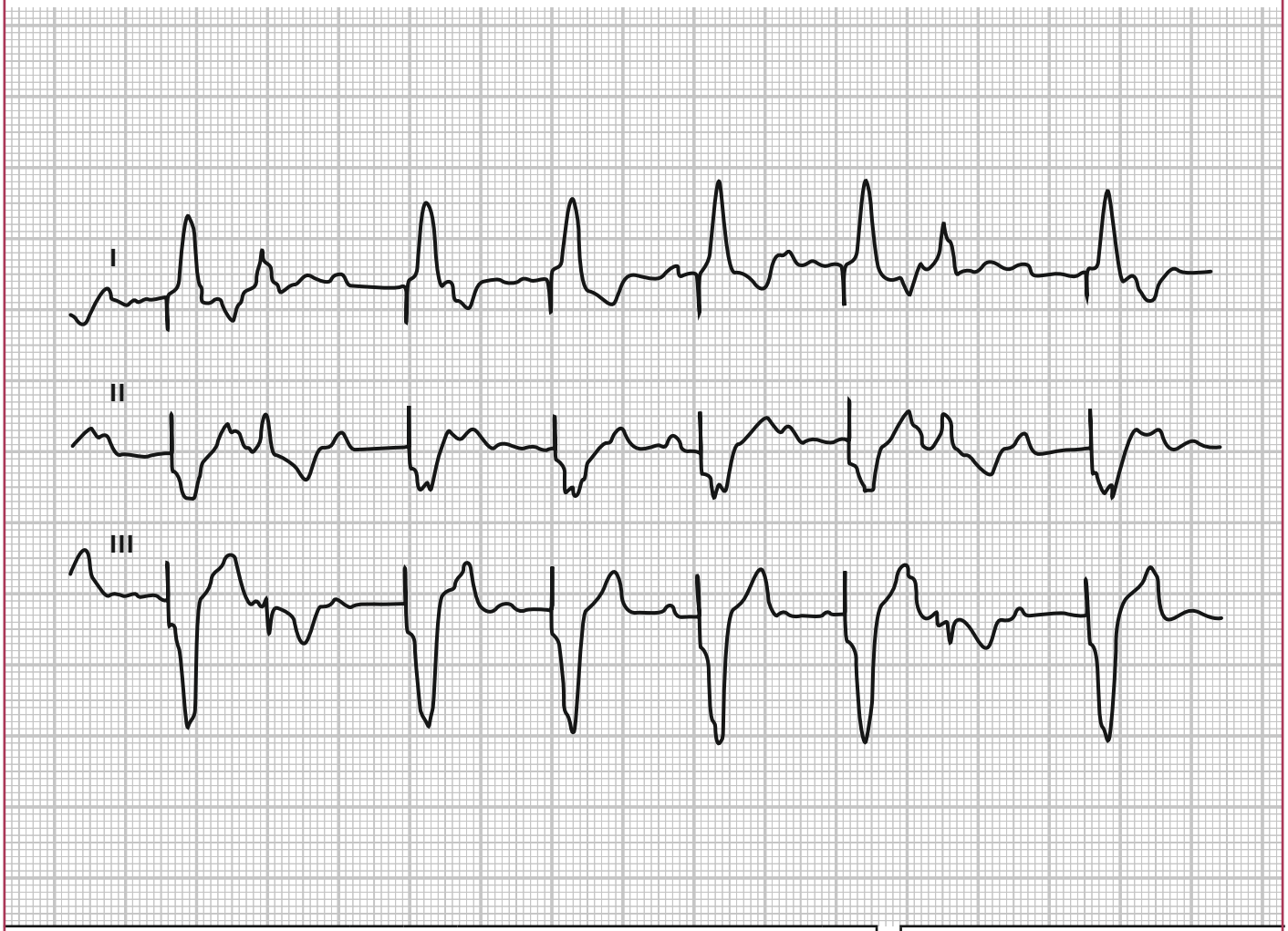
VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 9



Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

⬇

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

VPB with compensatory pause	
interpolated VPB	

P

QRS

T

ECG 10

Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

⬇

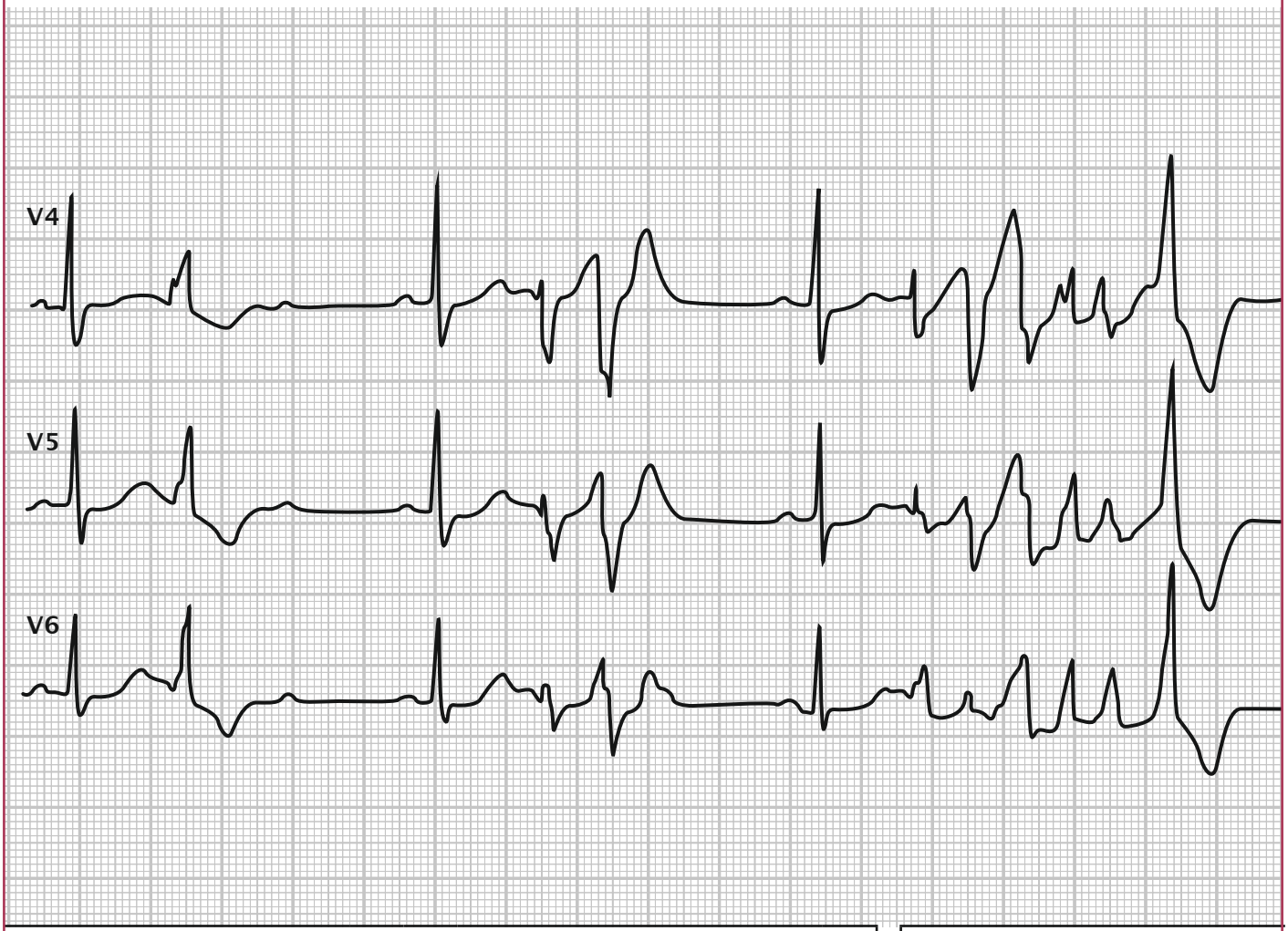
with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

VPB with compensatory pause	
interpolated VPB	

P
QRS
T

ECG 11



Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

VPB with compensatory pause	
interpolated VPB	
polymorphic VPB	

P

QRS

T

ECG 12

Can you identify the underlying rhythm?

Is there a change in the rhythm?

Other findings:

SUPRAVENTRICULAR

SVPB	
junctional premature beat	

with prolonged PR	
with AV block	
with aberrant ventricular conduction	

VENTRICULAR

VPB with compensatory pause	
interpolated VPB	
polymorphic VPB	

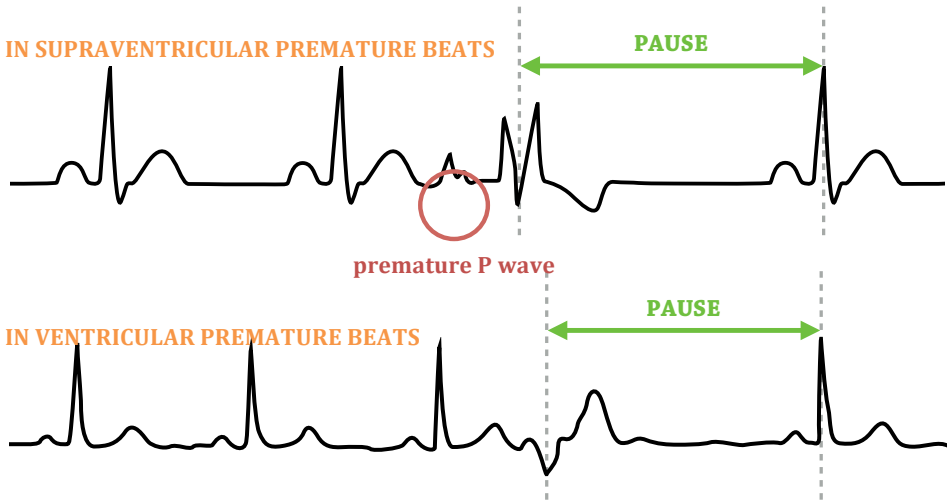
Level 9: Pauses & AV Dissociation

In this level, we are going to learn about pauses and AV dissociation.

Pauses… do we have to worry?

In this section, we are going to talk about five different kinds of pauses that can be seen on the ECG.

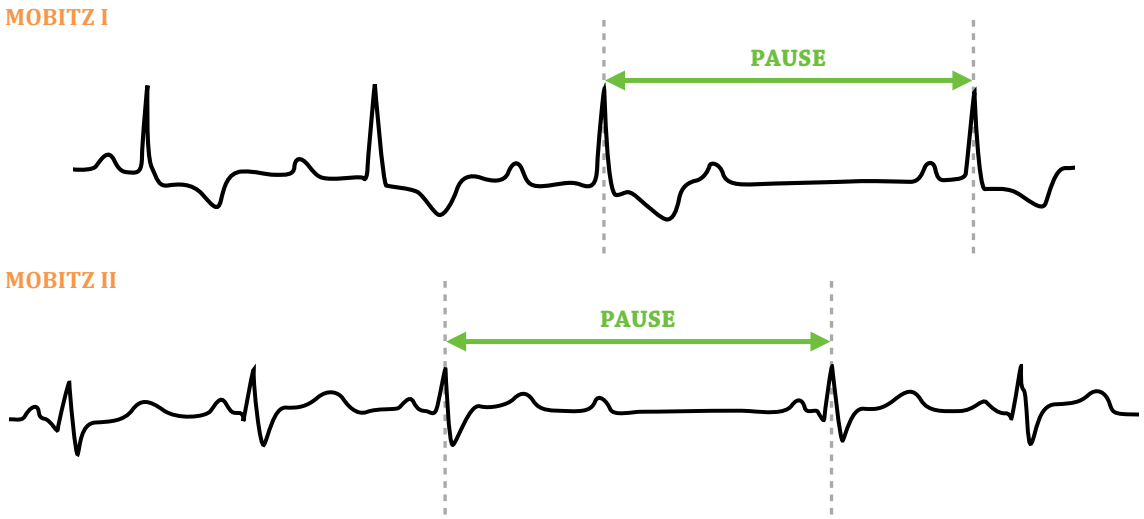
#1: Compensatory Pauses



In this case it is an SPB with a BBB morphology

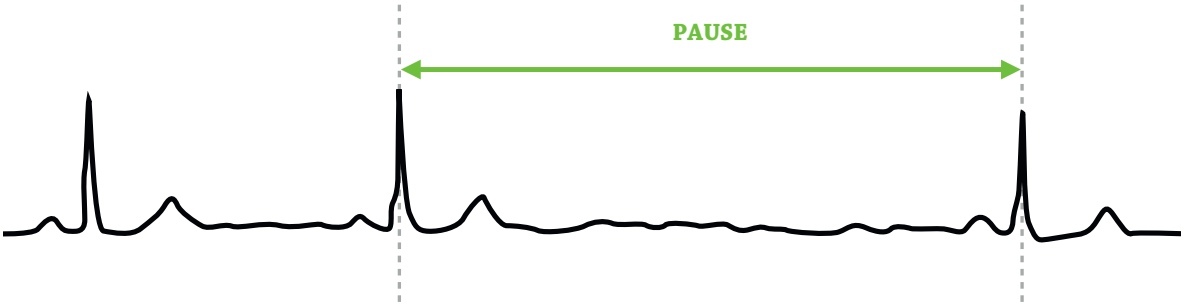
We have already seen the compensatory pause following many ectopic beats. The pause itself is not the problem, although that's what the patient actually feels when a premature beat occurs. The abnormal thing to worry about is the premature beat. Whether we try to do something about it is a clinical decision and depends upon many factors in each patient.

#2: Pauses in second degree AV block



We have already encountered pauses in second degree AV block, in Mobitz type I as well as in Mobitz type II. These pauses are part of the arrhythmia and should not bother us by themselves. Persisting second degree AV block, however, may become symptomatic. Therefore, the indication for pacemaker implantation should be carefully considered.

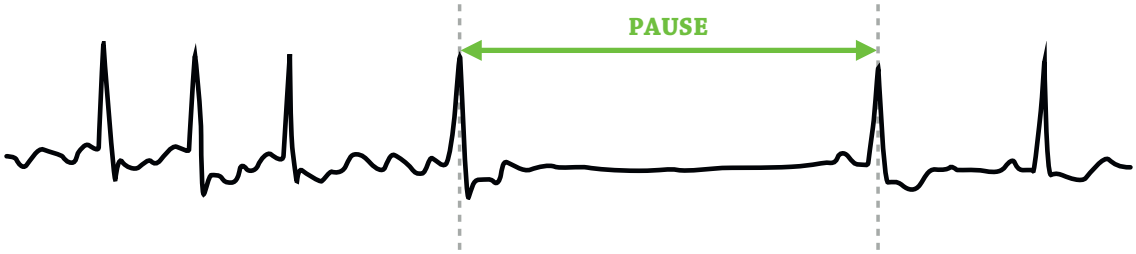
#3: Sino-auricular block (i.e., sino-atrial block)



Another type of pause is the so-called **empty pause**, which can be seen in **sino-auricular block** or **sinus arrest**. In this situation no other abnormality (e.g., a premature beat, rhythm switch, or a non-conducted atrial beat) apart from the pause can be identified on the ECG. All we see is a long pause without any electrical activity in it.

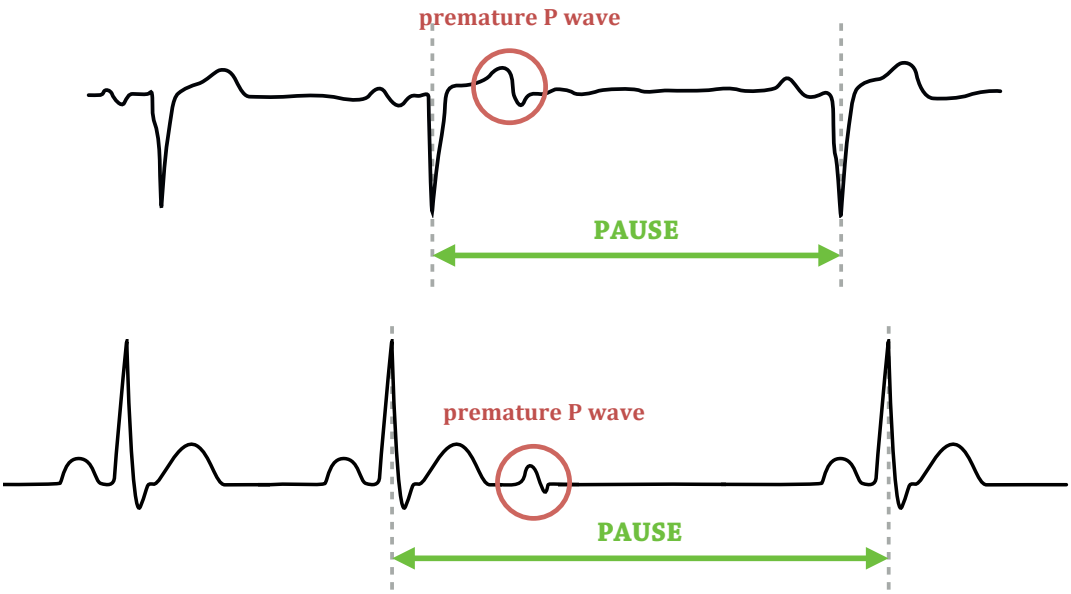
When we say sino-auricular block, we assume that the sinus node has produced an electrical impulse at the proper moment, but that this impulse was not conducted into the surrounding atrial myocardium. One other possible explanation for a pause like this is **sinus arrest**, a situation in which the sinus node does not work at all. Since we cannot record the sinus activity on the surface ECG, we cannot differentiate between these two types of pauses. If only one beat is omitted, it's called **intermittent SA block**, and the patient would hardly feel anything. If the pause gets longer and if we do not get any stimulation by an escape beat from a junctional or ventricular center, then dizziness or even syncope occur. A combination of this intermittent conduction problem in the sinus node with the tendency to intermittent atrial tachycardias typically suggests that **sick sinus syndrome is present**.

#4: Preautomatic pauses



A pause can also occur in the setting of a **rhythm switch** (e.g., when an atrial tachycardia terminates and sinus rhythm takes over the pacemaker function again, as can be seen in the example above). Such pauses are called **preautomatic pauses**. In these cases the sinus node takes some time to wake up again and take over its normal pacemaker function. If this pause gets long enough to make the patient symptomatic, this would be another feature of the **sick sinus syndrome**. Patients with sick sinus syndrome are not easy to manage: when we treat the tendency for atrial tachycardias with antiarrhythmic drugs or with medications to slow down their heart rate, we might on the other hand increase the tendency for bradycardia and pauses. Therefore, sometimes we have to combine adequate medication with pacemaker therapy in these cases.

#5: Non-conducted premature atrial beats



We already encountered another type of pause in the last module when we saw the supraventricular ectopic beat which was not conducted into the ventricles at all. Here we see a pause with two typical features:

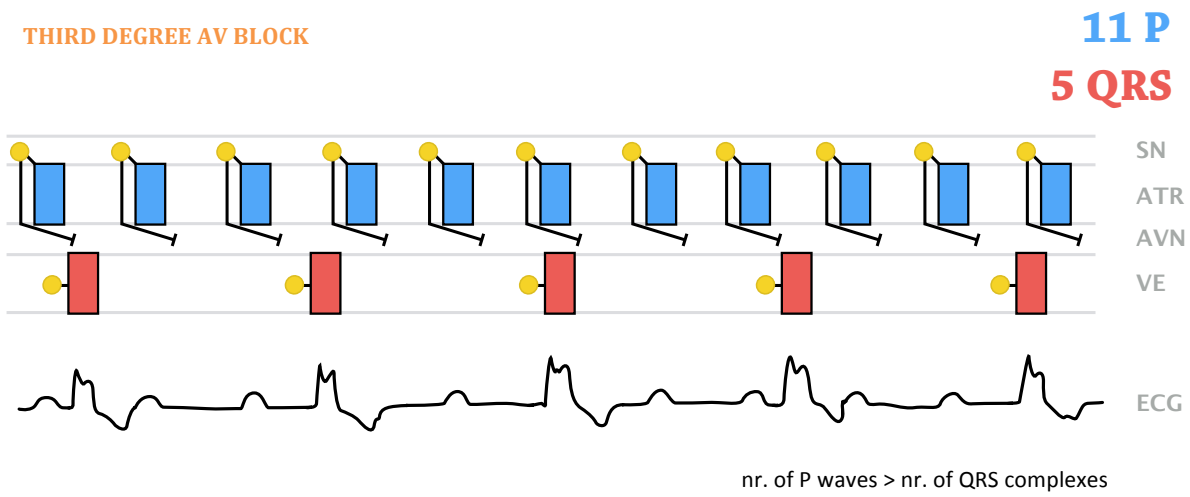
1. The duration of this pause is somewhat shorter than two regular R-to-R intervals.
2. When looking very carefully we can often identify the premature P hidden somewhere in the T wave of the preceding normal beat or in the isoelectric line following the preceding T wave.

Here again the pause is not the problem—it is the premature beat that could worry us. Whether we would consider treatment or not depends upon the individual circumstances of the patient and how often these events occur. A Holter ECG (an ambulatory ECG device for continuous rhythm monitoring) may also help with this decision.

AV dissociation vs. complete AV block

AV dissociation literally means that atria and ventricles are dissociated in terms of their respective pacemaker. In other words there is one pacemaker producing impulses for the atria (normally the sinus node), and a second one producing impulses for the ventricles (a stimulating center in the ventricular myocardium or in the junctional region). This usually results in the fact that P waves and QRS complexes occur independently of each other. We have seen similar findings in the case of complete AV block.

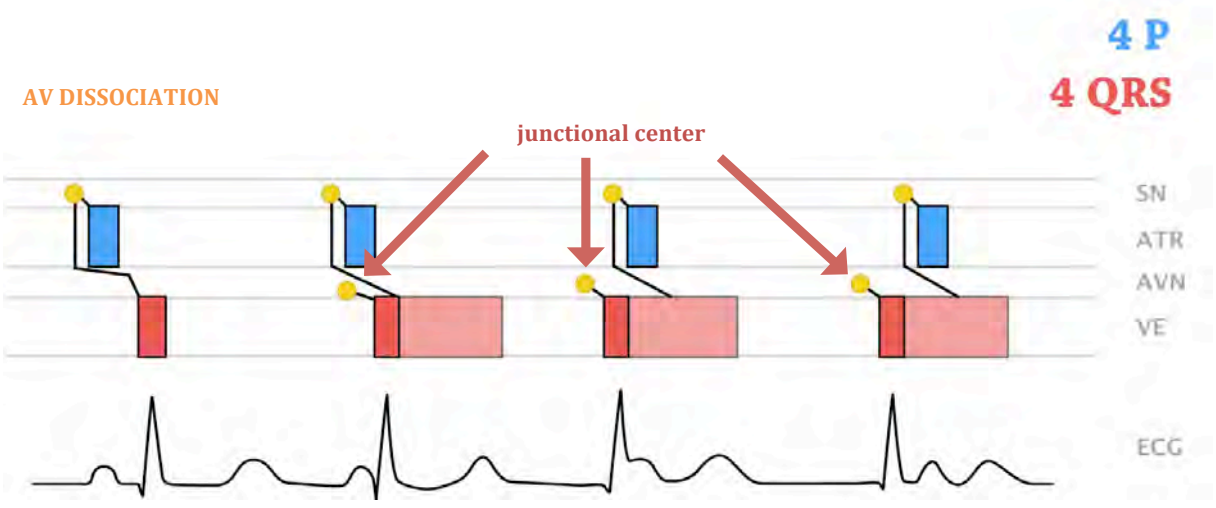
Here's a tracing of **third degree AV block** to refresh your memory:



nr. of P waves > nr. of QRS complexes

We are no longer surprised to find P waves preceding a QRS with extremely short PR intervals, and to find other P waves hidden within the QRS or within the ST segment. We know that PR intervals are usually variable, and most importantly that **the number of P waves exceeds the number of QRS complexes**.

This type of AV dissociation is generally called complete AV block or third degree AV block. However, it is generally agreed upon in electrocardiography to reserve the term "AV dissociation" to a very special form of arrhythmia, which is shown in the following example.



nr. of P waves = nr. of QRS complexes

The rate of the junctional center overtakes the sinus rate. The sinus impulse (i.e., P waves) can no longer activate the ventricles because they have already been activated by the junctional center. If the sinus rate speeds up again, it will take over the pacemaker function again.

There are two key characteristics in this tracing:

1. The PR interval continuously decreases.
2. P waves can be found before, in, or shortly after the QRS complexes (i.e., they seem to be "traveling" through the QRS complexes).

These findings could technically also be found in cases of complete AV block. The important difference, however, is that in AV dissociation **the number of P waves and the number of QRS complexes on the tracing are practically identical**.

The ladder diagram also shows us that P waves 2 to 4 could not activate the ventricles because they had already been activated by an ectopic junctional focus.

Since the rate of the junctional focus overtook the sinus rate after the first beat, it became the primary pacemaker. None of the sinus impulses could activate the ventricles from that point on.

Since the junctional impulses depolarize the ventricles just like the sinus impulses—through the normal conduction system—the shape of the QRS complexes is narrow and completely normal (unlike most cases of third degree AV block in which QRS complexes are broad).

The pattern of this AV dissociation is therefore only determined by the respective pacing rate of the sinus node and of the junctional center. If the rate of the junctional center exceeds the sinus rate, AV dissociation is present. If the sinus node speeds up again and its rate exceeds the junctional rate, the patient will be in sinus rhythm again.

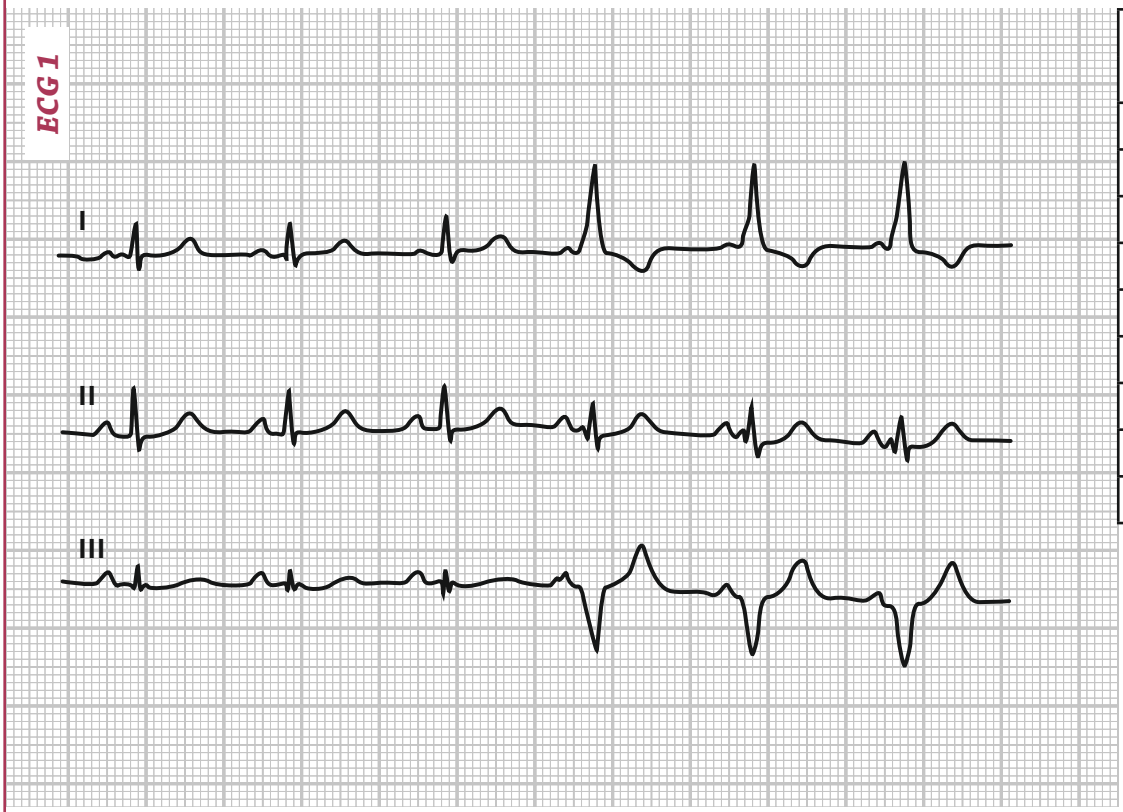
As you can imagine, the patient with this type of arrhythmia will practically have no symptoms at all, because the heart rate stays more or less unchanged and there are no extra beats or unexpected pauses. It is more a problem for the doctor reading the ECG tracing and being puzzled by the strange behavior of the P waves travelling into and through the QRS complex.

Level 9

QUIZ SECTION

Please apply steps 1-9 of our Rhythm Cheat Sheet in the evaluation of the following cases.

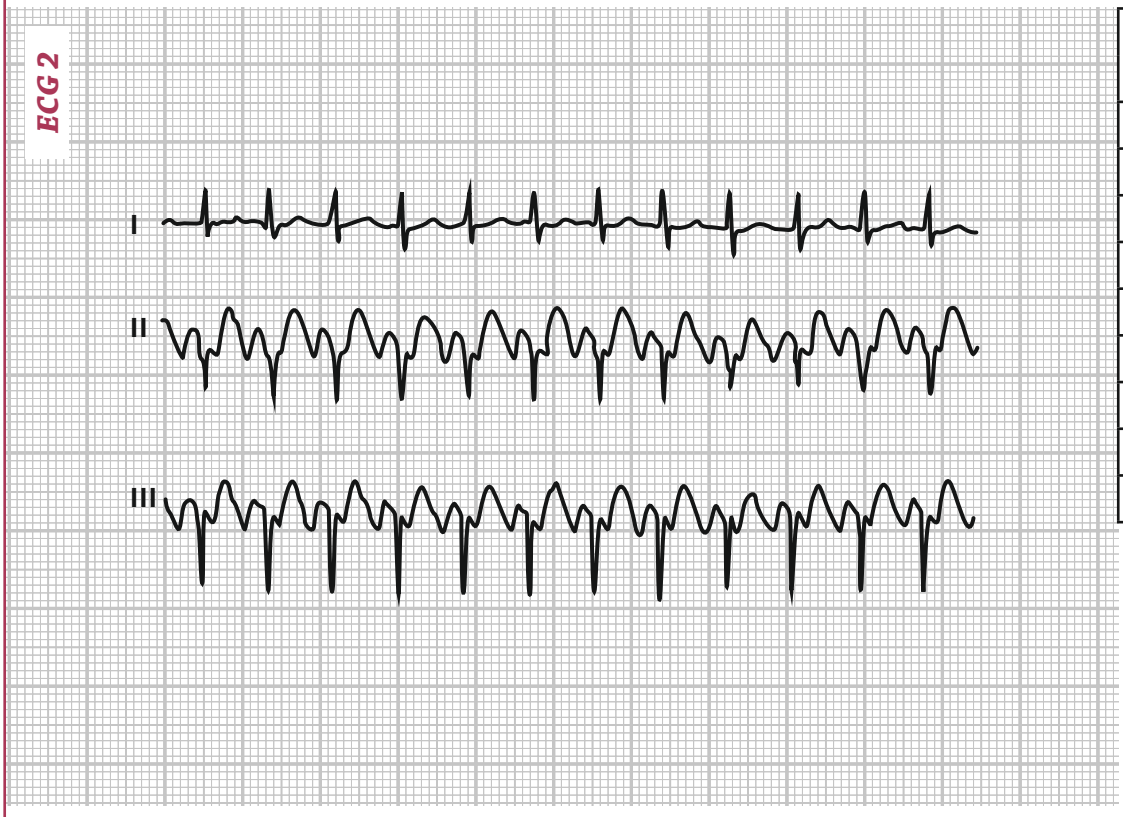
ECG 1



Cheat Sheet Step	Answer	
	yes	no
1:		
2:		
3:		
4:		
5:		
6:		
7:		
8:		
9:		

Other comments:

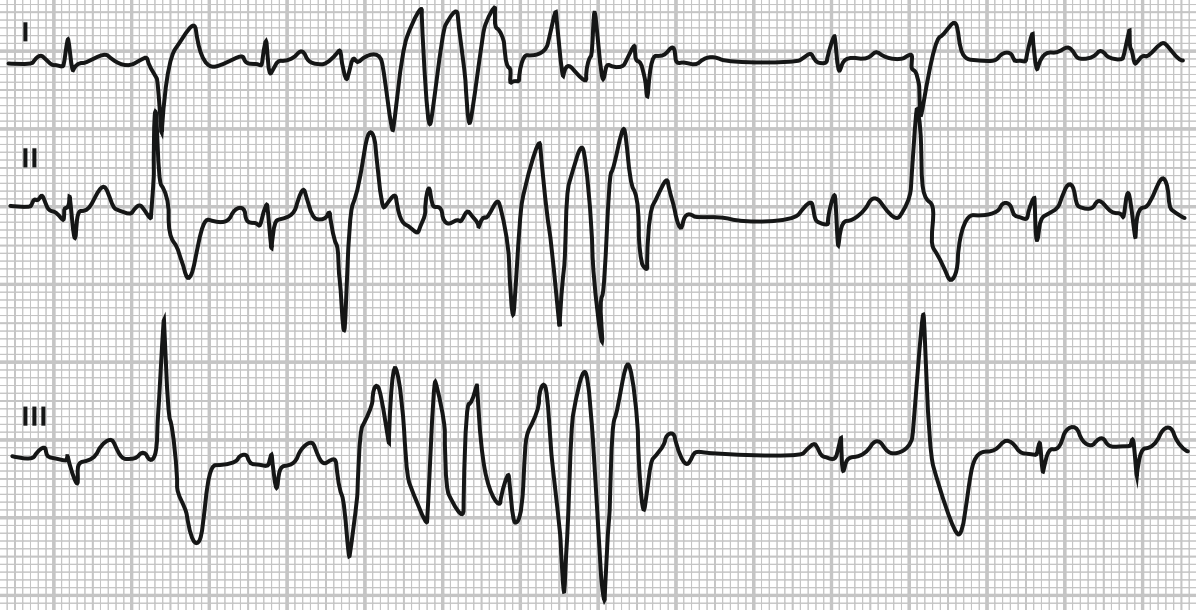
ECG 2



Cheat Sheet Step	Answer	
	yes	no
1:		
2:		
3:		
4:		
5:		
6:		
7:		
8:		
9:		

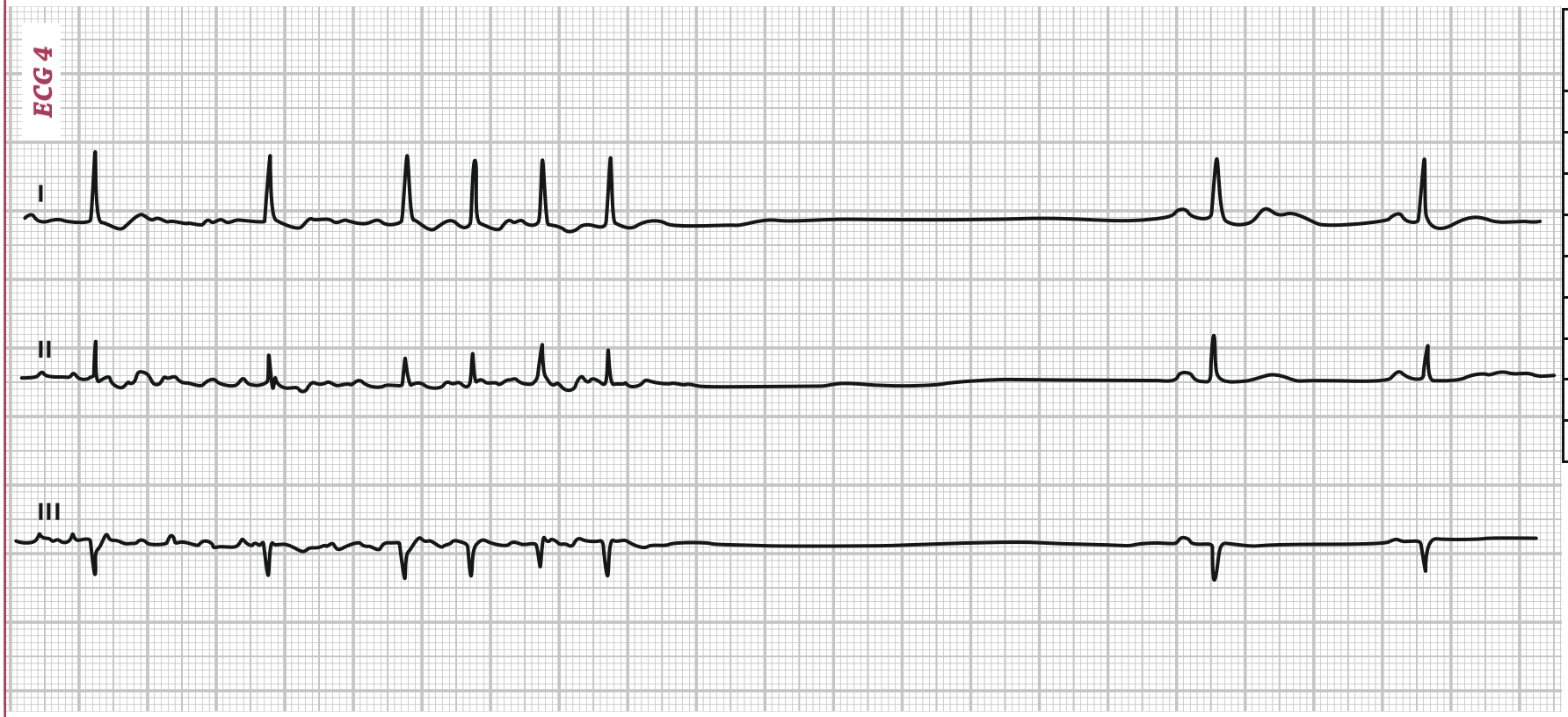
Other comments:

ECG 3



Cheat Sheet Step	Answer	
	yes	no
1:		
2:		
3:		
4:		
5:		
6:		
7:		
8:		
9:		

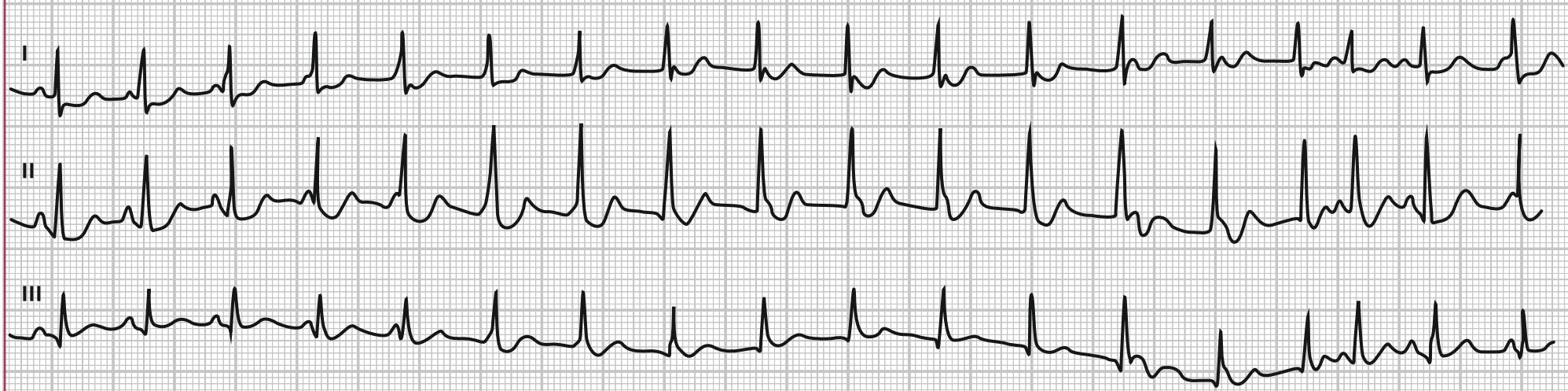
Other comments:



Cheat Sheet Step	Answer	
	yes	no
1:		
2:		
3:		
4:		
5:		
6:		
7:		
8:		
9:		

Other comments:

ECG 5



Cheat Sheet Step	Answer	
	yes	no
1:		
2:		
3:		
4:		
5:		
6:		
7:		
8:		
9:		

Other comments:

ECG 6

Cheat Sheet Step	Answer	
	yes	no
1:		
2:		
3:		
4:		
5:		
6:		
7:		
8:		
9:		

Other comments:

ECG 7

Cheat Sheet Step	Answer	
	yes	no
1:		
2:		
3:		
4:		
5:		
6:		
7:		
8:		
9:		

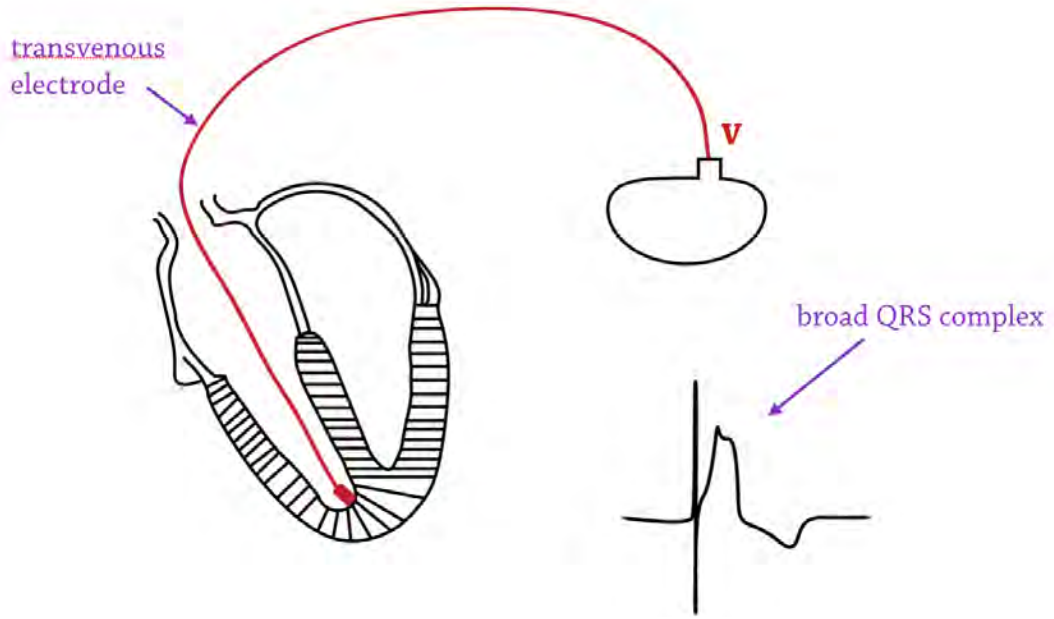
Other comments:

Level 10: Artificial Pacemakers

In Level 1 we learned about the characteristics of the pacemaker ECG: the vertical straight lines produced by the pacing stimulus. However, besides merely identifying a tracing as a pacemaker ECG, the doctor reading the curve should also be able to get more information out of it. This short history on pacemaker developments will teach you all you need to know.

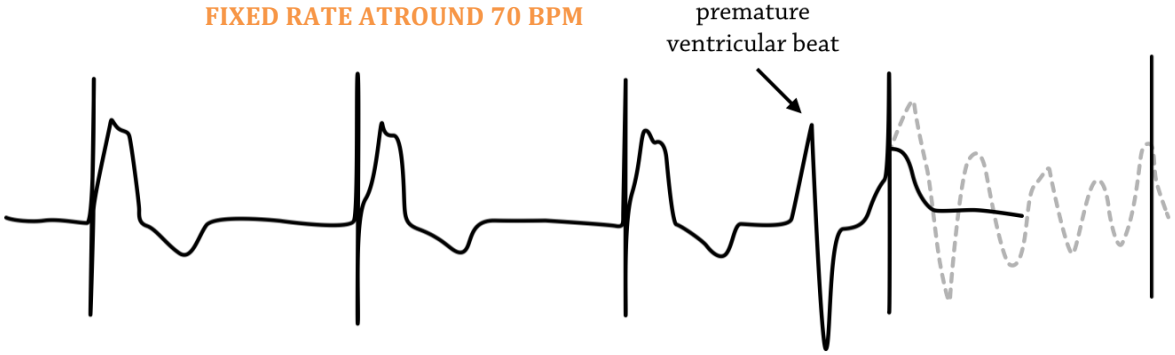
Fixed-rate pacemakers – a potentially life-threatening technology

First we'll look at the basic technology. Let's start with single-chamber pacemakers:



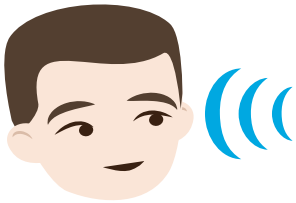
The pacing impulse is delivered by a transvenous electrode to the right side of the interventricular septum at the apex of the right ventricle. In these single chamber pacemakers there is only one electrode being connected to one cardiac chamber. In most instances this will be the ventricle, because the usual indication for a pacemaker is complete AV block. The resulting QRS complex in these pacemakers looks very similar to LBBB, because just as in LBBB, the entire ventricle is stimulated by impulses coming from the right side of the heart.

In the very early days of pacemaker therapy the pacemaker unit delivered pacing impulses at a fixed rate—e.g., 70 beats per minute:



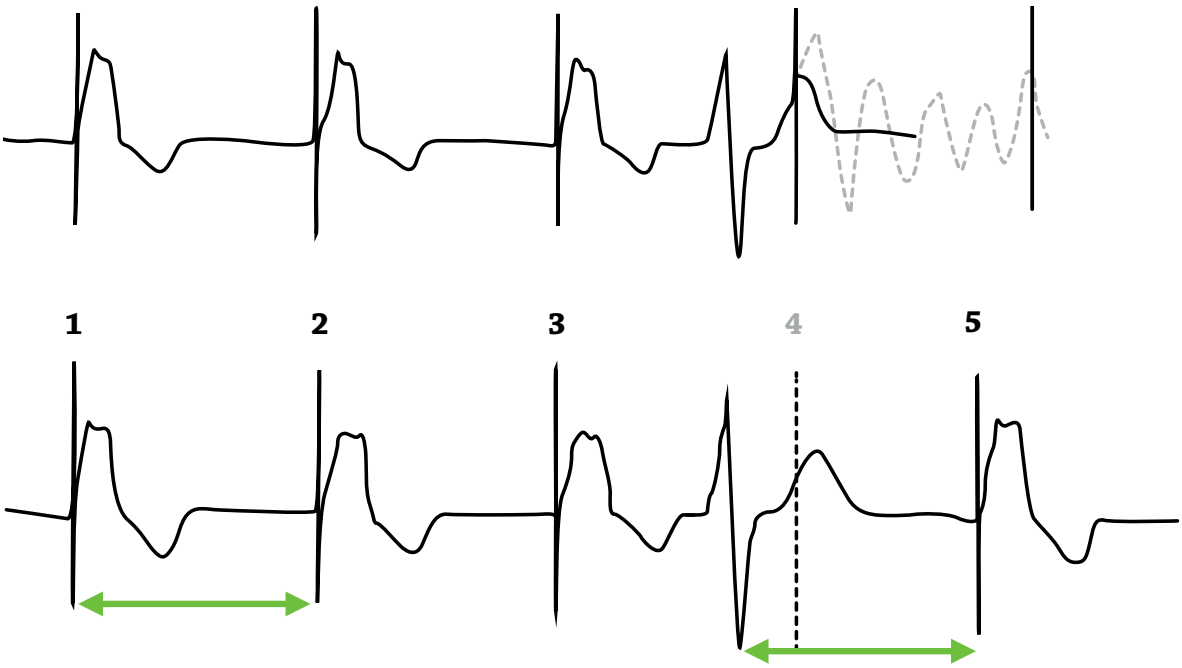
These types of pacemakers also delivered an impulse when by chance a ventricular premature beat (VPB) occurred after such a paced QRS. The pacing impulse therefore could eventually enter the heart just on the tip of the T wave (of the VPB). And we know that electrical stimulation towards the end of the refractory period (that is, on or after the tip of a T wave) can trigger ventricular fibrillation with cardiac arrest and eventually death. This was sometimes observed with these **fixed rate pacemakers**, so they **had to be taken off the market**.

Sensing solves the problem



The solution to this problem was as follows: the ventricular electrode was not only used to send an impulse into the heart (**pacing**), but also to record the electrical activity within the heart (the **sensing property of a pacemaker**).

This enabled the pacemaker unit to sense the VPB and to set the electronic "clock" responsible for the pacing interval to zero in the moment the VPB was detected. Therefore, the pacing interval started again right at this very moment.



Here pacemaker impulse number 4 was **inhibited** due to the sensing capacity of the pacemaker. Instead, pacemaker impulse number 5 was fired at a **preset pacing interval** after the VPB

Hence this type of pacemaker delivered impulses only if no spontaneous QRS occurred during a preset pacing interval, so pacing occurred only when necessary (**demand pacemaker**).

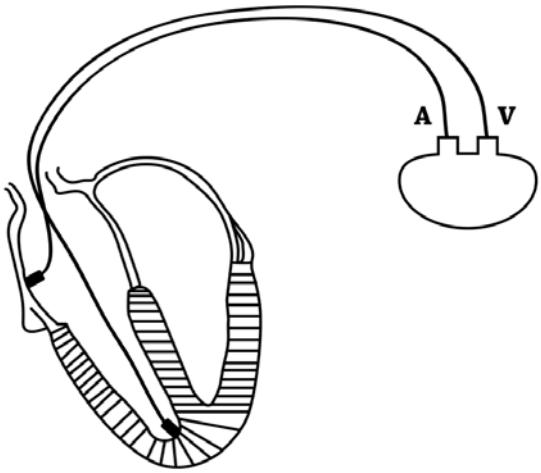
This type of pacemaker was not life-threatening, but it had the disadvantage that the pacing rate could not fall below and could not increase above a predetermined rate. The patient's heart, therefore, kept beating at, for example, 70 beats per min when he was climbing four flights of stairs or when he was sound asleep at midnight.

The introduction of rate-responsiveness

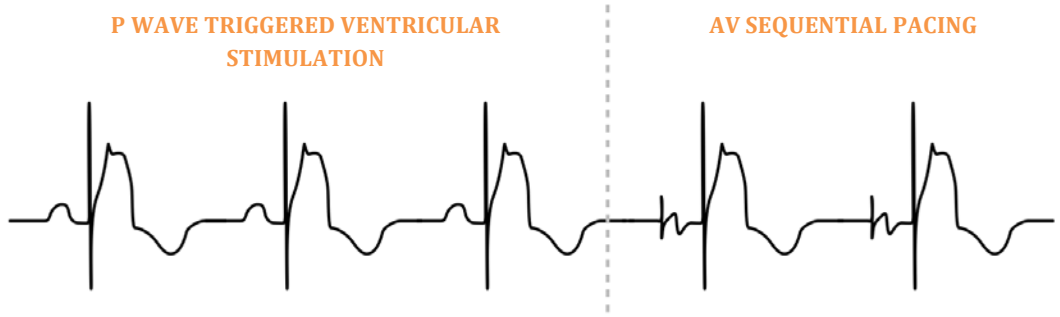
There were several attempts to solve this problem and to adapt the pacing rate to the needs of the organism. One was to integrate a Piezo element into the pacemaker unit. This element is very sensitive to movements; it changes its electrical charge with the level of vibrations, and can thus modify the pacing rate. A calibration method allows the pacemaker to pace at a low rate when the patient is quiet (sitting or sleeping) and to pace at higher rates when the patient is walking or running (and thereby shaking his pacemaker unit).

Even better: sensing atrial activity (i.e., physiologic P wave–triggered pacing)

One other method to provide "physiological" pacing is shown here:



There are two electrodes, one for the atrium and one for the ventricle. The atrial electrode (A) "senses" the electrical activity within the atria (i.e., the P wave) and sends this information to the pacemaker unit. The pacemaker then waits a couple of milliseconds to account for a physiologic PR interval before it stimulates the ventricles via the ventricular electrode (V). The ventricles, therefore, follow the rate of the patient's own P waves (i.e., the patient's sinus node activity), but the PR interval "happens" outside the heart in the pacemaker unit. This type of pacing is called **physiological pacing** or **P wave triggered ventricular stimulation**.



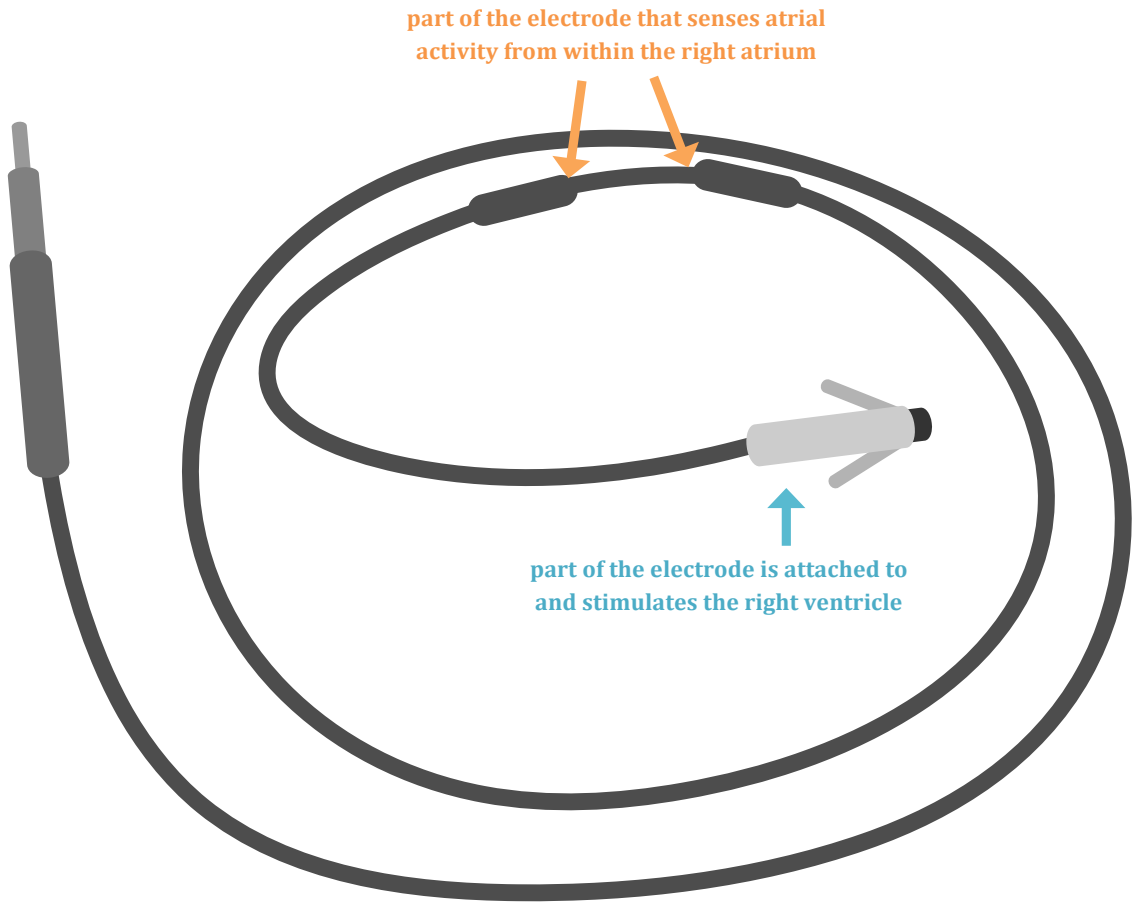
Killing two birds with one stone: the atrial lead makes atrial pacing possible

The introduction of the atrial lead was a huge innovation for two reasons. First, it enabled sensing and transmission of atrial activity to the ventricles, as we have learned above. And secondly, it was able to stimulate the atria in patients where the sinus node was not functioning properly.

When the pacemaker stimulates the atria and then the ventricles, we find tiny vertical impulses followed by P waves, and with a certain delay taller impulses followed by widened QRS complexes, the unit now paces the atria and the ventricles in a sequential manner. This type of pacing is called **A-V-sequential pacing**.

An alternative method to deliver P wave triggered pacing

If we don't need atrial pacing but want to get P wave triggered ventricular stimulation anyway, we can use another technical trick. We can implant only one electrode into the ventricle, but the part of this electrode that's passing the right atrium will contain a large sensor on its surface that is able to record P waves even though there is no direct contact to the atrial myocardial wall:



The pacemaker code

This short pacemaker history now ends with the so called **pacemaker code,** giving us information about the type of pacemaker implanted in an individual patient.

The code consists of four digits:

Digit #1: The cardiac chamber to which pacing impulses are delivered
(e.g., A= atrium; V = ventricle; D = dual, atrium and ventricle)

Digit #2: The chamber from which impulses are recorded/sensed
(e.g., A= atrium; V = ventricle; D = dual , atrium and ventricle)

Digit #3: The consequence of the sensed information (I = inhibition of a pacing impulse; T = triggering of a pacing impulse; D = dual, inhibition and triggering)

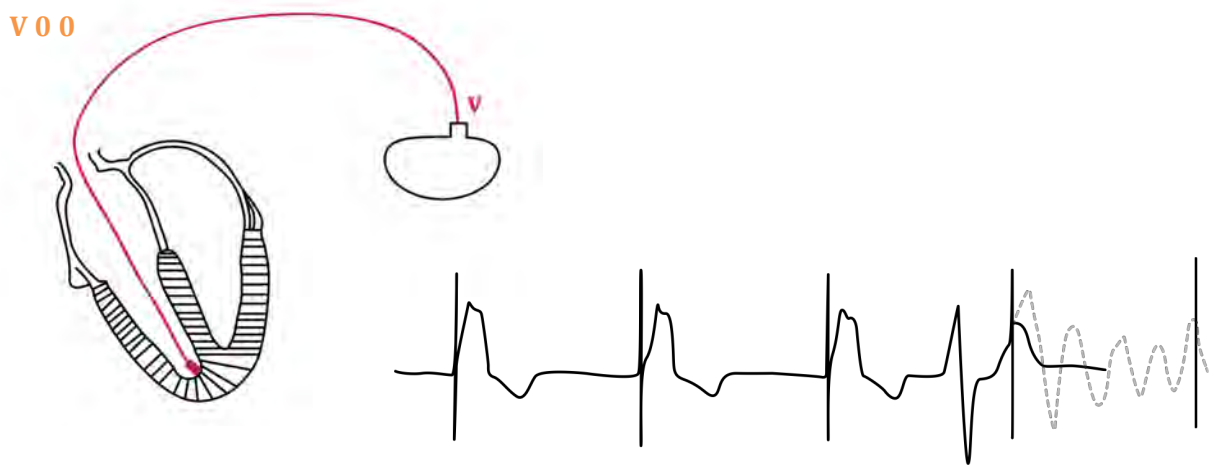
Digit #4: Rate responsiveness function (R = rate responsive),
e.g. Piezo element

stimulating chamber	#1	V	V	V	D	A
sensed chamber	#2	0	V	D	D	A
consequences of sensing	#3	0	i	D	D	I
rate responsiveness	#4		(R)	(R)		

In my opinion, #3 is the least important for you to understand.

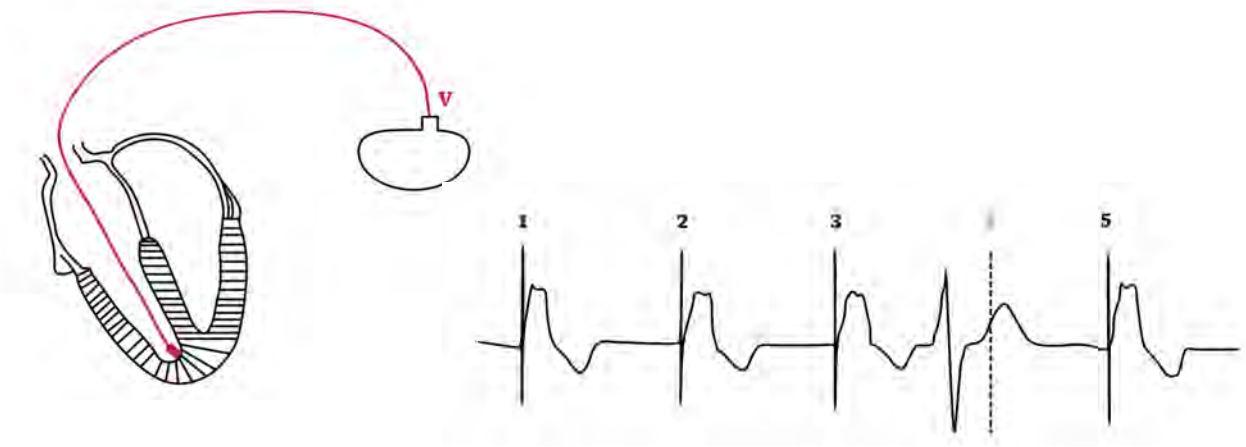
Here are a few examples:

V 0 0



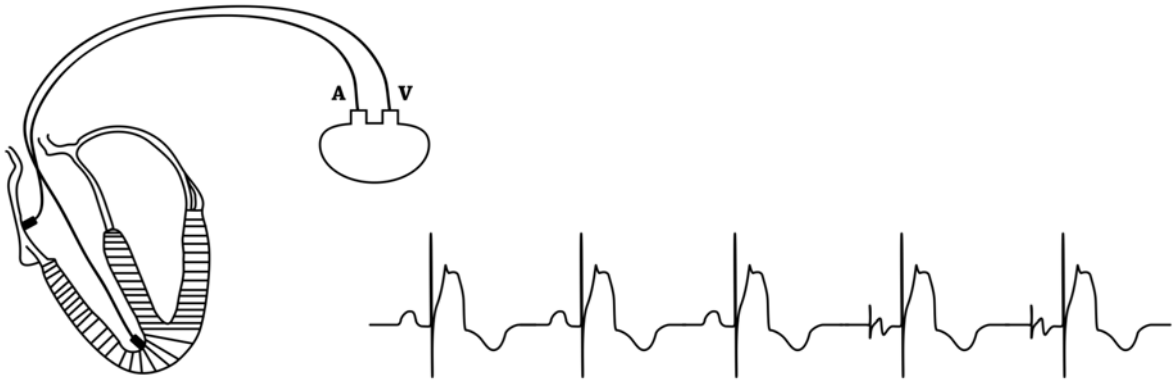
This type of pacemaker only has one electrode located in the right ventricle. It can only pace the ventricles but has no sensing properties (so digit #2 = 0). Since there is no sensing, nothing can happen after sensing (so digit #3 is also 0). This is a fixed rate pacemaker, which could trigger ventricular tachycardias and eventually death. So it has been taken off the market.

V V I



This pacemaker also only has one electrode, which is located in the ventricles. This electrode paces the right ventricle (digit #1 = V) and also senses in the ventricle (digit #2 = V). When it senses a premature beat (or any kind of ventricular depolarization) it inhibits the next planned impulse (digit #3 = I). So opposed to the V00 pacemaker, this type of pacemaker is not life-threatening. The VVI can be equipped with a rate-responsiveness function (VVI-R).

D D D

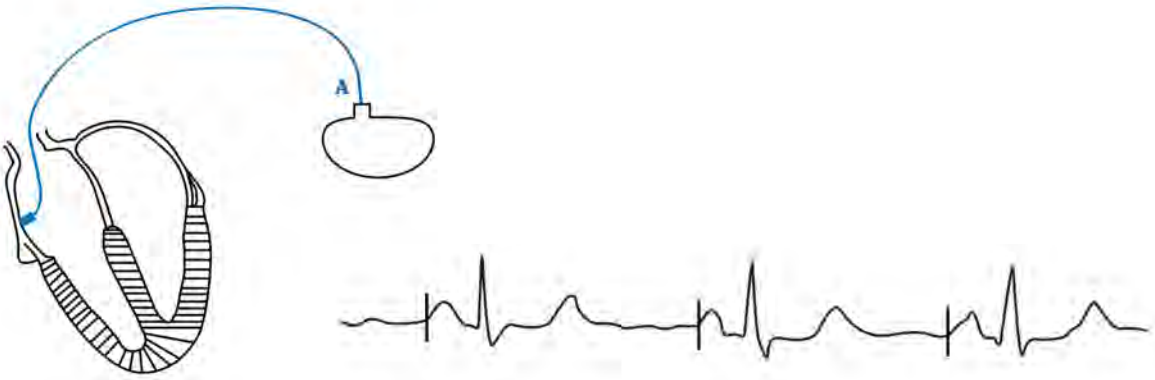


This is a dual chamber pacemaker with one electrode in the right atrium and another one in the right ventricle. This pacemaker paces both chambers (digit #1 = D) and also senses in both chambers (digit #2 = D). When a normal or premature impulse is sensed, the pacemaker inhibits the next planned pacemaker impulse and when the pacemaker doesn't sense any activity within a certain period, it can also trigger another pacemaker impulse (digit #3 = D). This pacemaker can also be equipped with a rate-responsiveness feature (DDD-R).

V D D

The VDD pacemaker only has one electrode, which paces the ventricle (digit #1 = V) but senses both the atrium and the ventricle (digit #2 = D). When a premature beat occurs, it can inhibit the next planned impulse, and when no beat occurs, it can trigger an impulse (digit #3 = D). The VDD can be equipped with a rate-responsiveness feature (VDD-R).

A A I



The AAI has one electrode, which is located in the right atrium (digit #1 = A), where it senses and paces the atrium (digit #2 = A). When it senses a sinus beat (or any other impulse in the atria) it inhibits the next planned impulse (digit #3 = I). The AAI is implanted in patients with sinus node dysfunction with normal AV nodal function. It is only rarely used. The AAI can also be equipped with a rate-responsiveness feature (AAI-R).

Pacemaker type		Normal PM function?	
VDD	☐	yes	no
VVI	☐	yes	no
AAI	☐	yes	no
DDD	☐	yes	no
other comments:			

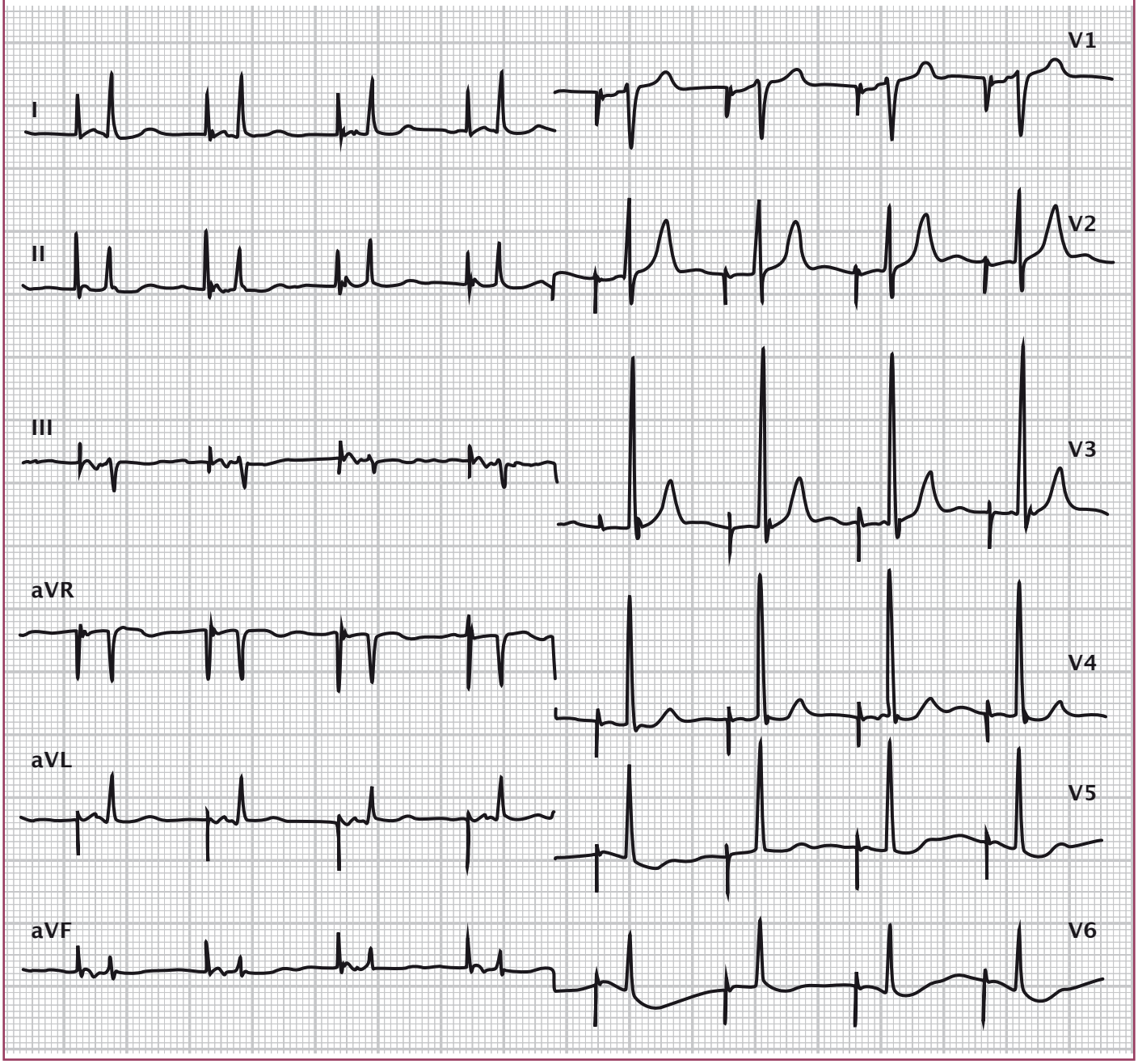
Level 10

QUIZ SECTION

Please identify the type of pacemaker and evaluate its function. Please note that in a lot of these cases, more than one right answer is possible.

P
QRS
T

ECG 1

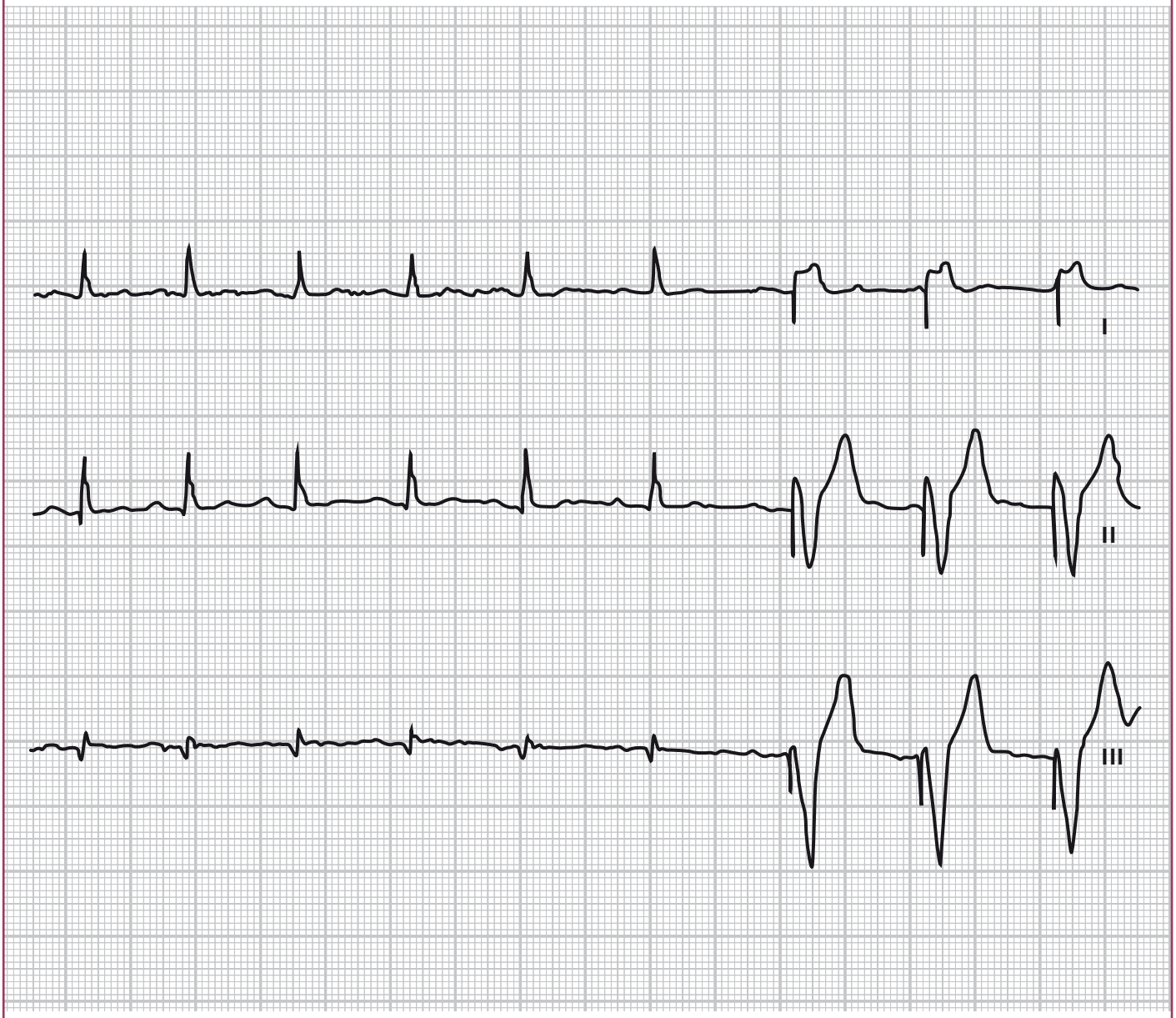


P

QRS

T

ECG 2



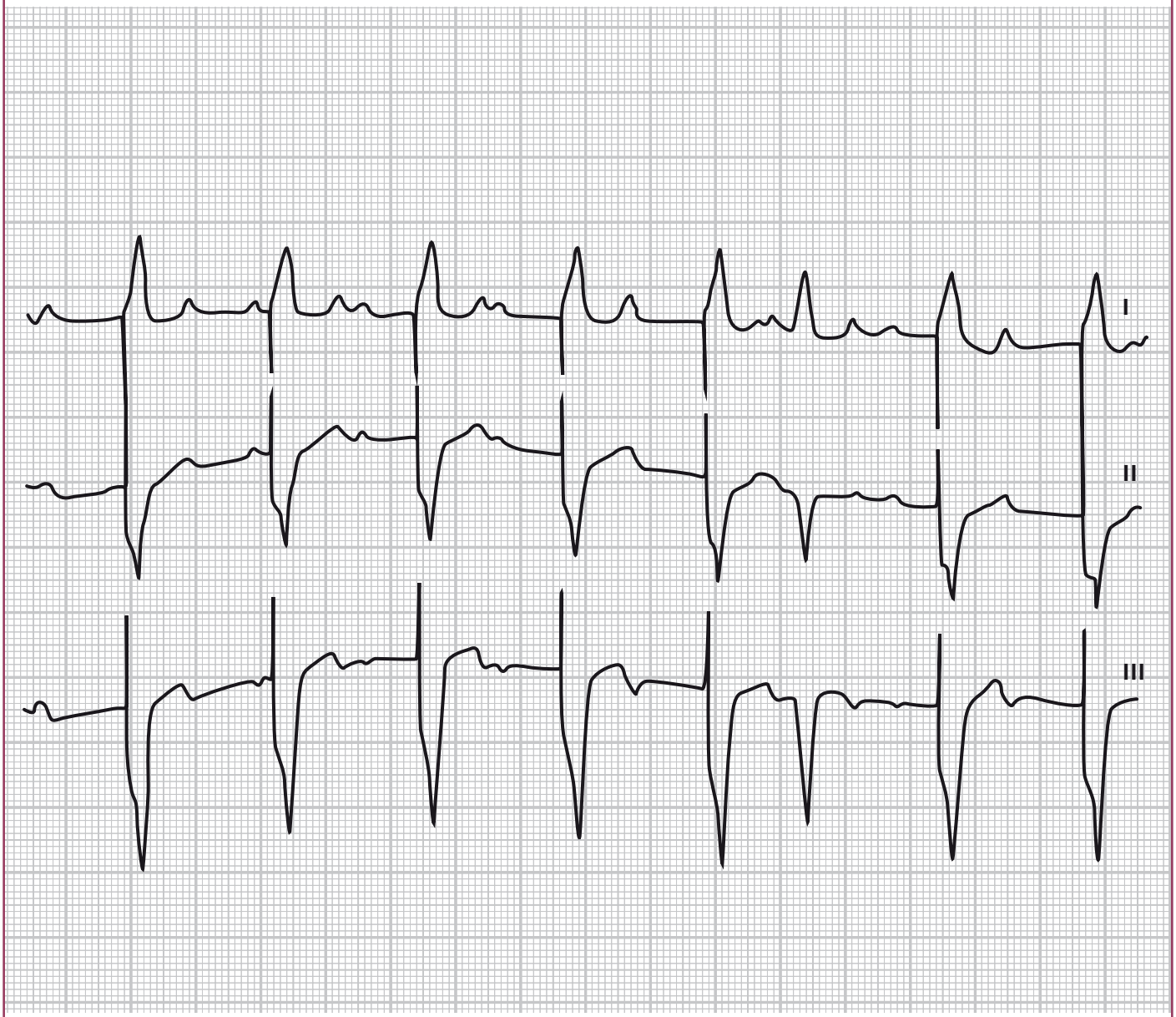
Pacemaker type		Normal PM function?	
VDD	☐	yes	no
VVI	☐	yes	no
AAI	☐	yes	no
DDD	☐	yes	no
other comments:			

P

QRS

T

ECG 3



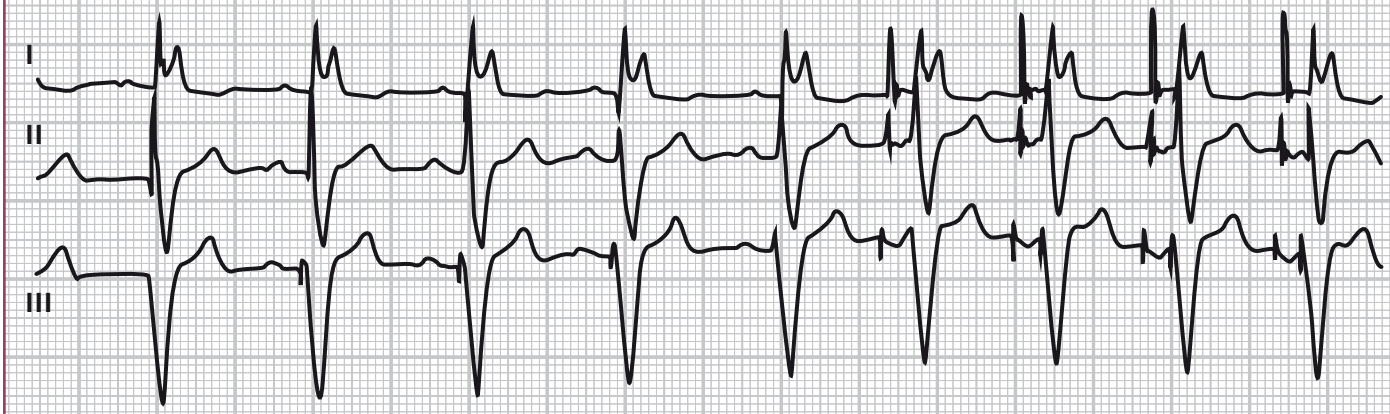
Pacemaker type		Normal PM function?	
VDD	☐	yes	no
VVI	☐	yes	no
AAI	☐	yes	no
DDD	☐	yes	no
other comments:			

P

QRS

T

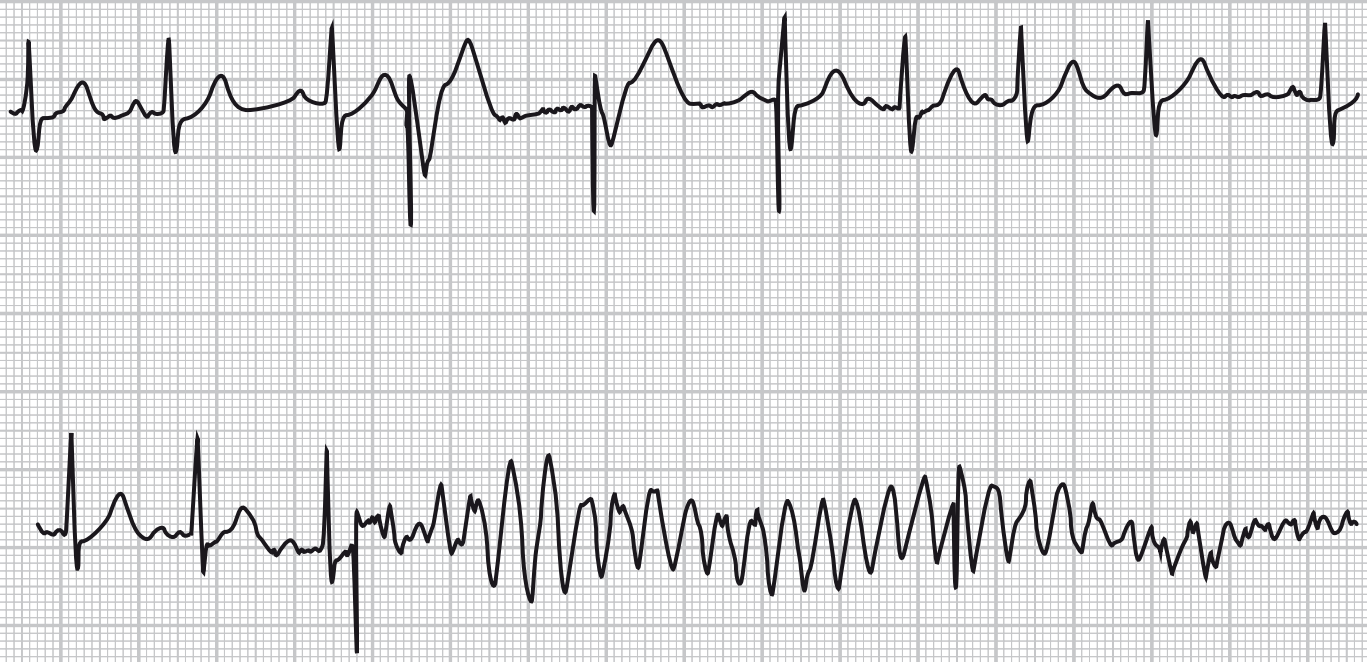
ECG 4



Pacemaker type		Normal PM function?	
VDD	☐	yes	no
VVI	☐	yes	no
AAI	☐	yes	no
DDD	☐	yes	no
other comments:			

P
QRS
T

continuous ECG strip



Pacemaker type	Normal PM function?	
VDD ☐	yes	no
VVI ☐	yes	no
AAI ☐	yes	no
DDD ☐	yes	no
other comments:		

P
QRS
T

ECG 6

Pacemaker type		Normal PM function?	
VDD	☐	yes	no
VVI	☐	yes	no
AAI	☐	yes	no
DDD	☐	yes	no

other comments: