Atrioventricular (AV) Blocks

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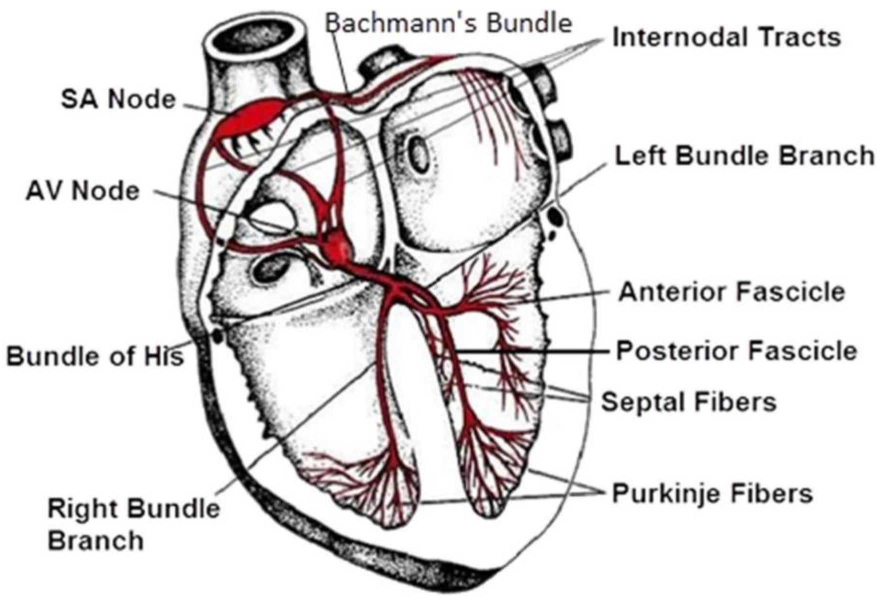
In order to understand atrioventricular blocks (henceforth, AV blocks), we have to know a little bit about the anatomy of the heart's conduction system.

First, an impulse develops spontaneously in the sinoatrial (SA) node which is located in the upper right atrium, just below the opening of the superior vena cava. That impulse then travels to the left atrium and also to the AV node, depolarizing both the right and left atria along the way. Bear in mind that the AV node is *completely within the right atrium* – it is *not* at the junction of the atria and ventricles as so many people think. How does the impulse travel from the SA node?



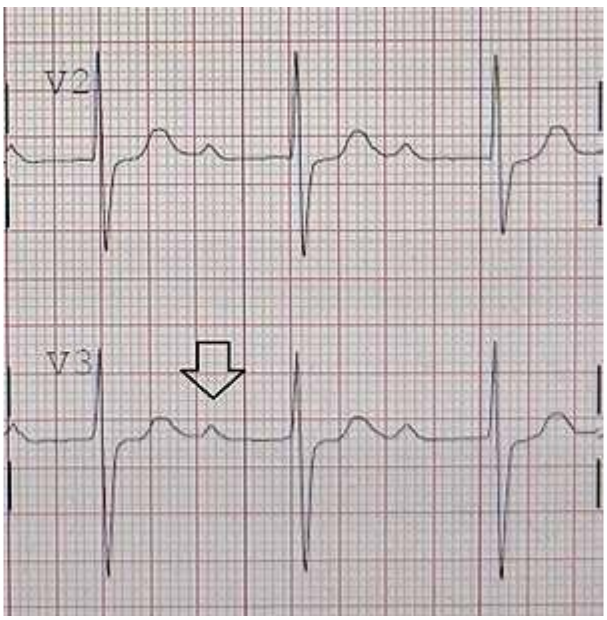
In the *ventricles* there are *Purkinje fibers* that fan out like a spiderweb and conduct impulses extremely rapidly. But there are *no Purkinje fibers in the atria*. Impulse transmission takes place by *cell-to-cell conduction… really fast cell-to-cell conduction*. There are four main "tracts" within the atria that help with impulse conduction. Now, these are not conducting fibers – remember, there are none in the atria. Instead, they are regular atrial myocytes that just happen to be arranged more in an "end-to-end" fashion in those areas which allows for a *more efficient and faster conduction*. Three of those "tracts" run from the SA node to the AV node. A fourth "tract" called *Bachmann's Bundle* (note the two n's) travels from the SA node directly to the left atrium. The three tracts traveling from the SA node to the AV node are called *internodal tracts* – internodal because they travel from the SA node to the AV node. Remember: the heart has only two "nodes" and *both* are contained completely within the right atrium.

Now the impulse has to get into the ventricles so they, too, can be depolarized. A lot of people have the incorrect idea about how that happens. They think the impulse directly enters the ventricles from the AV node. Let me assure you – *it doesn't*. When the impulse leaves the AV node, it enters the *bundle of His*. The bundle of His is the first point at which the impulse is conducted by *actual conducting fibers*. But the first portion of the bundle of His is – like the AV node – located in the right atrium. A short distance down the bundle of His is the point at which the impulse actually crosses from the right atrium into the interventricular septum. Right after it enters the interventricular septum it divides into *two branches* – the *right bundle branch* and the *left bundle branch*. The right bundle branch continues on down the right side of the interventricular septum while the left bundle branch almost immediately divides again into two more branches called *fascicles* – an *anterior fascicle* and a *posterior fascicle*. OK… although there's a lot more to be said about the anatomy of the conduction system of the heart, that is all you need to know to arrive at a clear understanding of the basics of AV blocks.

AV block refers to any interruption of the smooth and rapid transmission of the impulse from the AV node to the myocardium of both ventricles. Notice I did *not* say that it was a *block* of the transmission of the impulse because *not all AV "blocks" are actual blocks*. Let's get started…

First Degree AV Block

First degree AV block is not really a block – it's a *slowing of conduction*. That *slowing* can occur anywhere from the AV node to the first Purkinje-myocyte connection, but it's most often *within the AV node itself*. By definition, it means that the PR interval has exceeded 0.20 seconds (200 msec or one large square) in duration. Remember: when we are measuring distance *horizontally* on the ECG, we are measuring *time* and thus – *duration*. The PR interval (sometimes called a "PQ interval") is measured from the *beginning* of the P wave to the *beginning of the first deflection of the QRS*, which could be a Q wave or an R wave or an S wave. It doesn't *have* to be an R wave or a Q wave. The AV node *normally* has slow conduction, so it really doesn't take much to slow it even further. *Most* cases of first degree AV block are benign and require no treatment. Please understand that while there is an official upper limit for a normal PR interval (0.20 sec or five small squares), there is no official upper limit for a first degree AV block. There is a *medical urban myth* that if the PR interval lasts longer than 0.40 seconds, the P wave failed to conduct. *That is absolutely not true!* P waves occasionally conduct at PR intervals of 0.60 and 0.80 seconds.



And there really is no physiological meaning to 0.20 seconds as the upper limit of normal. It's a *statistical value*, meaning that most people will have a PR interval of 0.20 seconds or less. A patient with a first degree AV block and a PR interval of 0.24 seconds will do just fine.

OK… we've covered first degree AV block – which we found out really isn't a block at all – just a *conduction delay*. First degree AV block should still have a 1:1 conduction (each P wave should be followed by a QRS). (Illustration courtesy of Wikipedia)

Second Degree AV Block

This section I am dividing into three parts because there are *three types* of second degree AV block – *Mobitz I*, *Mobitz II* and *2:1 AV block*. Actually, there's really only two types, but you will understand what I mean when we discuss the third type of second degree AV block.

I am not going to use the name of Friedrich Wenckebach in this discussion (well… I guess I just did!) except to mention that – although he reported on what we now call Mobitz I and Mobitz II AV blocks, he did so *before* the invention of the string galvanometer (i.e., the ECG machine) by Willem Einthoven. And *even before Wenckebach*, Luigi Luciani, an Italian physiologist, reported the same discovery. Actually, Wenckebach himself always referred to Mobitz I AV block as "Luciani periods." It was Woldemar Mobitz who described the blocks as they appear on an ECG. Now, that being said…

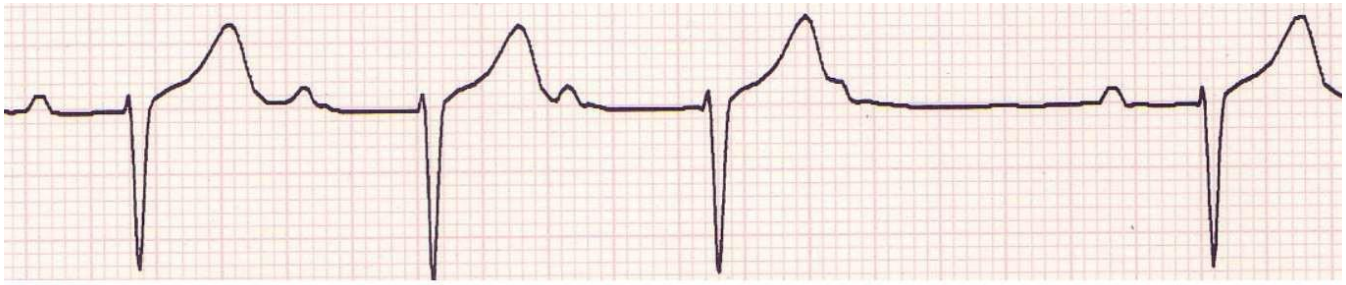
1. ***Mobitz I AV Block***

   We've already commented on how the AV node normally conducts rather slowly. It conducts by a process called *decremental conduction*. What exactly *is* decremental conduction? Decremental conduction means that the more rapidly the impulses arrive at the AV node, the slower they will be conducted through it. With each arriving impulse beyond a certain heart rate, it will take the AV node longer and longer to recover. Eventually, an impulse will arrive and the AV node will not have recovered enough to conduct at all, so there will be a P wave that is not conducted – not followed by a QRS complex. The pause that follows the non-conducted P wave is long enough for the AV node to fully recover, so the next impulse (P wave) that arrives at the AV node conducts normally *with a normal PR interval*.

   This is what a Mobitz I block looks like:

   The first PR interval is *normal.* As you can see, the PR intervals get gradually longer and longer until a P wave eventually fails to conduct. Sometimes when the PR intervals are rather long, it can be difficult seeing the increase in the PR interval duration without using ECG calipers. Here's another example of a Mobitz I AV block…



In this example from my own collection, it is probably easier to see the interval between the end of the T wave and the beginning of the P wave getting shorter and shorter while the PR interval gets longer and longer. There is something else interesting on this rhythm strip – there is also a *simultaneous first degree AV block!* The first and fifth P waves are the first of a Mobitz I *sequence* (sometimes we use the word *episode*) and each indicates a *first degree AV block*. This is *a very common finding in Mobitz I blocks* because, as you remember, *the AV node is already slow* and it conducts with *decremental conduction*. Here's a pearl for you:

PEARL

If determining an increase in the PR interval is difficult due to a long duration for that interval, just look at the interval from the end of the T wave to the beginning of the next P wave. Those intervals are shorter and will easily be seen to decrease progressively, as in this rhythm strip.

Let's say you are sleeping and your parasympathetic nervous system becomes dominant (which is *normal*). The parasympathetic stimulus causes the AV node to conduct slower and slower. Now, your heart rate is just a bit too fast for the AV node to conduct at an even, steady rate. Because of its *decremental conduction* properties, it starts conducting slower and slower and the PR intervals become longer and longer. Eventually, the AV node just doesn't have enough time to recover enough so that it can conduct the next beat and conduction fails – a P wave appears without a QRS to follow it.

This type of Mobitz I AV block is called a *typical* Mobitz I AV block. The blocked P wave is *not really blocked*. We say that "it fails to conduct." So… what's the difference between being *blocked* and *failing to conduct (as in "Gee, Mom… I didn't flunk history – I just failed to pass!")?* Well, a *block is due to a pathological process* – either *anatomic*, such as an *old infarction scar or* a disruption of the conduction system by *age-related fibrosis*, or it can be due to a *metabolic* process, such as *hyperkalemia*.

If an impulse "fails to conduct," the failure to conduct is due to a *temporary physiological change*. In the case of a Mobitz I second degree AV block, that may be nothing more than a little extra *parasympathetic input*. Mobitz I AV blocks are *virtually never permanent*, and, like first degree AV block, they are *generally well-tolerated* and *rarely require treatment*. Many of you reading this article likely had an episode or two of a Mobitz I second degree AV block while you were sleeping last night.

Like first degree AV block, a Mobitz I second degree AV block is also *not considered to be a true block but rather a delay in conduction*. So far, we've learned about two AV "blocks" that really aren't blocks at all.

2. ***Mobitz II AV block***

OK… we've finally arrived at a real, honest-to-goodness *block!* But before we go any further, I want to make sure everyone understands what is meant by "AV block." As I mentioned earlier, an AV "block" is either an *actual block* or a *conduction delay* that occurs somewhere *between the beginning of the AV node and the first ventricular myocyte* to be activated. At no point did I mention AV *nodal* block and that's because *not all of the AV blocks occur in the AV node*. The Mobitz II AV block is one of those. It occurs either within the *bundle of His* or in the *bundle branches* – *usually* in the bundle branches. And, as I said, it is a *true pathological block*.

Before we look at a Mobitz II block, let's think a moment about the implications of how a Mobitz I or a Mobitz II AV block can affect the ventricles. Since a Mobitz I AV block *always* occurs *within the AV node*, when the impulse finally leaves the AV node after its delay, it excites all the fibers of the bundle of His *simultaneously* and then transmits the impulse to the bundle branches *simultaneously*. This results in a *normal-appearing QRS* whose duration is 0.10 seconds or less (assuming there isn't a previously-existing bundle branch block).

But a Mobitz II AV block occurs *below the AV node* (we say it is *infranodal*). It is not going to excite the ventricles rapidly or simultaneously. There will be an *asynchronous discharge of the ventricles*. This is going to result in an *aberrantly conducted ventricular depolarization* with a *widened QRS* that *may* have a classic bundle branch block pattern or something even more bizarre due to the irregularity of the conduction pathway. Here is an example of a Mobitz II second degree AV block:

There are several points to make about this rhythm strip. First, note that all the PR intervals remain the same. There are no changes in the PR intervals. Second, notice that the QRS complexes are widened – in this case there is a *classic RBBB morphology*.

So, considering that the right bundle branch is blocked *completely*, what has happened to produce the blocked P waves (red arrows)? With the right bundle branch completely blocked, the left bundle branch has been the *only* lifeline from the AV node to the ventricles. This patient is being kept alive by just one bundle branch. “Well,” you say, “millions of people have chronic right bundle branch blocks and they do quite well. What’s different about this?” I would reply that while that is true, *this patient is not being kept alive by the same type of healthy left bundle branch*. His or her left bundle branch is *severely diseased* and has failed to conduct twice just on this very short rhythm strip leading to *two episodes of momentary complete heart block!*

So, let me amend my previous statement: “This patient is being kept alive by just one *severely diseased* bundle branch *that has already begun to fail*.” This is why a Mobitz II AV block is an indication for *immediate pacemaker placement*. A Mobitz II AV block is essentially an intermittent third degree AV block and it is ALWAYS very pathological. If you were to see this ECG on a patient who is in your office, you would immediately call for a paramedic ambulance transport to the emergency room. If you were to see this patient in the emergency room, you are not going to let this patient go home without a pacemaker. Here’s a pearl to help you distinguish between Mobitz I and Mobitz II AV blocks (it does *not*, however, help with 2:1 blocks coming up next):

PEARL

Mobitz I AV Block: *The duration of the PR interval immediately* *<u>before</u>* *the non-conducted P wave will always be longer than the PR interval immediately* *<u>following</u>* *the non-conducted P wave. ALWAYS!*

Mobitz II AV Block: *The PR intervals occurring immediately* *<u>before</u>* *and* *<u>after</u>* *the non-conducted P wave will always be* *<u>exactly the same duration</u>*. *ALWAYS!*

3. ***2:1 AV Block***

   Remember at the beginning of this section on second degree AV blocks when I said that there are *three types of second degree AV blocks* – but in actuality, there are *really only two*? This third type is the reason for that statement. Let me explain…

   A 2:1 second degree AV block consists of a P wave, a resulting QRS followed by a non-conducted P wave. Then the sequence starts all over again. What kind of AV block can result in that pattern? *Both Mobitz I and Mobitz II second degree AV blocks* can result in this pattern. Then why not call them by their names? The reason is that we cannot rule out a Mobitz I block because we only have *one PR interval in each sequence*. We would need at least *two PR intervals* to determine whether the PR intervals were increasing or not. In the case of a 2:1 block we just can't know for certain, so we "hedge" and call the sequence a 2:1 block. You may be tempted to say "But a Mobitz II block will always have a wide QRS." That's true, but there is no rule that says a Mobitz I block can't have a pre-existing bundle branch block or non-specific interventricular conduction delay, either. *Don't try to make a distinction – until you have a lot more experience with second degree AV blocks, just call it a 2:1 block and then get a cardiology consult*.

Third Degree (Complete) AV Block

This has got to be one of the most misunderstood concepts of electrocardiography. And it is also rife with misinformation in articles, textbooks and throughout the internet. If I were to ask you "How does one recognize a third degree AV block?" you might possibly reply "Well, the P waves and the QRS complexes show no relationship to each other." And you would be… WRONG!

What you just described is a situation called *AV dissociation*. And yes, *every* case of third degree AV block demonstrates AV dissociation. But third degree AV block only accounts for probably less than 10% of cases of AV dissociation. So, you see, if you used that definition you would be wrong *over 90% of the time!* And when doctors misdiagnose simple AV dissociation as third degree AV block, patients end up receiving pacemakers they never needed. There has to be a more specific definition – and there is! Obviously, the AV dissociation is likely to be the first thing that catches your eye – and that's good! But now that it has your attention, you have a decision to make – is this *AV dissociation due to third degree AV block* or something else… *something much more benign*?

Here's the difference between third degree AV block and regular AV dissociation: in regular AV dissociation – *not caused by third degree AV block* – a P wave will conduct as soon as it has the *opportunity* to conduct. The AV node is not blocked by a pathological process but rather a physiological refractoriness due to the fact that another pacemaker is activating it faster than the SA node. As soon as there is an opening in the rhythm for a P wave to slip through the AV node and activate the ventricles, it will do so. How do you know this has happened? There will be an *abrupt irregularity of the R-R intervals*. One R-R interval will suddenly be shorter than the others. The QRS that ends that "shorter-than-expected" R-R interval is the result of the preceding P wave that conducted.

The more specific part of the definition of third degree AV block is that ***<u>you must show that the P waves had every opportunity to conduct – but failed to do so</u>***. This is the most important part of the definition of third degree AV block and it is almost always omitted. In order to do this, you must *demonstrate P waves throughout diastole (from the end of the T wave to the beginning of the QRS complex) without any change in the ventricular rhythm*. Here is where you have to focus your attention (red arrow indicates *diastole*):

What happens when a third degree AV block occurs? Since there is no longer any transmission of atrial impulses to the ventricles, one of two escape pacemakers will be activated: the *junctional escape pacemaker* or the *ventricular escape pacemaker*. If the third degree AV block has developed within the AV node itself (and some do!), the junctional escape pacemaker will usually take over as the heart's effective pacemaker. This is the best-case scenario. The escape rhythm of the junctional pacemaker is usually from 40 to 60 beats/minute. This is usually fast enough to keep someone alive – often with a normal blood pressure and sensorium. And it tends to be a very *stable* and *reliable* rhythm.

But sometimes the third degree AV block occurs *below* the level of the junctional escape pacemaker, so the junctional escape pacemaker cannot be of any help. In those cases, we must rely on the *ventricular* escape pacemaker. Let me tell you about ventricular escape pacemakers:

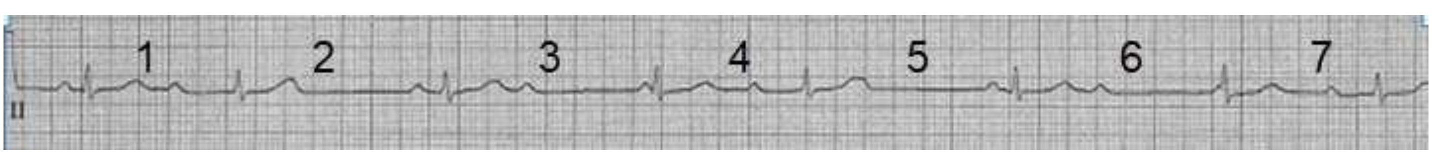
they are *very unreliable*. You can never be too sure if it is going to activate and, if it does, you have no idea how long it will last. Also, the intrinsic escape rate is from around 20 to 40 beats/minute. Now consider this: who develops third degree AV blocks resulting in a ventricular escape pacemaker? Young, fit athletes in peak condition? NO! It's likely to be an elderly person with compromised cardiovascular, pulmonary and renal systems – and 20 beats/minute is not going to sustain them!

To differentiate between a simple AV dissociation, which is often resolved by having the patient get up and walk around a bit, or a third degree AV block requiring an emergency permanent pacemaker, here are a few things to look for:

All escape rhythms – whether junctional or ventricular – are going to be *very, very regular*. Any sudden interruption of that regularity means that a P wave managed to cross through the AV node and the bundle branches and activated (or "captured") the ventricles. We call those beats *capture beats*. ***A capture beat always ends an R-R interval that is shorter than the other R-R intervals*****.** ALWAYS! It is easy to miss this fact if the ventricular rate is very slow. You will often need ECG calipers to make the distinction – *there is no way around this!* Here is an example of *real* third degree AV block:

There are a number of P waves throughout diastole (from the end of the T wave to the beginning of the QRS) but none of them conduct. We can also see that – although there are only two R-R intervals – they are the same size and have not been affected by any of the P waves. The longer tracing showed no variation in the R-R intervals.

How about *this* tracing:



At first glance, it certainly appears that none of the P waves appear to have any association with the QRS complexes. But – if we look more closely and use the knowledge we just learned – we also see that there is some variation in the length (duration) of the R-R intervals. The 1st, 4th and 7th R-R intervals are shorter than the others. The longer R-R intervals have exactly the same duration. ***This is NOT a 3rd degree AV block!*** It is simply a case of AV dissociation *without* any AV block. Each of the shorter R-R intervals ends with a QRS that is a result of the preceding P wave. Here's what's *really* interesting: all the P waves that actually managed to conduct, *conducted with a first degree AV block*. The only two "normal" PR intervals on this strip were NOT the result of an AV nodal conduction *because neither one shortened the R-R interval*.

Here is a pearl to help you better understand this concept:

PEARL

During AV dissociation, some P waves will appear to have a normal PR interval following them. That is coincidence! If the QRS does not end a shortened R-R interval, then the P wave and the QRS have no relationship – no matter how "normal" the PR interval appears. In instances of AV dissociation, don't look for "normal" PR intervals to indicate successful AV conduction – look for shortened R-R intervals!

Third degree AV block can occur within the AV node itself or infranodally, in the bundle of His or in the bundle branches. When third degree AV block occurs *within the AV node*, it usually has an excellent prognosis – often resolving completely within a few days to a few weeks – sometimes even within a few hours! If the third degree AV block occurs *below the AV node* (infranodal), it is due to considerable destruction of the conduction system, is permanent and also quite lethal!

PEARL

Pure AV Dissociation – An occasional R-R interval will be shorter than the others.

AV Dissociation Due To Third Degree AV Block – There will be no variation in the R-R intervals, Even if there appear to be an occasional "normal" PR interval, the R-R intervals never vary.

To make these distinctions, you will often need a rhythm strip that is much longer than the 10-second strip on a standard ECG recording.
