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Simple atrioventricular (AV) dissociation or AV dissociation caused by third degree AV block?

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1. Introduction

One of the most difficult decisions for many physicians and advanced practice providers occurs when having to distinguish between simple atrioventricular (AV) dissociation and AV dissociation caused by a third degree AV block. Third degree AV block is only one cause of AV dissociation and it is a very infrequent cause. The majority of simple AV dissociations are caused by variations in the balance of sympathetic and parasympathetic inputs from the autonomic nervous system. All of us probably experience an occasional episode of simple AV dissociation while we are asleep. Treatment for simple AV dissociation may be as simple as having the patient get out of bed and walk around the room a few times, while AV dissociation caused by a third degree AV block is going to require an emergent placement of a permanent pacemaker. In order to make this decision properly and confidently, you must have a very clear understanding of the difference. Here, in this educational paper, we aim to discuss more in this regard (1-6).

Most people define third degree AV block as "The P waves and QRS complexes are unrelated to each other." Not only is that statement not an accurate definition of third degree AV block, it is also not a very good definition of simple AV dissociation. AV dissociation is caused by the presence of two independent pacemakers, one in the atrium and one in the ventricle. Both pacemakers discharge impulses at their own fixed rate. These two rates form a ratio which eventually will result in an "opening" during the two rhythms that will allow an impulse from the atrium to pass through the AV node and capture the ventricles. So, in contrast to the definition above, there actually is occasional association between the atrial impulse (P wave) and the following QRS complex during simple AV dissociation. The ventricular depolarization (QRS complex) that results from the atrial impulse that succeeded in crossing through the AV node is called a capture beat.

2. What causes simple AV dissociation?

The most common cause of AV dissociation is slowing of the sinus node rate. There exists a hierarchy of accessory pacemakers throughout the heart, a type of "failsafe" system to keep us alive in case the sinus node should fail. These accessory pacemakers are located in certain areas of the right atrium, the AV junctional area and in the Purkinje system of the ventricles. Each of these accessory pacemakers has its own rate of depolarization which takes longer than depolarization of the sinus node. That is why the sinus node is the dominant pacemaker of the heart. Each time it fires, the impulse created passes by and through all the other accessory pacemaker foci, discharging and resetting their timing. This is referred to as "overdrive suppression". In the event the sinus node fails, or at least slows to a rate that is less than the next pacemaker in the hierarchy, that pacemaker will "awaken" and start discharging impulses (usually at its inherent rate) which is referred to as an "escape rhythm". When the sinus node slows too much, the next pacemaker to step in is typically the junctional accessory pacemaker and not an atrial accessory pacemaker. We don't see atrial accessory pacemakers very often, though they do make an occasional appearance. One reason is that we may be overlooking them: an atrial accessory pacemaker that is located near the sinus node may take over the function of pacing the heart with a P wave that is morphologically very similar to the sinus P wave at a rate that is very similar to the sinus rate. Another reason is that whatever caused the sinus slowing or failure also may have the same effect on the atrial accessory pacemakers.

The junctional accessory pacemaker escape rate is between 40 – 60 beats/minute; a ventricular escape rate is between 20 – 40 beats/minute. Occasionally, one of the accessory pacemakers may develop "enhanced automaticity" in which the accessory pacemaker begins to discharge faster than the upper limit of it inherent (or escape) rate. This will also result in a simple AV dissociation.

When simple AV dissociation occurs, because the sinus rhythm has slowed to a rate less than that of the next accessory pacemaker in the hierarchy, we call that AV dissociation by default. The sinus node has allowed the accessory pacemaker to take over "by default." When simple AV dissociation occurs because an accessory pacemaker has spontaneously begun to discharge itself at a rate that is faster than the prevailing sinus rate, we call that AV dissociation by usurpation. The abnormally rapid rate of the accessory pacemaker has "usurped" the role of the sinus node as the pacemaker of the heart.

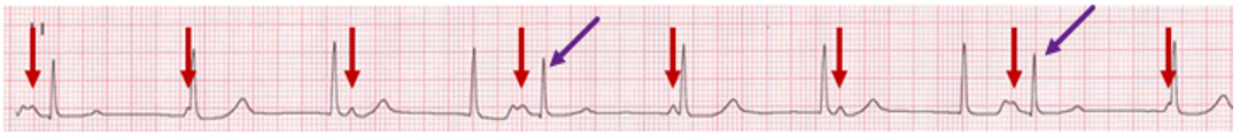

Figure 1 AV dissociation without third degree AV block; P waves (red arrows) and capture beats (blue arrows)

Figure 2 Examples of fusion beat: normal beat (blue circle), ventricular ectopic beat (red square) and fusion beat (black square)

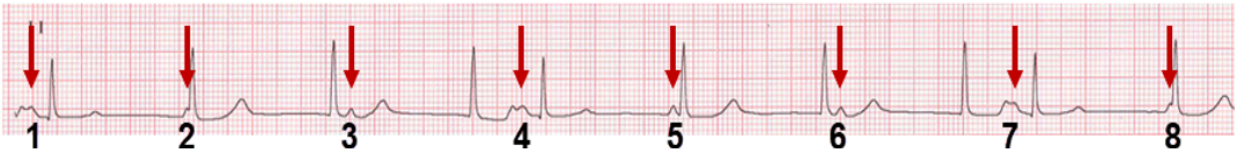

Figure 3 AV dissociation without third degree AV block with numbered P waves

3. Determine the sinus rate and rhythm

In the electrocardiogram (ECG) presented in figure 1, the first obvious finding is the inconsistent relationship between the P waves and the QRS complexes. The second obvious finding is that, while the P-P intervals are very regular, the R-R intervals are not! All the R-R intervals on the strip (Figure 2) are the same duration except for two. We know that the escape rhythm here is junctional because the QRS complexes are narrow and of normal duration. Escape rhythms are very regular, more so than sinus rhythm because they are not influenced by the autonomic nervous system. Each capture beat (QRS), marked with blue arrows in figure 2, is visibly smaller than the QRS complexes of the junctional escape rhythm. Again, the real significance of the capture beat lies in the fact that it appears early; its morphology is not pertinent. Each of the short R-R intervals ends with a QRS that was captured by a P wave that passed through the AV node and depolarized the ventricles, resulting in a sinus-conducted QRS complex, which is a capture beat. Here is a very important point: **a capture beat always appears "out of sync" with the rest of the ventricular rhythm.** It will always appear early, sometimes very obviously early, sometimes only slightly early. A capture beat does not have to look like a "normal" QRS, either. Because of the circumstances of its appearance, it may be aberrantly conducted. But the point is: **it will appear earlier than expected for the prevailing ventricular rhythm.**

Another sign of AV dissociation is a fusion beat. This is a type of capture beat that appears at about the same time that the ectopic QRS occurs. It may not appear to be early. The morphologies of the two beats blend, with the fusion beat having aspects of both beats. Generally, the first portion will resemble the sinus-conducted beat and the second half will resemble the ectopic beat. Fusion beats have the same significance as a capture beat, but they are more apt to be seen at the beginning and end of an episode of AV dissociation (Figure 2).

Simple AV dissociation is mostly a process of one impulse colliding with another, causing one of the impulses to fail to conduct. In other words, if a P wave cannot conduct to the ventricles and depolarize them, it will be because it has encountered another impulse that left refractory tissue in its path. This is a normal physiological consequence of an impulse encountering myocardium that is temporarily refractory. Therefore, if a P wave fails to capture the ventricles, it will be because of a physiological refractoriness of the myocardium and not a pathological process resulting in a true block! Therefore, during the course of a simple AV dissociation, any P wave that fails to conduct to the ventricles should have an obvious reason for not conducting that is easily discernible from the ECG or rhythm strip (figure 3).

Let's begin with P wave #2: the P wave is too close to the onset of the QRS to conduct; #3: P wave is within the refractory period of the ventricles; #4: P wave managed to conduct and produce the QRS that follows it (shorter R-R interval); #5: P wave is too close to the QRS to have conducted; #6: P wave falls during the refractory period of the ventricles; #7: P wave managed to conduct and produce the QRS that follows it (shorter R-R interval); #8: P wave is too close to the QRS to have conducted. As you can see, every P wave that failed to conduct during this episode of simple AV dissociation had an obvious physiological reason for not conducting. There are two main physiological reasons for a P wave to fail to con-

Figure 4 AV dissociation with third degree AV block

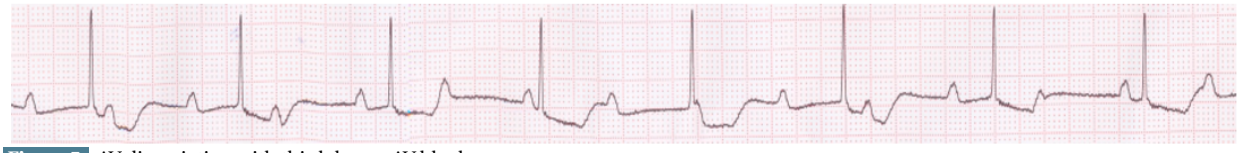

Figure 5 AV dissociation with third degree AV block

Figure 6 Simple AV dissociation with an interfering PVC

duct:

1. The **PR interval** it makes with the following QRS complex is too short to have allowed conduction to occur. This usually applies to any PR interval less than 0.120 seconds. (#2, #5 and #8)

2. The **RP interval** is too short to allow conduction. The His-Purkinje system is still refractory from the previous depolarization (QRS complex). Because this depends on the refractoriness of the ventricular conduction system, which is not seen on the ECG rhythm strip, a non-conducting RP interval can be quite variable and may include P waves that appear after the end of the T wave. (not shown on this strip)

Please note that if the QRS complex remains "in sync" with the rest of the prevailing ventricular escape rhythm, then the preceding P wave did NOT conduct to the ventricles. This is a concept that many people fail to recognize: during ANY AV dissociation, a "normal" PR interval does NOT necessarily imply that the P wave conducted, producing the QRS complex.

So, these are **My Three Rules for Simple AV Dissociation:**

Rule 1: An inconsistent relationship between the P waves and the QRS complexes

Rule 2: Occasional QRS complexes that appear "out of sync" (must be seen!)

Rule 3: P waves that fail to conduct will have a physiological reason for not conducting.

4. AV dissociation caused by third degree AV block

When a third degree AV block occurs, no impulses from the atria can travel through the AV node. Because of that, an escape rhythm will appear. Which escape rhythm is determined by the location of the third degree AV block. If the block is in the AV node itself, often seen with acute inferior myocardial infarctions, the escape rhythm is likely to be junctional. Even if the block is in the junctional area itself, the escape rhythm may still be junctional since there are different levels in the AV junction. As stated earlier, escape rhythms tend to be precisely regular. Remember the irregularity in the ventricular rhythm caused by a capture beat during a simple AV dissociation (Figure 1); that cannot happen when the AV dissociation is due to a third degree AV block. There will be no premature QRS complexes unless a premature ventricular contraction (PVC) occurs. Figure 4 shows a rhythm strip demonstrating AV dissociation caused by a third degree AV block with a ventricular escape rhythm.

Though the rhythm strip is short, there is no interruption of the ventricular rhythm which is precisely regular. There are also a number of P waves that had the opportunity to conduct, but did not! That is a very important distinction between simple AV dissociation and AV dissociation due to third degree AV block. Although the ventricular rate may be slow in both simple AV dissociation and AV dissociation due to third degree AV block, the rate during a third degree AV block should be less than 50 beats/minute for a more confident diagnosis. Figure 5 shows AV dissociation caused by third degree AV block with a junctional escape pacemaker. As you can see, the junctional escape rhythm is precisely regular, the sinus rhythm is regular, there is obvious AV dissociation present and there are P waves during diastole that had every opportunity to conduct, but didn't!

These are **My Three Rules for Diagnosing AV Dissociation Due to Third Degree AV Block**:

Rule 1: AV dissociation must be present

Rule 2: No interruption of the regular ventricular rhythm

Rule 3: P waves present during diastole that did not conduct when given the opportunity

5. Rate and diagnosis

Whenever we discuss heart "rate" during a dysrhythmia analysis, we really mean two rates: atrial and ventricular. Since the main cause of simple AV dissociation is slowing or failure of the sinus node, it should be apparent that the escape pacemaker will have a rate that is faster than the sinus rate. So, in simple AV dissociation, look for a sinus rate that is slower than the ventricular rate. During AV dissociation due to third degree AV block, the sinus node is usually not involved in the pathological block process. Therefore, the sinus node continues to fire at its regular rate. But because it cannot result in ventricular depolarization, accessory escape pacemakers will appear, either in the junctional area (preferred) or in the ventricular Purkinje system. The sinus node can no longer suppress these accessory pacemakers through overdrive suppression so either one may activate. Thus, the sinus rate remains faster than the ventricular rate.

A junctional escape rhythm is preferred because it is a dependable, stable rhythm with a rate that can sustain life and the function of vital organs. For this to happen, the AV block must be in the AV node itself or very high in the junctional area.

A ventricular escape rhythm appears when the AV block occurs below the lowest junctional accessory pacemaker. This is usually not a good sign. The ventricular accessory pacemaker is often very unreliable, you can never be sure that it will even begin to function and, if it does, you can't be certain how long it will last. Also, because its intrinsic rate is so slow, it may prove insufficient to maintain life and/or the functioning of vital organs.

6. Pearl learning points

First, during the course of AV dissociation – whether simple or caused by third degree AV block – there will be instances of a P wave and QRS complex separated by a normal or nearly normal PR interval. This is a trick the ECG is playing on you! If there has been no interruption of the ventricular rhythm, then there is still no association between that P wave and the QRS complex that follows, even if the PR interval is normal.

In figure 5, the 3rd, 4th, 7th, and 8th QRS complexes are preceded by PR intervals that could be considered conductible. But the R-R intervals never vary! Those P waves did NOT conduct, even though they look like they SHOULD have conducted. This is a very frequent mistake. Pay very close attention to the R-R intervals: if there has been no interruption of the ventricular rhythm, then there has been no sinus conduction to the ventricles.

Second, you may need a rather long rhythm strip to make this determination. During simple AV dissociation, a capture beat may take longer than 10 seconds (the usual length of an ECG tracing with its rhythm strips) before it makes an appearance. In the emergency department, I would frequently order rhythm strips that were about two meters long before deciding on a diagnosis.

7. An example for training

Here is an example of a Lead II rhythm strip demonstrating simple AV dissociation along with a PVC that interrupts the junctional pacemaker rhythm but not the sinus rhythm (Figure 6).

Note that the ectopic junctional pacemaker is firing much faster than its intrinsic rate. This is not an escape rhythm. This junctional focus has undergone enhanced automaticity – and that is not normal! It has overtaken the sinus node NOT because the sinus node is firing too slowly; it's because the junctional accessory pacemaker is suddenly firing much too fast. This is AV dissociation by usurpation. Find a clear P-P interval to measure (there are some in the middle of the strip). Using that measurement, assure yourself that all the P-P intervals are the same – they even march through the PVC with no interruption. That means the PVC did not enter the atrium and consequently had no effect on the sinus node.

The two junctional beats that surround the PVC have resulted in a non-compensatory pause because the PVC did succeed in discharging and resetting the junctional ectopic pacemaker. The first junctional beat that occurs after the PVC is out of sync with the preceding junctional beats. The PVC entered the junctional ectopic pacemaker focus and reset it. Find the capture beat located near the middle of the strip (it ends the short R-R interval). Measure the PR interval of that capture beat (the P wave is located at the end of the previous junctional beat). Note that the capture beat (early QRS) is "out of sync" with the rest of the junctional rhythm. Also note two things about the PR interval of the capture beat: first, it is prolonged and second, it ends with an aberrantly conducted capture beat.

Does this patient normally have a first degree AV block? I doubt it, though we would really need to see a succession of normally-conducted P waves to determine that. A PR interval that is prolonged for just one or two beats does not indicate a first degree AV block. With first degree AV block, all the sinus-conducted beats will have the same prolonged PR interval.

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