



### OVERVIEW OF THE ECG

This ECG shows an irregular bradycardia with a ventricular rate of 36bpm. The QRS complexes are borderline wide (100ms). Each QRS complex is preceded by a P wave. The P wave morphology is consistent with sinus P waves with a fixed PR interval of 160ms. QRS axis is 0 degrees. The T waves are notched (2 peaks or deflections noted).

### MORE DETAILED ANALYSIS OF THE ECG

At a first glance, this rhythm appears to be sinus bradycardia. However, every bradycardia needs exclusion of AV block. A fixed PR interval excludes complete heart block, but second degree heart block like 2:1 AV block needs to be excluded. No P waves are seen half-way between any 2 conducted P waves which excludes 2:1 AV block.

The T waves have an unusual morphology and are notched. While T waves per se can be notched i.e. can have 2 peaks – other causes of T wave notching include U waves and P waves superimposed on T waves. In this ECG, the notching is seen in all 12 leads with a high-frequency component causing a peak which is not usually seen with isolated T wave notching.

A U wave is a low-amplitude, low-frequency deflection following the T wave. U waves are typically concordant with the T wave with a distance of at least 150ms (widely spaced) between the peak of the T wave and U wave and less than 1 - 2mm in amplitude. In this ECG, the notching is very tightly spaced (80ms), with a discordant notched T wave in V1. These findings are not compatible with U waves. U waves are typically seen in leads V2 and V3 in patients with a bradycardia and can be large in patients with hypokalaemia. See Figure 1.

This high frequency component of the T wave is most likely a non-conducted P wave superimposed on a T wave. While the morphology of the non-conducted P wave is difficult to determine because it is distorted by the T wave, the prematurity of this non-conducted P wave excludes a sinus P wave and 2:1 AV block.

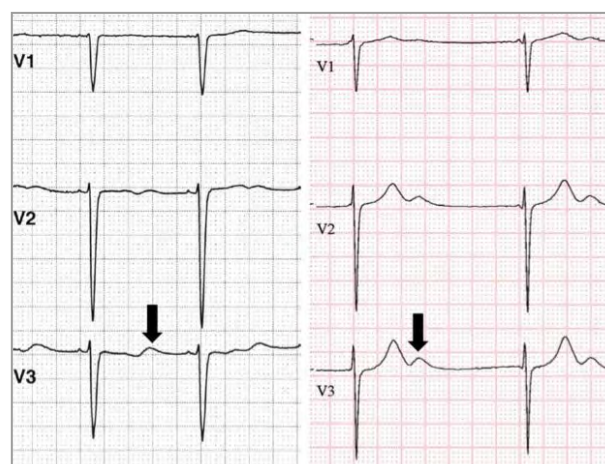
Sinus rhythm with 2:1 AV block with ventriculophasic sinus dysrhythmia is an important differential. In this condition (usually seen complete heart block or with 2:1 AV block), the atrial cycle length slightly shortens (<5% change in atrial cycle length) when a QRS complex occurs between 2 P waves.<sup>(1)</sup> As

the P wave following the QRS complex occurs slightly prematurely, this can sometimes be confused with non-conducted PACs. This is probably due to acute vagal baroreceptor feedback on the sinus node which delays the P wave following the non-conducted P wave. See Figure 2. In this ECG, the non-conducted P wave occurs too prematurely for this to be a non-conducted sinus P wave.

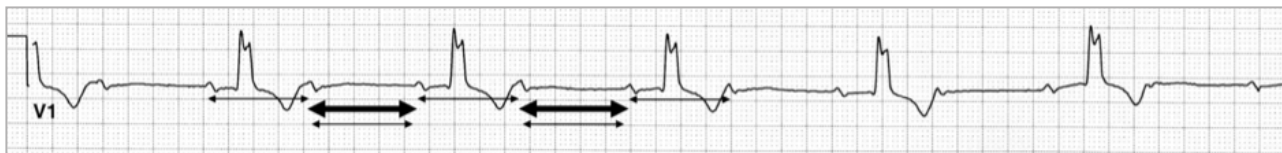
**The answer is therefore c) Non-conducted premature atrial complexes (PACs).**

This patient had a 24 hour Holter which confirmed both intermittent conducted and non-conducted PACs (Figure 3). Conduction of the P waves is dependent on the refractory period of the AV node. In this case, the timing of the PAC occurred at the refractory period of the AV node which explains the reason for intermittent PAC conduction. Non-conducted PACs may reset the timing of the sinus node. In this case, full compensatory pauses occurred (sinus node was not reset) after every PAC, which results in a very slow ventricular rate. This is seen in Figure 3 where the sinus rate of 2 consecutively conducted sinus P waves (around 104bpm) is exactly double the sinus rate interspersed by a non-conducted PAC (52bpm).

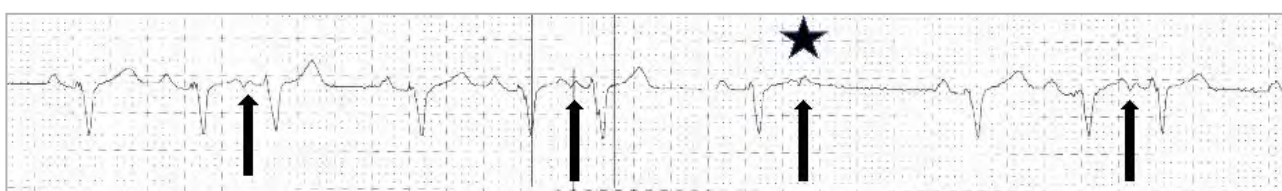
In this case, the patient had only mild symptoms and no treatment was necessary.



**FIGURE 1: U waves (arrows) in patients with hypokalaemia (left) and bradycardia (right).**



**FIGURE 2: 2:1 AV block with ventriculophasic sinus dysrhythmia.** Note that the P-P intervals either side of the QRS complexes (thin arrows) are shorter than other P-P intervals (thick arrows).



**FIGURE 3: 2:1 Holter strip from this patient confirming three conducted PACs and one non-conducted PAC (arrows).** Note the non-conducted PAC (star). Full compensatory sinus pauses occur following the PACs. When the PAC is non-conducted this results in a bradycardia.

## DISCUSSION

Premature atrial complexes (PACs) are frequently encountered in everyday practice. When PACs occur when the AV node is in the absolute refractory period, they block in the AV node and are unable to conduct to the ventricles. Occasionally, PACs conduct with a longer PR interval than sinus rhythm due to decremental physiological AV nodal conduction.

Non-conducted PACs must be distinguished from isolated notched T waves, U waves and 2:1 AV block with ventriculophasic sinus dysrhythmia (especially if the P waves are slightly premature). The latter is particularly important to diagnose as permanent pacing is indicated. Holter monitoring can be useful to distinguish the various conditions – in this case, PACs with intermittent conduction are particularly helpful to confirm the presence of PACs.

Non-conducted PACs with minimal or no symptoms do not require treatment. The treatment of frequent symptomatic non-conducted PACs can be challenging. Although beta-blockers may reduce the number of PACs and potentially improve symptoms, PACs may still occur and full compensatory sinus pauses may prolong with beta-blockade and potentially worsen symptoms. Flecainide has been used to reduce the

number of PACs. Catheter ablation of the PACs can also be considered.<sup>(2)</sup> This may be the rare indication for catheter ablation for a patient with a bradycardia!

## SUMMARY

T wave notching has a differential diagnosis of premature atrial complexes, isolated T wave notching and 2:1 AV block with ventriculophasic sinus dysrhythmia.

Non-conducted PACs may result in full-compensatory sinus pauses and may result in a profound bradycardia.

## REFERENCES

1. Dadu RT, McPherson CA. The ventriculophasic response: Relationship to sinus arrhythmia and the duration of interposed QRS complexes. *Ann Noninvasive Electrocardiol.* 2013 Jul;18(4):336-43.
2. Alper A, Gungor B, Turkkan C, Tekkesin A. Symptomatic bradycardia caused by premature atrial contractions originating from right atrial appendage. *Indian Pacing Electro-physiol J.* 2013 Jun 25;13(3):114-7.

**Conflict of interest: none declared.**