Teachable Moments in ECG: The Physiology Behind the Pattern

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ABSTRACT

The electrocardiographic analysis of heart blocks provides great opportunities for the discussion of mechanisms of electrical cardiac conduction, serving as "teachable moments" in medicine. Recognition of heart blocks can sometimes be a challenge as they can present in many forms, different severities and levels of blocks that present as varied patterns on electrocardiographic tracing. The ultimate key to correct diagnosis rests on adequate understanding of normal electrophysiology of the electrical system of the heart. While it is vital to recognize the pattern, we should always know and understand the physiology behind the pattern. This article presents a detailed analysis of a case of heart block which can easily be misinterpreted on first look. The case is featured not for its rarity but for the interesting concepts in cardiac electrophysiology that are highlighted. Navigation of the different elements of tracing can be an adventure and a great learning experience enjoyed by both students and experts.

Keywords Heart block, ECG, electrocardiography

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INTRODUCTION

The electrocardiograph (ECG) has stood as a very important tool in the diagnosis of cardiovascular diseases and other important medical conditions, and as a fundamental of clinical practice.[1] ECG interpretation is an important skill acquired by physicians, internists, cardiologists and other subspecialists through years of training and experience, and most of all, actual cases and electrocardiographs deciphered, dissected and diligently discussed. Through the years, it has evolved into a teaching tool where the teacher and pupil connect and engage in stimulating discussions about various aspects related to the case and to cardiovascular medicine. These "teachable moments" in ECG are priceless treasures that can serve as opportunities for learning and improving one's knowledge and skill in interpretation. The ECG analysis and interpretation of heart blocks can be one great "teachable moment". Heart blocks can present in different levels of severity which can appear as different patterns on ECG tracing. While quick recognition of this condition relies on identification of ECG patterns, a deeper understanding of the electrical basis and electrophysiologic mechanisms of the pattern is imperative and will reduce the likelihood of error.[2]

Case Description

A 91-year-old female patient who was admitted for pneumonia presented with bradycardia and the following electrocardiogram (ECG) tracing (Figure 1). The patient had stable vital signs with blood pressure 110/70 mmHg, heart rate 50 bpm, respiratory rate 16 cpm.

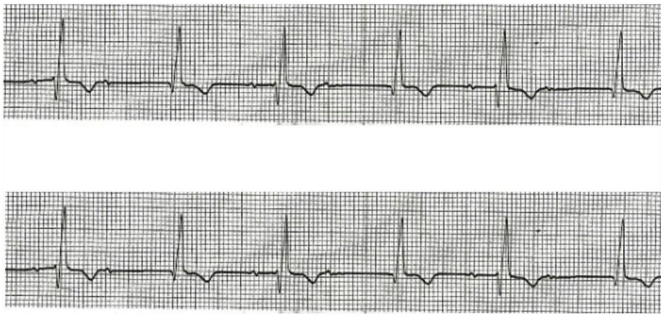

Figure 1. Single lead (V1) continuous ECG tracing from the patient

Figure 3. A third P wave, P3, is demonstrated as hidden in the second QRS complex, the junctional escape beat, pointing to a 3:1 AV block. Note the subtle differences in the QRS pattern between R1 and R2, indicating different depolarization mechanisms.

DISCUSSION

This single continuous ECG tracing taken from lead V1 shows a slow "regularly irregular" rhythm. The R to R interval alternates from 1040 ms and 940 ms (heart rate of 57 bpm and 63 bpm) every other beat as seen in Figure 2. There are P waves surrounding the first QRS complex with a P to P interval of 640 ms (heart rate of 93 bpm). The PR interval of the conducted beats appear constant at 240 ms, consistent with first degree atrioventricular (AV) block. The QRS complex has a complete right bundle branch block pattern (RBBB) with a QRS duration of 140 ms. The second QRS complex does not have a preceding P wave, suggestive of a junctional beat, then the same cycle repeats.

If we interpret this tracing based on the patterns, this ECG appears to show cycles of 2:1 AV block with a junctional escape beat. However, ECG interpretation should not be based on just patterns, but on physiology. And we know that in normal electrophysiology, the heart's natural pacemaker which is the sinus node continues to form electrical impulses to set the normal regular heart rate, leading to regularly occurring P waves at a rate of 60-100 bpm. Let's look closely at the P to P intervals and the R to R intervals as seen in Figure 2. The P to P interval of the first two P waves is 640 ms. The P to P interval between the second P wave and the third visible P wave which comes after the second QRS complex, is 1280 ms, which is a multiple (exact double) of 640 ms. This gives us a clue that there is actually another P wave "hidden" in the second QRS complex, the junctional escape beat. Figure 3 illustrates the first two P waves depicted as P1 and P2, respectively, while the third P wave is hidden in the QRS complex as P3. If we compare the QRS patterns of the first and second QRS, designated as R1 and R2, respectively in Figures 2 and 3, we see subtle morphologic differences with R1 appearing as an RSR pattern consistent with a typical RBBB morphology, while R2 appears differently as a qR pattern. This indicates that the depolarization of the R2 occurs differently from R1, which in this case comes from the AV node as a junctional escape beat, but conducting with an RBBB pattern. The interval rate (1040 ms or 57 bpm) is consistent with the rate of AV junction latent pacemaker.[3]

All these findings therefore suggest a 3:1 AV block, a more advanced form of heart block, instead of a 2:1 AV block. AV blocks with a 3:1 conduction or higher are diagnosed as high-grade AV blocks and are consistent with an advanced conduction system disease. The presence of baseline prolonged PR interval, complete RBBB and the 3:1 AV conduction all point to an advanced form of AV conduction disease and an infranodal level of block.[4] A ladder diagram of this tracing is illustrated in Figure 4.

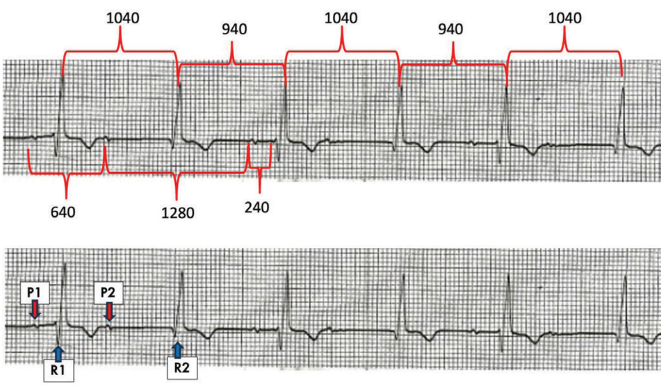

Figure 2. Single lead (V1) continuous ECG tracing with corresponding cycle length intervals in milliseconds (ms) and labels.

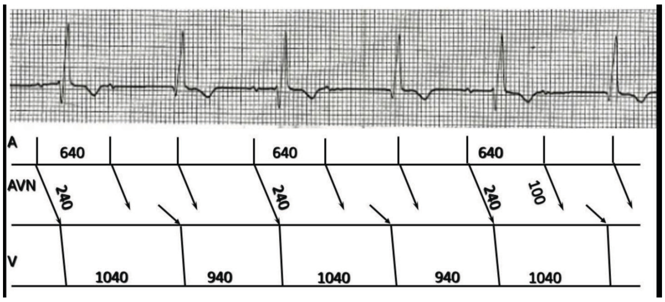

Figure 4. Ladder diagram of the ECG tracing of the patient

The Physiology Behind the Pattern

The sinus node is the heart's natural pacemaker with automatic spontaneous electrical activity that drives the normal heart rate of 60 to 100 bpm at a regular rhythm. There are latent or subsidiary pacemakers below the sinus node - the AV junction and ventricle which can spontaneously depolarize when the sinus node fails to discharge, hence they act as "escape" pacemakers and fail-safe mechanisms ensuring that ventricular activation is maintained (Figure 5).[5] The rates of discharge of these latent pacemakers are slower compared to the sinus node (AV junction 40-60 bpm, Purkinje network in the ventricle 20-40 bpm). In a normal individual, the spontaneous discharge rate of the sinus node exceeds that of these latent or escape pacemakers. In this patient, the AV block caused the first escape pacemaker, the AV junction, to spontaneously discharge at an interval of 1040 ms or 57 bpm, leading to the junctional escape beat.

Final interpretation: 3:1 AV block with complete RBBB with junctional escape beats

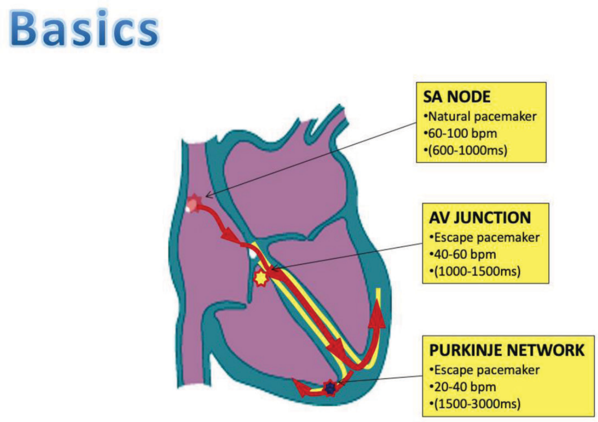

Figure 5. The sinus node and other latent pacemakers of the heart

Clinical Implications: This patient has evidence of advanced AV conduction disease and is at high risk for syncope and will warrant a permanent pacemaker insertion.

Insight: Teachable Moments in ECG

For an accurate diagnosis of cardiac abnormalities on the ECG such as heart blocks, a good knowledge and understanding of the physiology of cardiac conduction is essential. ECG tracings of these abnormalities can present "trickily" and can easily lead to misinterpretation of the condition. While identification of the rhythm abnormality relies on recognition of abnormal ECG patterns, the clinician should know the physiology behind the pattern.

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