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ECG CASE STUDY

An Irregular Rhythm with Missing P Waves

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An electrocardiogram on a life insurance applicant with a history of surgically repaired congenital heart disease displays an irregular rhythm with occasional missing P waves.

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HYPOTHETICAL SCENARIO

A 53-year-old female is applying for life insurance. She has a history of hypertension and had a stroke in 2004 due to a "hole in the heart, which was subsequently surgically repaired." She is 5 feet 6 inches tall and weighs 148 pounds. Blood pressure is 136/84, and heart rate is 50 beats per minute. Her attending physician's report and laboratory test results are pending.

Figure 1 represents the applicant's current electrocardiogram (ECG) obtained for age and amount by a paramedic company.

ECG FINDINGS

The prevailing rhythm is a bradycardia with an average ventricular rate of 52 bpm. This is best seen in lead III, where the rhythm is perfectly regular and accompanied by a consistent P wave morphology (Figure 2). However, as seen in lead I, there are periods when there is gradual slowing of the rhythm accompanied by changes in the P wave morphology (Figure 3). Though each QRS complex is preceded by a P wave, each P wave has a different morphology, suggesting it is originating from a different area. These changes are accompanied by a variable PR interval. The frontal plane QRS axis is borderline normal at approximately 0 degrees. The QRS duration is 0.11 second with an incomplete right bundle branch block pattern. There is flattening of the ST segment in leads I, AVL, V1-V4. A single ventricular premature beat is seen in lead V6.

ECG INTERPRETATION

The rhythm in our applicant's tracing will be the focus of our discussion.

As noted above, the ventricular rate is <100 bpm, and the QRS is borderline in duration. Although there are periods of regular rhythm, there are also periods where the R

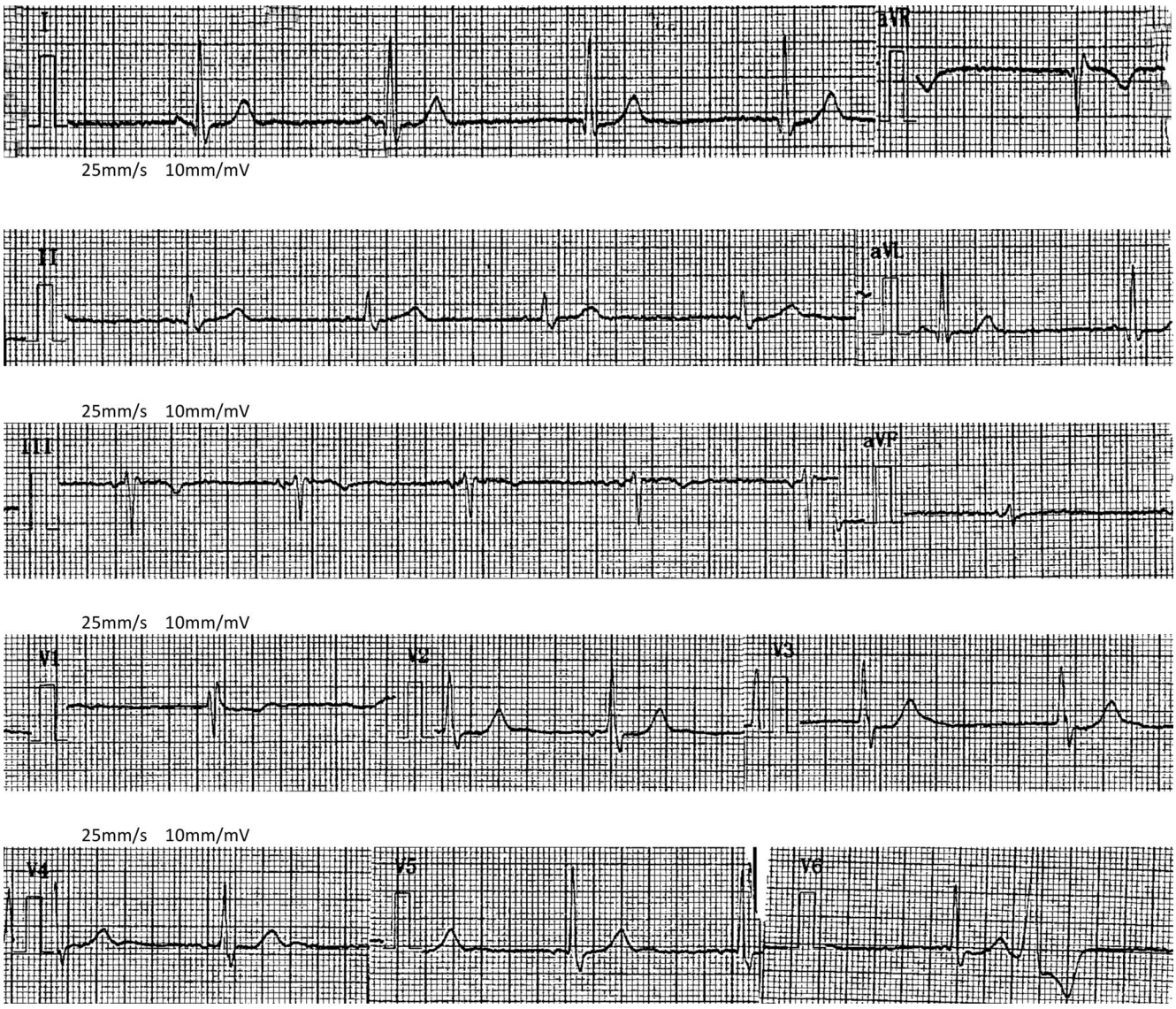

Figure 1. *Applicant's Electrocardiogram.*

to R intervals have variable cycle lengths resulting in an irregularly irregular rhythm. This raises the possibility of several types of rhythm disturbance, especially sinus arrhythmia, atrial fibrillation and multifocal atrial arrhythmias.[1-4]

Sinus arrhythmia may be irregularly irregular, however, although the P to P interval varies, there is one P wave morphology and a stable PR interval. With atrial fibrillation, there is no organized P wave identified. With multifocal atrial arrhythmias, there are at least 3 different P wave morphologies without a dominant P wave morphology and variable PR intervals. With a ventricular rate <100 bpm, there are 2 possibilities: *wandering atrial pacemaker* or *multifocal atrial rhythm*.[1-4]

Could this be atrial fibrillation?

In lead III, there are minimal undulations in the baseline that look like miniature P/flutter/fibrillation waves, but they do not capture the rhythm and are probably artifact. Instead, definite atrial activity is seen in most leads, especially true in leads I and III. In lead III, the rhythm is perfectly regular at 52 bpm, with consistent P wave morphology and

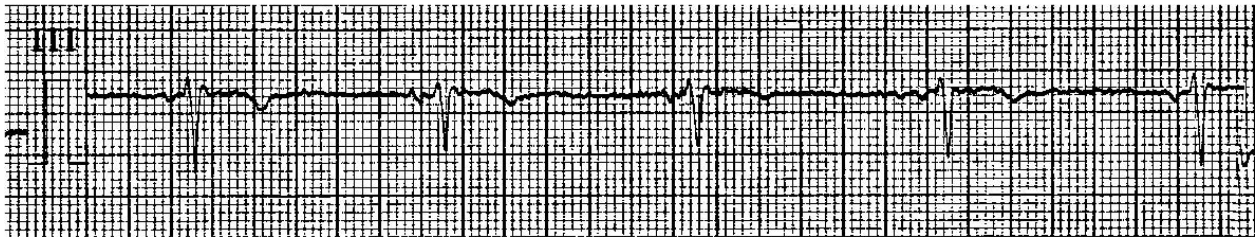

Figure 2. *Applicant's lead III, where the rhythm is regular and accompanied by a consistent P wave morphology.*

consistent PR intervals. In lead I, at least 3 distinct P wave morphologies are seen with gradual slowing of the ventricular rate to 45 bpm. The presence of 3 distinct P wave morphologies in a single lead with an atrial rate <100 bpm is in keeping with our third diagnostic possibility: multifocal atrial arrhythmias either wandering atrial pacemaker or multifocal atrial rhythm.

The most likely possibility is wandering atrial pacemaker (WAP). By definition, wandering atrial pacemaker must have at least 3 distinctly different P wave morphologies in the same lead and a ventricular rate of <100 bpm. But there is one additional characteristic – a *gradual* change in P wave morphology as the site of the atrial pacemaker changes. We see this in lead I with the slow, gradual transition of the P wave morphology from upright to flattened. Initially, the P wave in lead I is an upright, probably, sinus complex. In the second complex, the P wave has changed slightly. By the third and fourth complex, the P wave has become isoelectric. Therefore, the P to P, PR and R to R intervals vary. Unfortunately, we don't have a rhythm strip to capture the eventual resumption of sinus rhythm.[1-4]

Wandering atrial pacemaker is usually caused by varying vagal tone. With increased vagal tone, the SA node slows, allowing a pacemaker in the atria or AV node area to take over the prevailing rhythm. After vagal tone decreases, the SA node assumes its natural pace. This shifting of the pacemaker from the SA node to adjacent tissues is identifiable on the ECG by morphological changes in the P wave; sinus beats have smooth upright P waves, while atrial beats have notched, diphasic or flattened (intermittently absent or concealed) P waves, as illustrated in lead I of our applicant's ECG. Each pacemaker site generates consecutive action potentials that are all conducted to the ventricles so that each P wave is followed by a QRS complex.[1-4]

Wandering atrial pacemaker is often seen in the very young, the very old and in athletes. It is usually transient and rarely causes symptoms or requires treatment. Occasionally, it can be unmasked by medications such as beta-blockers or calcium-blockers. More severe forms may occur with sinus node dysfunction and in the setting of acute inferior myocardial infarction.[1-4]

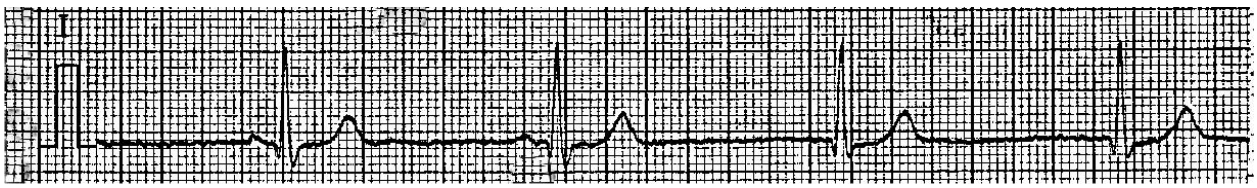

Figure 3. *Applicant's lead I, where there are periods when there is gradual slowing of the rhythm accompanied by changes in the P wave morphology.*

Why is this not multifocal atrial rhythm?

As noted, an important ECG criteria for wandering atrial pacemaker is the *gradual* change of P wave morphology as a manifestation of gradual transfer of the dominant pacemaker. If it is not gradual, the term multifocal atrial rhythm (MAR) is used. MAR belongs to a group of arrhythmias called multifocal atrial arrhythmias (MAA), which includes multifocal atrial tachycardia (MAT) also known as chaotic atrial tachycardia.

The ECG criteria for MAA (MAR when the atrial rate is <100 bpm and MAT when the atrial rate is >100 bpm) is like WAP and consists of a variable P wave morphology of at least 3 configurations and an irregular P to P and PR interval. The difference from WAP is that the change in P wave morphology is *random* not gradual. MAR (and MAT) are often misinterpreted as atrial fibrillation. The prognostic implications of MAT and MAR differ from WAP in that they often occur in older individuals with chronic obstructive pulmonary disease (COPD) and congestive heart failure (CHF) and often presage the development of atrial fibrillation. In COPD, the heart rate threshold for MAR vs MAT is <90 bpm.[5-6]

Having interpreted the rhythm, the other feature of our applicant's ECG that warrants comment is the incomplete right bundle branch block pattern. The history of a stroke in 2004 due to a "hole in the heart, which was subsequently surgically repaired" raises the possibility of an abnormality of the atrial septum such as a patent foramen ovale (PFO), an atrial septal defect (ASD) or an atrial septal aneurysm (ASA). Stroke in these settings may be due to a paradoxical embolus originating in the systemic venous circulation and entering the systemic arterial circulation through a right-to-left intra-cardiac shunt or via fibrin-platelet particles adhering to the left atrial side of an atrial septal aneurysm. Our applicant's incomplete right bundle branch block morphology with its delayed transition extending across the precordial leads is certainly compatible with previous closure of a PFO or ASD or excision of an ASA.

CONCLUSION

Our applicant's ECG provided brief periods of an interesting rhythm disturbance. Its intermittent irregularly irregular pattern raised several diagnostic possibilities with differing prognostic implications. Despite the history of structural heart disease, the rhythm appears to be benign.

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