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The Clinical Picture
It's all in the P wave

A 49-year-old man with rheumatic mitral valve stenosis, which had been diagnosed 3 years previously, presented to the outpatient department with worsening exertional dyspnea, fatigue, and cough.

At rest, he appeared comfortable; his pulse rate was 94 bpm and his blood pressure was 117/82 mm Hg. Cardiac auscultation revealed a loud first heart sound, a mid-diastolic murmur with presystolic accentuation at the cardiac apex, and a pansystolic murmur at the left lower sternal border that increased in intensity with inspiration. A prominent left parasternal heave was present.

His 12-lead electrocardiogram is shown in **FIGURE 1**.

Transthoracic echocardiography confirmed severe mitral stenosis with an estimated mitral valve area of 0.7 cm^2 without significant mitral regurgitation. In addition, right ventricular dilatation with moderately severe systolic dysfunction and 4+ (severe) tricuspid regurgitation were present. On the basis of the peak tricuspid regurgitant velocity, the right ventricular systolic pressure was calculated to be 80 mm Hg, consistent with severe pulmonary hypertension. The left ventricular end-diastolic volume was reduced and the ejection fraction was normal.

On right heart catheterization, the pulmonary artery pressure was 92/51 mm Hg.

Q: Electrocardiographic findings that support a diagnosis of pulmonary hypertension include which of the following?

- ☐ QRS complex axis of +110°
- ☐ R/S (QRS complex) ratio greater than 1 in lead V_1
- ☐ Sum of the amplitudes of the R wave in lead V_1 and the S wave in lead V_6 greater than 1.0 mV
- ☐ All of the above

doi:10.3949/ccjm.80a.12044

A: The correct answer is all of the above. Regardless of the cause, patients with long-standing pulmonary hypertension possess varying degrees of right ventricular hypertrophy that may be accompanied by right ventricular enlargement and systolic dysfunction. A QRS complex axis of 110° or more, an R/S (QRS complex) ratio greater than 1 in lead V_1, and the sum of the amplitudes of the R wave in lead V_1 and the S wave in lead V_6 greater than 1.0 mV all support right ventricular hypertrophy.[1]

As noted in this electrocardiogram, T-wave inversion in leads V_1 and V_2 supports a right ventricular repolarization abnormality secondary to the hypertrophy.[2]

Q: Important electrocardiographic findings in this patient that support secondary pulmonary hypertension due to mitral stenosis include which of the following?

- ☐ Tall peaked P waves in lead II of at least 0.25 mV and positive P waves in V_1 greater than 0.15 mV
- ☐ Prolonged P waves of at least 120 ms in lead II and terminal negative P waves in V_1 greater than 40 ms
- ☐ Right ventricular hypertrophy
- ☐ All of the above

A: The correct answer is prolonged P waves of at least 120 ms in lead II and terminal negative P waves in V_1 greater than 40 ms.

Abnormal surface electrocardiographic findings reflecting atrial enlargement or slowed atrial conduction are difficult to differentiate and are best characterized as "atrial abnormalities." On surface electrocardiography, an atrial abnormality is represented by a P wave morphology that is best studied in leads II and V_1. In lead II, a tall peaked P wave of at least 0.25 mV supports right atrial abnormality, and a prolonged P wave (≥ 120 ms) supports left atrial abnormality. In lead V_1, right

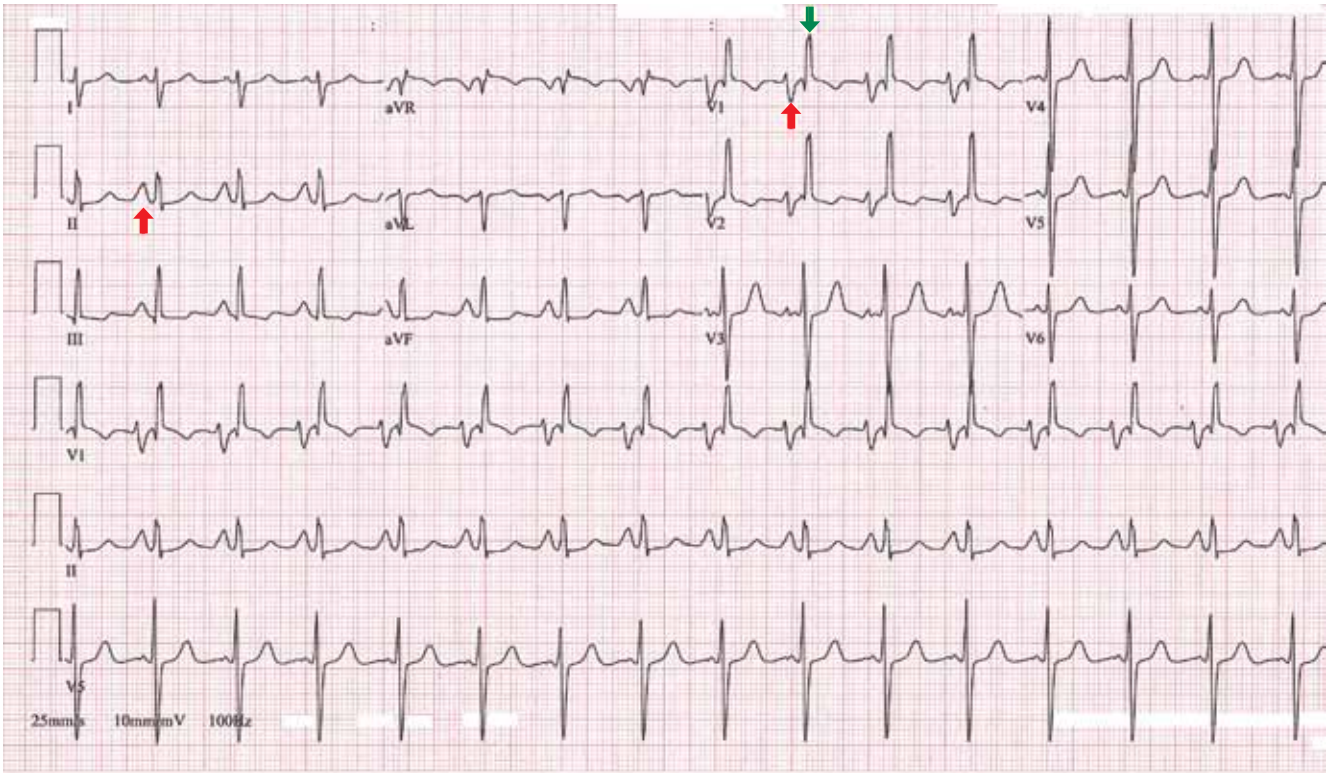

FIGURE 1. This 12-lead electrocardiogram demonstrates bi-atrial abnormality and right ventricular hypertrophy compatible with severe pulmonary hypertension in the setting of mitral stenosis. Specific findings:

Normal sinus rhythm with heart rate 94 bpm

Bi-atrial enlargement (red arrow)

Tall, peaked, and broad-based P wave in lead II (0.3 mV, 120 ms)
Positive P in lead V_1 (0.2 mV)
Negative terminal component of P in lead V_1 (0.4 mV, 60 ms)

Right ventricular hypertrophy

R/S (QRS complex) ratio >1 in lead V_1 (green arrow) with T-wave inversion in leads V_1 and V_2
Right axis QRS complex deviation (+110°)
Delayed R wave progression in leads V_1–V_6
R in lead V_1 plus S in lead V_6 = 1.9 mV
Right ventricular conduction delay

atrial abnormality is suggested by a positive P wave in V_1 greater than 0.15 mV, and a terminally negative P wave greater than 40 ms in duration and greater than 0.1 mV deep supports left atrial abnormality.[3]

It is well recognized that the pathophysiology of pulmonary hypertension involves both the right ventricle and the right atrium.[4,5] Therefore, irrespective of the cause of pulmonary hypertension, electrocardiography may additionally reveal right atrial abnormality.[6]

When the findings suggest pulmonary hypertension (ie, right ventricular hypertrophy with or without right atrial abnormality), it is also important to evaluate for concurrent left atrial abnormality. If present, concomitant left atrial abnormality is a valuable, more specific clue that may help characterize secondary pulmonary hypertension from left-sided heart disease, as illustrated in this example with long-standing severe mitral stenosis.[2]

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