Challenges in Clinical Electrocardiography

Incorrect ECG diagnoses?—Follow the Leads

Xingli Xin, MD; Xuanxuan Li, MD; Qingjie Xin, MD

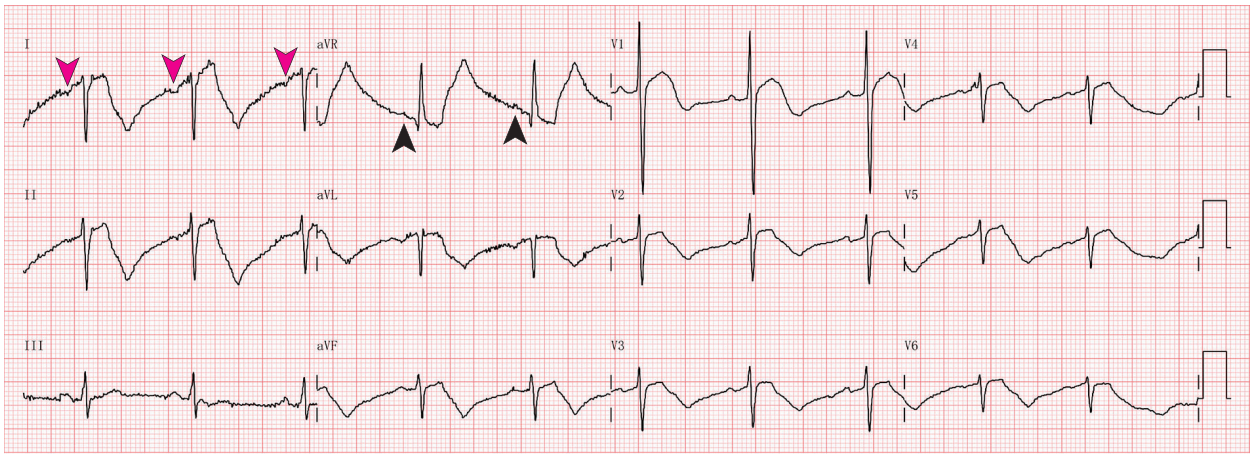
Case Presentation

An individual in their early 70s presented to the emergency department with frequently recurring paroxysmal chest pain; each episode had a duration of 3 to 5 minutes. The patient had a medical history of hypertension and diabetes mellitus; vital signs were normal, except for elevated blood pressure (153/92 mm Hg). Chest auscultation revealed normal breath and heart sounds with no murmurs. The laboratory test results (hemogram, serum electrolytes, and troponin I and D-dimer levels) were all within normal limits. A chest radiograph showed no abnormality, and transthoracic echocardiography findings revealed normal left ventricular systolic function (ejection fraction, 60%). The electrocardiogram (ECG) tracing obtained on admission is shown in the **Figure**, A.

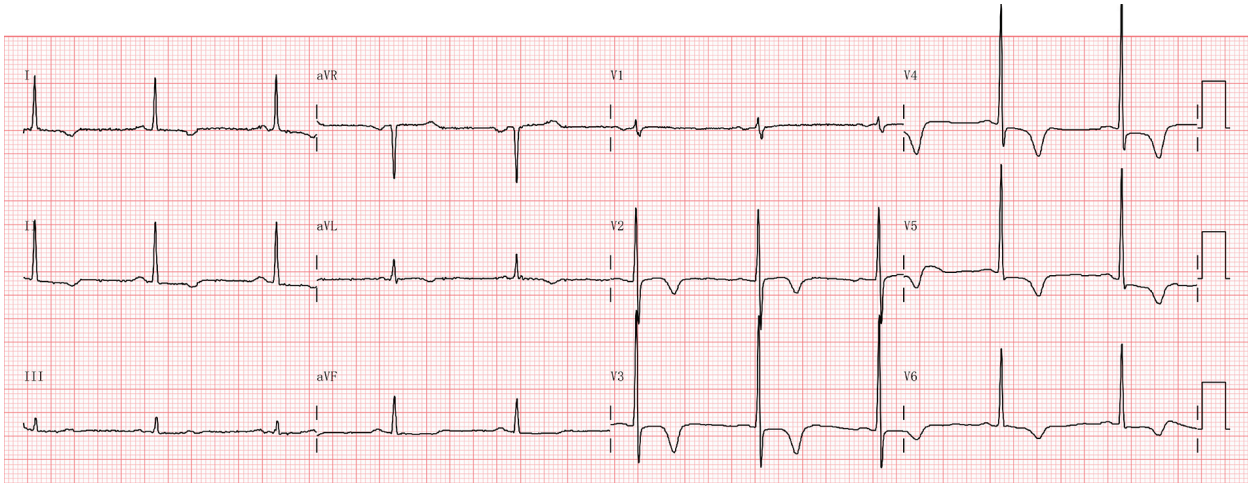
Questions: What is the most likely explanation for the ECG findings in the Figure, A? What would you do next?

Figure. Electrocardiogram (ECG) Findings Before and After Correcting the Lead Placement

A ECG at initial presentation



B ECG performed after correct lead placement



A, The initial ECG shows a negative P wave (magenta arrowheads) in lead I, a positive P wave (black arrowheads) in lead aVR, and a diminishing amplitude progression of QRS complex from V_1 to V_6. The tracing also reveals giant T waves in all leads except lead III. The prolonged corrected QT interval was 644 milliseconds (ms). B, A repeated ECG reveals a positive P wave in lead I and a negative P wave in lead aVR—characteristic of a P wave in sinus rhythm. In addition, the amplitude of the QRS complex in leads V_1 to V_6 returned to normal. T-wave inversion in leads I, II, aVL, and V_2-V_6 suggests anterior myocardial ischemia. The QTc interval was 437 ms (normal range).

Interpretation

The initial ECG tracing reveals a negative P wave (magenta arrowheads) in lead I, a positive P wave (black arrowheads) in lead aVR, and a diminishing QRS complex amplitude progression from V_1 to V_6. In addition, the ECG reveals giant T waves in all the leads except lead III. The prolonged corrected QT interval was 644 milliseconds (ms).

When we examined the placement of the leads on the patient's body , we observed the following: (1) right–left arm lead reversal, (2) placement of electrodes of the precordial leads on the right side of the chest, and (3) placement of left arm electrode over the left radial artery, which produced artifacts (giant T waves) on the ECG tracing. Therefore, before proceeding with further patient care, we performed another ECG, ensuring that the precordial leads were placed on the left side of the chest and that the left and right arm electrodes were placed correctly and not clipped on the radial artery. The repeated ECG (Figure, B) with corrected lead placement revealed sinus rhythm with T-wave inversion in leads I, II, aVL, and V_2 to V_6.

Clinical Course

The patient was diagnosed with unstable angina pectoris. Results of a coronary angiography showed 90% stenosis in the proximal left anterior descending coronary artery. A drug-eluting stent was placed, and the patient was discharged from the hospital 4 days later.

Discussion

When electrodes are placed in the wrong anatomic locations or clipped on the radial artery, they can produce incorrect ECG diagnoses. If the electrodes of leads V_1 to V_6 are placed on the right side of the chest, the amplitude of the QRS complex will gradually decrease from lead V_1 to V_6. When the left and right arm leads are placed inversely, the ECG manifests as follows[1]: (1) the P-QRS-T waves are inverted in lead I, ie, lead I is flipped (P wave is negative); (2) lead aVR resembles a normal aVL (P wave of aVR is positive), and lead II resembles a normal lead III; and (3) the precordial leads and aVF are unaffected. When the 2 aforementioned electrode misplacements occur simultaneously, the ECG characteristics will be the same as those of mirror-image dextrocardia.[2] No mirror-image dextrocardia was found after performing a physical examination and chest radiography of the patient; therefore, these ECG changes denoted an instance of electrode misplacement.

When a limb-lead electrode is placed over the radial pulse, the artifact is recorded on the ECG.[3] Moreover, the pulsation of the radial artery may allow for poor electrode contact, which may produce sharp changes in electric impedance, thus distorting the electric signals.[4] These distorted signals may manifest as phase shifts and produce ECG artifacts, such as giant T waves, ST-segment elevation, ST-segment depression, abnormal U waves, and prolonged QTU intervals.[5,6] In this case, these artifacts appeared after the QRS complex. The QRS complex appears when the heart's contraction is being initiated; therefore, these artifacts appeared when the contraction of the ventricles produced arterial pulsation. The initial ECG recorded pulse-tapping artifact (giant T waves) associated with the left radial arterial pulsation, and the giant T-wave, in turn, led to a prolonged corrected QT interval.

According to the Einthoven triangle theory,[6] lead I compares the electrical differences between the right and left arms; lead II, between the right arm and left leg; and lead III, between the left arm and leg. Therefore, when the artifacts originate from the left arm, the lead between the right arm and left leg (lead II) remains normal. Similarly, when the artifacts originate from the right arm, the lead between the left arm and leg (lead III) remains normal. When the artifacts originate from the left leg, the lead between the left and right arms (lead I) remains normal. Artifacts associated with arterial pulsation also affect the precordial leads because the Wilson central terminal is produced by connecting the 3 limb electrodes.[6] Therefore, only 1 limb lead (I, II, or III) will remain unaffected when a single limb arterial pulsation is the source of the artifacts.

In this patient's initial ECG, only lead III remained unaffected (without giant T waves); therefore, according to the aforementioned analysis, it appeared that the artifacts originated from the right radial arterial pulsation. However, because the electrodes on the left and right arms were reversed, the artifacts actually originated from the left radial arterial pulsation.

Take-home Points

- When electrodes for leads V_1 to V_6 are placed on the right side of the chest, the amplitude of the QRS complex will gradually decrease from lead V_1 to V_6.
- When 1 limb lead electrode is placed over the radial pulse, the artifact is recorded on the ECG tracing.
- Only 1 limb lead (I, II, or III) will remain unaffected when a single limb arterial pulsation is the source of the artifacts.
- Artifacts associated with limb arterial pulsation appear after the QRS complex.

ARTICLE INFORMATION

Author Affiliations: Department of Cardiology, Huanghua Boai Hospital, Affiliate of Oriental College of Beijing University of Traditional Chinese Medicine, Huanghua, Hebei, China (X. Xin); Department of Cardiology, Shijiazhuang Great Wall Hospital of Integrated Traditional Chinese and Western Medicine, Shijiazhuang, Hebei, China (Li); Center for Coronary Artery Disease, Division of Cardiology, Beijing Anzhen Hospital, Capital Medical University, Chaoyang District, Beijing, China (Q. Xin).

Corresponding Author: Qingjie Xin, MD, Center for Coronary Artery Disease, Division of Cardiology, Beijing Anzhen Hospital, Capital Medical University, Anzhen Rd, Chaoyang District, Beijing 100029, China (qingjiexingood@126.com).

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