

## ST-Segment Elevation: Defined by the Company It Keeps

*For every problem, there is one solution which is simple, neat, and wrong.*

— H. L. Mencken

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Electrocardiographic (ECG) interpretation, whether performed by human or computer, is largely an exercise in pattern recognition. As cardiovascular (CV) fellows years ago, training at Mayo Clinic in Rochester, Minnesota, we marveled at how our staff cardiology mentors could instantaneously interpret ECGs, even when we unintentionally projected the tracings upside down or backwards onto the conference room screen. ST-segment elevation, in all of its nuanced presentations and causes, is among the most crucial ECG patterns to promptly recognize and correctly classify. Sometimes the difference between a potentially lethal injury pattern and an innocent normal variant finding can be a deceptively fine line. Small misinterpretations can result in patients' lives hanging in the balance and, on a lesser plane, board scores for physicians in training swinging from pass to fail.<sup>1</sup>

One of the classic ECG patterns is early repolarization (ER), characterized by concave upward ST-segment elevation at the end of the QRS complex, most often present in the lateral precordial leads and less commonly in the inferior and/or anterior precordial leads.<sup>1-5</sup> Traditionally, ER has been viewed as a benign normal variant that is commonly seen in young individuals, especially male athletes. Clinical wisdom gleaned over generations of cardiologists held that the presence of ER on an ECG was gener-

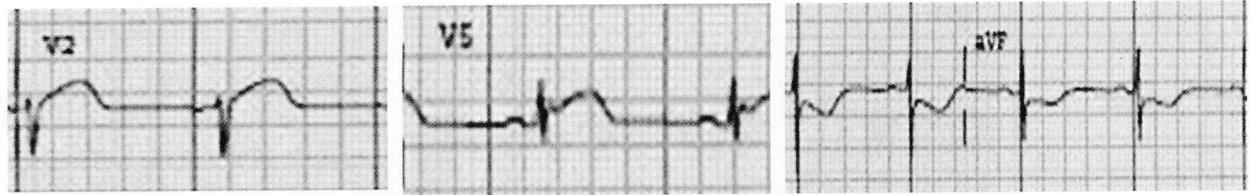
ally harmless, if not even protective against future adverse CV events. However, beginning with a report<sup>6</sup> published in 2008, the benign nature of ER has been called into question.<sup>7,8</sup>

In the current issue of *Mayo Clinic Proceedings*, Uberoi et al<sup>9</sup> definitively address this controversy in the largest and most methodologically robust study regarding the prognostic significance of ER. They evaluated a population of more than 29,000 individuals who underwent ECG 13 to 24 years ago at the Palo Alto Veterans Affairs Health Care Center. The tracings were acquired on a centralized, computerized ECG system (GE Healthcare, Wauwatosa, WI) that has been widely used around the world for collection, storage, and analysis of ECGs. Early repolarization was defined by the computer algorithm as a 1-mm (0.1-mV) or greater elevation at the end of the QRS complex with an isoelectric PR segment. These investigators found that ER, when appearing as an isolated finding in an otherwise normal ECG, was entirely benign. Indeed, isolated lateral ER appeared to be cardioprotective against future CV death, in part because this finding usually occurs in young individuals. However, when the ST-segment elevation occurred in conjunction with Q waves or T-wave inversion, the ER portended a highly significant 5-fold increased risk for future CV death. Anterior ST-segment elevation, when accompanied by Q waves or T-wave inversion, was particularly ominous.<sup>9</sup>

These findings will resonate with experienced physicians who instinctively are reassured by the pattern of isolated ER, yet alarmed by a pattern of



**FIGURE 1.** Electrocardiographic tracings showing normal variant ST elevation. Although small Q waves are present, these are not pathologic.



**FIGURE 2.** Electrocardiographic tracings showing acute anterior myocardial infarction, with reciprocal ST-segment depression in aVF.

ST-segment elevation associated with Q waves or T-wave inversion. Unfortunately, computer algorithms for ECG interpretation are entirely inadequate for distinguishing between benign and pathologic ST-segment elevation,<sup>9,10</sup> and thus physicians who rely on ECG computer reports are often misled in their assessment of a potentially critical clinical scenario.

Bayesian theory adds greatly to the clinical decision making regarding ST-segment elevation. Individuals with a true normal variant ER are nearly always younger than 35 years and generally younger than 25 years; coronary heart disease is extremely rare in this demographic group, and their 5- to 10-year CV prognosis is typically superb.<sup>11</sup> On the other hand, Q waves and T-wave inversions (particularly when deeply inverted) are uncommon in young healthy populations. An exception to this generalization is the individual with ST-segment elevation in the setting of pathologic left ventricular hypertrophy (LVH), including hypertrophic cardiomyopathy, who even when young is at increased CV risk.

The clinical setting is also of pivotal importance; ST-segment elevation in the context of chest pain should always markedly raise the clinical index of suspicion, prompt closer scrutiny, and encourage further testing. Even repeating the resting ECG a few minutes to hours later will often provide valuable information because dynamic repolarization abnormalities can signify an unstable and potentially dangerous CV condition.<sup>1</sup>

In addition to classifying ST-segment elevation by the company it keeps (eg, Q waves and/or inverted T waves) and the demographic subgroup in which it appears, this important ECG finding can also be broadly but not pathognomonically characterized by its morphologic features.

#### Various Causes of ST-Segment Elevation

The more common and clinically important (for the purpose of predicting patient risk) variants of ST-segment elevation are benign normal variant, myocardial injury or infarction, LVH, acute pericarditis, and left bundle branch block (LBBB).

Benign normal variant is characterized by concave upward-sloping ST-segment elevation (generally <2 mm), sometimes with notching (termed *J wave*) on the downward slope of the R wave (Figure 1). The T waves tend to be large, upright, and symmetrical. The repolarization findings are typically stable over time.

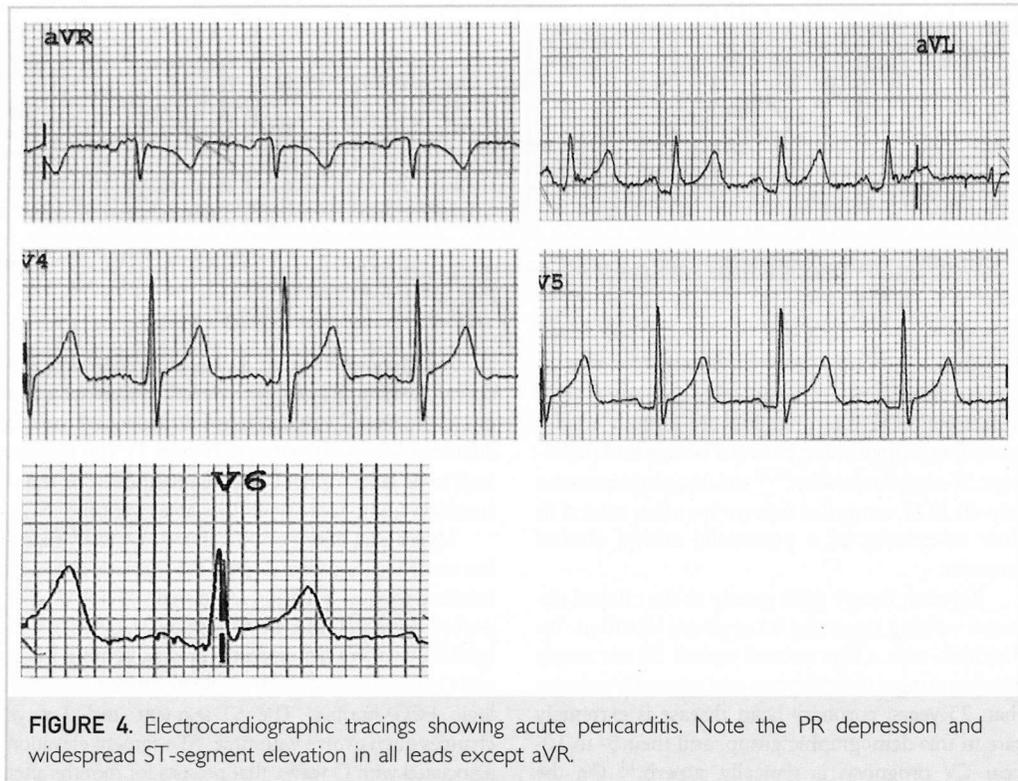
Myocardial injury or infarction is typically manifest as convex upward-sloping ST-segment elevation localized to a few leads and associated with inverted or peaked (hyperacute) T waves (Figure 2). Often, reciprocal ST-segment depression is present in other leads, and Q waves are frequently associated with this pathologic ECG finding. The ST-segment and T-wave changes often evolve with time. ST-segment elevation associated with Q waves that persists for months after an acute myocardial infarction can be a marker for a left ventricular aneurysm.

The ST-segment elevation associated with pathologic LVH is usually seen in leads V<sub>1</sub> and V<sub>2</sub> and is typically associated with large S waves and upright T waves (Figure 3). The ST-segment elevation is typically 1 to 2 mm, but with more severe LVH and higher R-wave voltages, it can be 2 to 3 mm in leads V<sub>1</sub> and V<sub>2</sub>.

Acute pericarditis is typically manifest as widespread ST-segment elevation (I-III, aVF, V<sub>3</sub> through

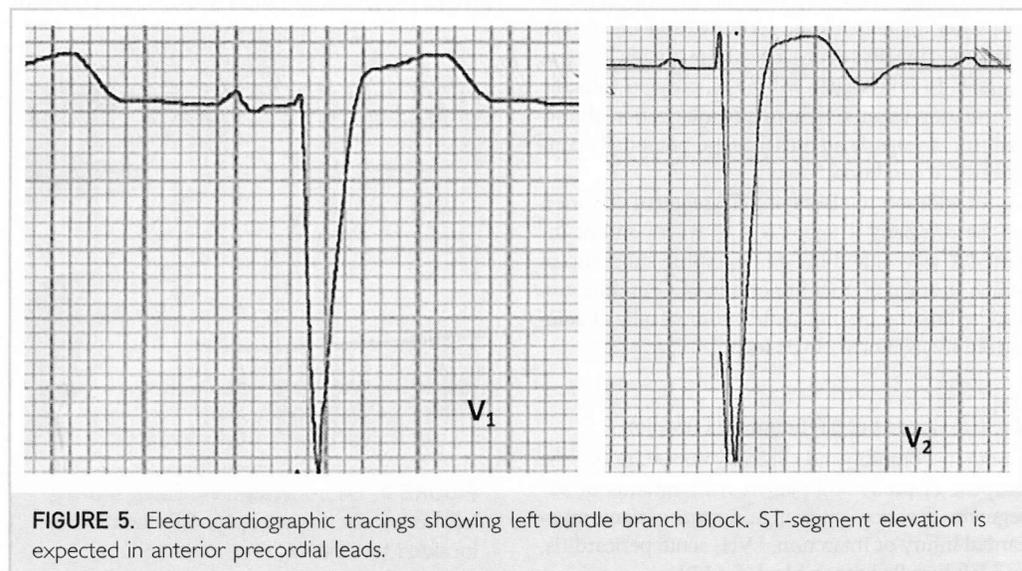


**FIGURE 3.** Electrocardiographic tracing showing left ventricular hypertrophy. ST elevation is localized to V<sub>1</sub> to V<sub>2</sub>.



$V_6$ ) without reciprocal ST-segment depression in other leads except aVR (Figure 4). In this condition, PR segment depression is often present and is specific for pericarditis. Generally, a Q wave is not present, and the repolarization changes due to acute pericarditis usually evolve over time.

Left bundle branch block ST-segment elevation is usually present in leads  $V_1$  and  $V_2$  and is associated with prolonged QRS duration (>120 ms) with typical LBBB morphologic features (Figure 5). The ST-segment elevation in the anterior leads is part of the expected repolarization pattern noted with LBBB.



### Unresolved Issues

We also agree with Uberoi et al in their call for standardization of terms. For example, benign ER findings might be termed *normal variant ST-segment elevation*. In contrast, ST-segment elevation associated with Q waves or T-wave inversions should be in a distinct, mutually exclusive category that necessitates further clinical scrutiny and consideration of additional testing and treatment. Furthermore, the presence of ST-segment elevation in association with LVH is another category in which the ER abnormalities should not be dismissed as benign. J waves and slurring of the terminal portion on the R-wave downward slope have been associated with higher CV risk, and this finding will require separate classification and further clarification with respect to their clinical significance.<sup>7,8,12-15</sup> In addition, further improvement in computerized ECG technology and inclusion of the various subgroups of ST-segment elevation in the computer algorithms for ECG interpretation are greatly needed. Finally, population-based studies are needed to better understand the incidence of the various ER patterns and the risk of early, unexpected death in the general population.

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**Abbreviations and Acronyms:** CV = cardiovascular; ECG = electrocardiogram; ER = early repolarization; LBBB = left bundle branch block; LVH = left ventricular hypertrophy

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