Is the Electrocardiogram Still Useful for Detection of Left Ventricular Hypertrophy?

Richard B. Devereux, MD

Electrocardiographic (ECG) methods of detecting left ventricular hypertrophy (LVH) have played an important role in the understanding of clinical heart disease. It has long been recognized that the risk of developing coronary heart disease or complications of hypertension is higher in individuals with LVH detected by ECG than in otherwise comparable subjects with normal ECGs. Early trials of antihypertensive therapy revealed that the benefit of treatment was also greatest in patients identified as being at high risk for developing coronary heart disease because of LVH detected by ECG or other evidence of preexisting heart disease. Based on these results, LVH detected by ECG has been accepted as a major risk factor for subsequent cardiac events.

However, the practical usefulness of ECG-determined LVH for identifying high-risk patients has recently been questioned. The principal reason for this is that ECG-detected LVH occurs in only a small proportion of patients (e.g., 5% or fewer of those with hypertension of average severity). As a result, most patients who will suffer cardiac morbidity remain undetected by ECG.

Insights From Echocardiography

The development and anatomic validation of echocardiographic methods to measure left ventricular muscle mass directly has led to an increased knowledge about the role of cardiac hypertrophy in clinical heart disease. In a comparative study, we found that echocardiographic measurements had a sensitivity of 57% for mild LVH by necropsy criteria and 98% for moderate-to-severe LVH by necropsy criteria. In contrast, the sensitivity of various standard ECG criteria ranged from 15% to 35% among patients with mild LVH and from 10% to 57% among those with moderate-to-severe LVH in the same patients examined at necropsy. As expected from these results, echocardiographically determined LVH has been found to be much more frequent than ECG-determined LVH, being detected in 20–80% of different groups of patients with established hypertension and in 5–50% of adults of different ages in the general population.

In addition to being useful for classifying patients as having or not having LVH, echocardiographic measurements of LV mass have also proven useful as continuous variables. Thus, echocardiographic LV mass has been shown to integrate the level over time of blood pressure and other components of hemodynamic load in hypertensive patients. Most important, recent studies showed echocardiographic LV mass measurements to be an extremely strong predictor of prognosis, independent of conventional risk factors or ECG-determined LVH.

Reexamination of the Accuracy of Electrocardiographically Determined Left Ventricular Hypertrophy

Against this background, the performance of ECG criteria of LVH has been critically reassessed by comparison with necropsy and echocardiographic reference standards. In clinical populations, enriched to a variable degree by patients with severe anatomic LVH who have prominent ECG manifestations, sensitivity of standard ECG criteria for LVH has ranged from a low of 6% to a maximum of 53%. In general, the criteria with the highest sensitivity have had the lowest specificity and vice versa, a trade-off that has limited the proportion of subjects correctly classified as having or not having LVH to 60–85% in most studies.

The reason for this limited diagnostic accuracy has been revealed by comparison of ECG findings used for the diagnosis of LVH with necropsy or echocardiographic measurements of LV mass. Only weak relations, with correlation coefficients ranging from 0.11 to 0.63 (most between 0.25 and 0.45), have been found between LV mass and such ECG variables as single-lead QRS voltages, QRS duration and axis or measures of abnormal ventricular repolarization, or left atrial activation. Use of the Cornell voltage combination of $SV_1 + RaVL$ or the Sokolow-Lyon voltage combinations of $SV_1 + RV_5$ or $V_6$ results in modestly strengthened relations with LV mass, in
part because these voltage combinations have less variability between successive ECGs than do voltages in single leads. Further improvement has been obtained in clinical studies by combining QRS voltages and other ECG variables that have statistically independent relations to LV mass in the Romhilt-Estes point score system or in multivariate equations that are suitable for use in computerized ECG interpretation systems. This approach has the advantage that it permits ECG repolarization abnormalities of typical or atypical "strain," a marker for especially prominent LVH, to be used as evidence of LVH even when QRS voltages are normal.

**Electrocardiographic Detection of Left Ventricular Hypertrophy in the General Population—The Evidence From the Framingham Heart Study**

In this issue of *Circulation*, Levy and associates report on the performance of the ECG criteria traditionally used in the Framingham Heart Study for detecting LVH in 4,684 adults ranging in age from the 20s to the 90s. Echocardiographic LV mass, indexed for height rather than for body surface area to enhance detection of obesity-induced LVH, was used as the reference standard. In this sample of the general adult population, LVH was detected by echocardiogram in 755 of 4,684 or 16% and by ECG in only 99 or 2%. Overall, specificity of ECG criteria in subjects with normal LV mass was excellent at 98.8%, but sensitivity for increased ventricular mass was astonishingly low at 6.9%.

The explanation for the poor performance of ECG criteria for detection of LVH appears to be both biologic and methodologic. Thus, ECG sensitivity was diminished both by obesity and by cigarette smoking, a cause of emphysema, as expected from the previous observation that an increase in the distance between the left ventricle and chest surface decreases the QRS voltage generated by a given LV mass. Of note, the effect of obesity on ECG detection of LVH was partially dependent on the decision to index LV mass by height, because it became statistically insignificant when the more common body surface area indexation was used. Furthermore, Figure 3 of Levy et al showed that ECG sensitivity for LVH was extremely low, from 0% to 6%, in the first three quartiles of subjects with LVH and became appreciable only in those with the most severe LVH. Because severe LVH occurred disproportionately in older subjects, ECG sensitivity also rose with age, from 3% to 6% in subjects younger than age 70 years to 14% in subjects older than 70 years. Although these results indicate that ECG performance may be enhanced by consideration of demographic variables, it is unlikely that ECG sensitivity for LVH would be much higher than 25% among individuals who are elderly, not obese, and do not smoke, whereas it would be vestigially low among most adults who do not share all three of these characteristics.

An even more important reason for the poor performance of ECG criteria in this study lies in the particular ECG criteria that have been traditionally used in the Framingham Heart Study. Thus, two of the voltage criteria used (RaVL > 11 mm and R1 + S1 + SII > 25 mm) were previously shown to have sensitivity of only 6–10% for detection of increased LV mass, whereas the Sokolow-Lyon precordial voltage combination has been found to have modest sensitivity (20–33%) but excellent specificity. Voltage abnormalities were not considered unless repolarization abnormalities were present, and valuable ECG indicators of LVH such as QRS prolongation were not considered. These decisions are likely to have made the Framingham ECG criteria less sensitive, but also more specific, than those generally found in the medical literature and used in clinical practice. Also, ECG sensitivity may have been somewhat diluted by use of highly sensitive echocardiographic criteria for LVH, as suggested by the increase in ECG sensitivity from 6.7% to 9.2% when LV mass was indexed by body surface area rather than height.

**Current and Future Perspectives**

Because of the relatively low cost of the ECG and the great frequency with which it is performed for other reasons, the results of Levy et al constitute not a call for abandonment of the ECG as a means of detecting LVH, but rather a stimulus to improvement of ECG methods by consideration of biological variables. Thus, it is the particular combination of relatively insensitive voltage criteria plus repolarization abnormalities used in the Framingham Heart Study rather than all ECG criteria of LVH that Levy and colleagues have shown to have very low sensitivity. Clinicians and investigators should continue to use other ECG criteria (e.g., Sokolow-Lyon voltage alone or a Romhilt-Estes score of 5 or more points) that are known to have more reasonable sensitivity for LVH. These other ECG criteria should be used especially in clinical patient populations in whom a specificity of 95%, rather than the 99% attained with Framingham criteria, is acceptable. Second, a variety of voltage combinations and multivariate equations have been developed that appear to be more successful than the Framingham ECG criteria for detecting LVH in clinical populations and deserve further prospective evaluation. Third, the performance of different ECG criteria for detecting LVH should be assessed in the future by receiver-operator curve analysis rather than by testing the sensitivity and specificity of particular cutoff points. This is especially important because methodologic changes such as the shift from analog to digital ECG instruments with potentially different frequency-response characteristics may have changed the appropriateness of traditional partition values. Last, new techniques such as signal-averaging of the ECG may improve ECG detection of LVH by making available more accurate measurements of QRS voltage and duration.
as well as of repolarization, which are the most important ECG correlates of LV muscle mass.

Acknowledgments
I thank Drs. Paul Klugfeld and Peter M. Okin for their critical reading of this manuscript and Virginia Burns for assistance in its preparation.

References
16. Casale PN, Devereux RB, Alonso DR, Campo E, Klugfeld P: Improved sex-specific criteria of left ventricular hypertrophy for clinical and computer interpretation of electrocardiograms: Validation with autopsy findings. Circulation 1987;75:565–572
17. Murphy ML, Thenahadn PN, deSoysa N, Meade J, Doherty JE, Baker BJ: Sensitivity of electrocardiographic criteria for left ventricular hypertrophy according to type of heart disease. 1985;55:545–549
19. Farb A, Devereux RB, Klugfeld P: Day-to-day variability of voltage measurements used in electrocardiographic criteria for left ventricular hypertrophy. J Am Coll Cardiol 1990 (in press)

(Circulation 1990;81:1144–1146)
Is the electrocardiogram still useful for detection of left ventricular hypertrophy?
R B Devereux

*Circulation.* 1990;81:1144-1146
doi: 10.1161/01.CIR.81.3.1144

*Circulation* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1990 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/81/3/1144.citation

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Circulation* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Circulation* is online at:
http://circ.ahajournals.org//subscriptions/