Diagnosis of Left Ventricular Hypertrophy in the Presence of Left Anterior Fascicular Block: A Reexamination of the 2009 AHA/ACCF/HRS Guidelines

Sandeep Ravi, M.D., Vladimir Rukshin, M.D., Gilead Lancaster, M.D., F.A.C.C., Stuart Zarich, M.D., F.A.C.C., and Craig McPherson, M.D., F.A.C.C.

From the Department of Cardiology, Bridgeport Hospital, Yale University, Bridgeport, CT

Background: The 2009 “AHA/ACCF/HRS Recommendations for Standardization and Interpretation of the Electrocardiogram” state that left ventricular hypertrophy (LVH) criteria that include R-wave amplitude in leads I and aVL are not likely reliable in the presence of left anterior fascicular block (LAFB). This statement was referenced to three relatively small studies. The present study reexamines the utility of selected electrocardiographic (ECG) criteria for LVH in the presence of LAFB.

Methods: We identified 185 ECG tracings with LAFB from patients in whom echocardiogram had been performed within 30 days of the ECG. These ECGs were evaluated for the presence of selected LVH criteria: (1) Sokolow index (R-wave-aVL > 11 mm); (2) Cornell criteria (R-wave-aVL + S-wave-V3 > 28 mm in men (>20 mm in women); (3) Gertsch criterion (S-wave-III + (R + S) maximal precordial >30 mm); and (4) Bozzi criterion (SV1 or SV2 + (RV6 + SV6) > 25 mm). The “gold standard” for LVH was left ventricular mass index on echocardiogram.

Results: Although the aVL-based LVH criteria demonstrated lower sensitivity (45–68%) and a trend toward higher specificity (67–81%) compared to non-aVL-based criteria, the four studied criteria demonstrated similar diagnostic accuracy.

Conclusions: In the presence of LAFB, the aVL-based Sokolow index and Cornell criteria, which were excluded from 2009 multisociety ECG guidelines, identify LVH with similar diagnostic accuracy as the non-aVL-based criteria that were included. Moreover, they are easier to calculate and are included in some of the computer-assisted ECG interpretation software presently in use. Their exclusion from the 2009 guidelines was unnecessary.

Ann Noninvasive Electrocardiol 2013;18(1):21–28

electrocardiogram; left ventricular hypertrophy; left anterior fascicular block; hemiblock

Left ventricular hypertrophy (LVH) is an independent, strong predictor of cardiovascular morbidity and mortality.¹ When detected by electrocardiography, LVH has been demonstrated to be associated with adverse outcomes in diverse patient populations.^{2,3}

Over the last century, numerous electrocardiographic criteria have been proposed to detect LVH. In April 2009, The American Heart Association,

American College of Cardiology Foundation, and the Heart Rhythm Society (AHA/ACCF/HRS) published joint recommendations for Standardization and Interpretation of the Electrocardiogram. Section 5 of these guidelines listed 36 ECG criteria for detecting LVH. In the presence of left anterior fascicular block (LAFB), however, the writing committee opined: “In left anterior fascicular block, the QRS vector shifts in a posterior and superior

Address for correspondence: Craig McPherson, M.D., F.A.C.C., Director, Cardiac EP Service & Cardiology Fellowship Program, Bridgeport Hospital, Clinical Professor of Medicine, Yale University School of Medicine, 267 Grant Street, Bridgeport, CT 06610. Fax: 203 384 3443; E-mail: pcmcph@bpthosp.org

None of the authors have any financial disclosures.

Figure 1. Enrollment algorithm of patients of the study. LAFB = Left anterior fascicular block.

direction, resulting in larger R waves in leads I and aVL and smaller R waves but deeper S waves in leads V5 and V6. R-wave amplitude in leads I and aVL are not reliable criteria for LVH in this situation.⁴ Based upon this concern, and three previously published studies, only two electrocardiogram (ECG) LVH criteria were recommended in presence of LAFB.⁵ These criteria were proposed in two of the cited studies^{6,7}; the third reexamined them in a separate population of patients.⁸

The purpose of the present study was to reexamine the ECG diagnosis of LVH in the presence of LAFB in a larger study population using computer-derived ECG measurements. We specifically sought to compare the diagnostic utility of the criteria of Bozzi and Figini and Gertsch et al., which were included in the 2009 multisociety ECG guidelines, with two well-established aVL-based voltage criteria for LVH (Sokolow index and Cornell criterion)^{9,10} that were not included.

METHODS

Based upon the nature of the study, the Institutional Review Board (IRB) of our hospital waived need for written informed consent. An outline of the procedure used to identify study subjects is provided in Figure 1. We first searched the hospital ECG database (Marquette MUSE, version 7.1.1, GE Medical Systems, Information Technologies, Inc., Milwaukee, WI, USA) for ECG recordings performed between July 1, 2007 and March 1, 2009 that revealed LAFB. The criteria used to define LAFB were those recommended

by the 2009 multisociety ECG guidelines.⁵ They included: (1) mean QRS axis between (-45°) and (-90°) , (2) R-wave amplitude in leads I and aVL more than Q- amplitude, and (3) either S or S' is of greater amplitude than both R and R' in lead II. In applying ECG criteria for LVH, we excluded patients younger than 36 years as recommended in the 2009 guidelines.⁴ As did Gertsch et al.,⁷ we excluded from our analysis those ECG tracings with QRS duration greater than 120 ms or Q-wave myocardial infarction, as these abnormalities may interfere with ECG determination of LAFB and LV mass. Finally, we searched the hospital echocardiogram database (Philips Xcelera R2.2L1 SP2 2.2.1.558-2009, Philips Healthcare, Andover, MA, USA) and identified 185 patients in whom an echocardiogram had been performed within 30 days of the index ECG. In 152 (82%) of these patients, the echocardiogram had been obtained within 1 week of the index ECG. In 57 patients (30%) echocardiography had preceded the ECG.

In the 185 patients so derived, we evaluated 4 ECG criteria for diagnosing LVH. Two were aVL-based LVH criteria: (1) The Sokolow index (R-wave amplitude in aVL greater than 11 mm⁹); and (2) The Cornell criteria (R-aVL + S-V3 greater than 28 mm in men and greater than 20 mm in women.¹⁰ The other two were the non-aVL-based LVH criteria included in the 2009 ECG guidelines: (1) the criterion proposed by Bozzi and Figini $(SV1 + [(RV5 + SV5) \text{ or } (RV6 + SV6)])$ greater than 25 mm;⁶ and (2) the criterion proposed by Gertsch et al. (S-III + maximum precordial lead voltage (R + S) greater than 30 mm).⁷ The patient demographics (age and sex), mean R-wave axis and the Q-, R-, and S-wave amplitudes of each of the 12 individual ECG leads were extracted directly from the ECG database and entered into an electronic spreadsheet (Microsoft Excel, version 7.01, Microsoft, Inc., Redmond, WA, USA). Values for the four studied LVH criteria were calculated from the stored QRS amplitudes. No manual measurements of QRS voltage were used in the study.

We used two-dimensional echocardiographic measurements as recommended by the American Society of Echocardiography to calculate left ventricular mass (LVM).¹¹ Diastolic interventricular septal diameter (IVSd), diastolic left ventricular posterior wall diameter (LVPWd), and diastolic left ventricular internal diameter (LVIDd) were extracted from the echocardiogram database

and LVM was calculated using the Devereux formula.^{12,13}

$$\text{LVM} = 0.8 \times [1.04 \times ([\text{IVSd} + \text{LVPWd} + \text{LVIDd}]^3 - \text{LVIDd}^3)] + 0.6.$$

The LVM index (LVMI) was determined by dividing LVM by estimated body surface area. As per guidelines established by the American Society of Echocardiography, we defined LVH as being present when LVMI was greater than 95 g/m² in women and greater than 115 g/m² in men.¹¹ A random sample of 100 echocardiograms was independently reviewed by two experienced echocardiographers blinded to the ECG findings. A 94% correlation was found between measurements of the cardiologists and those in the echo database. Thus the data stored in the echo database were used for the study. With these echo measurements of LVMI serving as the gold standard for the presence of LVH, the sensitivity, specificity, predictive values, and diagnostic accuracy were calculated for each of the four analyzed ECG criteria for LVH, according to the following formulas: sensitivity = true positives/(true positives + false negatives); specificity = true negatives/(true negatives + false positives); positive predictive value (PPV) = true positives/(true positives + false positives); negative predictive value = true negatives/(true negatives + false positives); and diagnostic accuracy = (true positives + true negatives)/185, the total number of patients.

STATISTICAL ANALYSIS

A series of 2×2 contingency tables were constructed, one for each studied ECG LVH criterion, with the predefined echocardiographic LVH criteria as the gold standard. Sensitivity, specificity, predictive values, and diagnostic accuracy of each criterion were calculated from these tables. In addition, 2×2 tables were created to examine the diagnostic performance of the combined aVL-based LVH criteria and the two non-aVL-based LVH criteria. In this analysis using paired ECG criteria, if LVH was present by either criterion, the ECG was considered to be positive for LVH. Fisher's exact test was utilized to determine that the distribution of subjects within each 2×2 table was nonrandom. Exact binomials were used to calculate confidence intervals for sensitivity

Table 1. Demographic Characteristics of the Study Population

Age median (years)	72
Age range (years)	41–99
Females N (%)	79 (43)
Caucasians N (%)	147 (79)
Blacks N (%)	27 (14)
Hispanics N (%)	9 (4)
Asians N (%)	2 (1)

Table 2. LVH Characteristics of the Study Population

	Echocardiography	
	LVH	No LVH
Patients (185)	95	90
LVMI (g/m ²) in men	151 ± 31	93 ± 18
LVMI (g/m ²) in women	130 ± 37	75 ± 12

LVMI displayed as g/m².

LVH = left ventricular hypertrophy; LVMI = left ventricular mass index.

and specificity. Different diagnostic criteria were compared utilizing confidence intervals for sensitivity and specificity. Also a single diagnostic test characteristic, Youden's index¹⁴ was used to compare the combined utility of both sensitivity and specificity of different ECG LVH criteria with each other. Youden's index = (sensitivity + specificity) - 1. For a perfect test with 100% sensitivity and 100% specificity, Youden's index would equal one. A test with random performance, similar to a simple coin toss (50% sensitivity and 50% specificity), would yield Youden's index of zero. Tests with the same Youden's index would have the same degree of misclassification.

RESULTS

As shown in Figure 1, 1033 patients with LAFB were identified from the ECG database search. Among these, 275 patients were excluded due to their age, presence of wide QRS, or infarction pattern on the ECG; and 573 were excluded for lack of suitable echo study. The remaining 185 patients constituted the study group. Their demographic characteristics are listed in Table 1. The median age was 72 years (range 41–99); 43% were women. They were predominantly Caucasian.

Among the 185 patients, 95 had LVH by echo (prevalence = 51.3%). As expected and demonstrated in Table 2, the LVMI in patients

Table 3. 2×2 Contingency Tables for the Four Studied LVH Criteria.

	LVH+	LVH-		
Sokolow +	30	8	38	0.79 (PPV)
Sokolow –	65	82	147	0.56 (NPV)
	95	90	185	
P < 0.001	0.32 (Sn)	0.91 (Sp)		0.61 (Acc)
Gertsch +	56	26	82	0.68 (PPV)
Gertsch –	39	64	103	0.62 (NPV)
	95	90	185	
P < 0.001	0.59 (Sn)	0.71 (Sp)		0.65 (Acc)
Cornell +	42	14	56	0.75 (PPV)
Cornell –	53	76	129	0.59 (NPV)
	95	90	185	
P < 0.001	0.44 (Sn)	0.84 (Sp)		0.64 (Acc)
Bozzi & Figini +	37	14	51	0.73 (PPV)
Bozzi & Figini –	58	76	134	0.57 (NPV)
	95	90	185	
P < 0.001	0.39 (Sn)	0.84 (Sp)		0.61 (Acc)

LVH = left ventricular hypertrophy; Sn = sensitivity; Sp = specificity; PPV = positive predictive value; NPV = negative predictive value; Acc = diagnostic accuracy.

with LVH was significantly higher than in those without LVH (153 ± 31 g/m² vs 88 ± 18 g/m² for men and 127 ± 37 g/m² vs 75 ± 12 g/m² for women; $P < 0.0001$). As illustrated in Table 3, among the 185 studied subjects, ECG criteria for LVH were present in 38 by the Sokolow index, 56 by the Cornell criterion, 51 by the criterion of Bozzi and Figini, and 82 by the criteria of Gertsch et al. Each criterion segregated the population into nonrandom proportions. All four ECG criteria demonstrated relatively low sensitivity for detection of LVH [32%, 44%, 39%, and 59% for Sokolow index, Cornell, Bozzi and Figini, and Gertsch criteria, respectively]. Relatively higher specificity was achieved for each criterion [91%, 84%, 84%, and 71% for Sokolow index, Cornell, Bozzi and Figini, and Gertsch criteria, respectively]. These results are depicted in Figure 2 and summarized with respective confidence intervals in Table 4. The sensitivity of the Gertsch criterion was statistically better than all other criteria without any overlap in confidence intervals. The specificity of the Sokolow index was statistically superior to all other criteria. Overall, the four criteria yielded similar PPV of 68–79% and similar overall diagnostic accuracy of 61–65% without any statistically significant differences. Analysis of sensitivity and specificity by Youden's index confirmed that the performance of the four studied ECG LVH criteria were not significantly different from each other.

Figure 2. Diagnostic performance of individual ECG LVH criteria. All criteria demonstrated relatively low sensitivity and higher specificity. PPV was comparable. Diagnostic accuracy was similar among all four criteria. ECG = Electrocardiogram; LVH = Left ventricular hypertrophy; PPV = positive predictive value.

The analysis of combined aVL-based LVH criteria versus non-aVL-based criteria revealed statistically similar diagnostic accuracy (Fig. 3). Compared to non-aVL-based criteria, the aVL-based criteria demonstrated statistically lower sensitivity (45% vs 68%) with a trend toward higher specificity (81% vs 67%).

We performed a gender-based analysis to see if any of the LVH criteria behaved differently in men or women. PPVs were 75%, 85%, 77%, and 63% in men and 82%, 69%, 67%, and 76% in women for Sokolow index, Cornell criteria, Bozzi and Figini criterion, and the Gertsch criteria, respectively. The diagnostic accuracy was 57%, 63%, 65%, and 62% in men and 64%, 64%, 56%, and 68% in women for the Sokolow index, Cornell criterion, Bozzi and Figini criterion, and the Gertsch criteria, respectively. These data represent the application in women of the standard Gertsch criteria. Given that the 2009 ECG guidelines recommended using gender-specific Gertsch voltage criteria, we reanalyzed our data using the gender-specific criteria proposed, but not tested, by Gertsch et al.: a voltage sum criterion of 28 mm or greater indicating LVH in women and 30 mm or greater in men. This analysis yielded slightly higher sensitivity (63% vs 59%), slightly lower specificity (71% vs 66%), and identical diagnostic accuracy of 65%. Based on analysis using confidence intervals and Youden's index, the Gertsch criterion with or without gender-specific correction yielded statistically similar results.

Table 4. Sensitivity, Specificity, and Youden's Index for the Study Criteria with 95% Confidence Intervals in Parenthesis

Criteria	Sensitivity	Specificity	Youden's Index
Sokolow (95% CI)	0.316 (0.224–0.419)	0.911 (0.832–0.960)	0.227 (0.056–0.597)
Cornell (95% CI)	0.442 (0.340–0.547)	0.844 (0.752–0.912)	0.286 (0.092–0.459)
Bozzi (95% CI)	0.389 (0.291–0.494)	0.844 (0.752–0.912)	0.233 (0.043–0.406)
Gertsch (95% CI)	0.589 (0.483–0.689)	0.711 (0.606–0.801)	0.3 (0.089–0.490)
AVL (95% CI)	0.452 (0.350–0.558)	0.811 (0.714–0.885)	0.263 (0.064–0.443)
Non-AVL (95% CI)	0.684 (0.580–0.775)	0.666 (0.559–0.762)	0.35 (0.139–0.537)

Figure 3. Diagnostic performance of combined ECG LVH criteria. aVL-based criteria demonstrated lower sensitivity, higher specificity with similar PPV, and accuracy compared to non-aVL-based criteria. $P < 0.0001$ for both criteria. aVL-based criteria are Sokolow index and Cornell criteria, non-aVL-based criteria are Bozzi and Figini and Gertsch criteria. ECG = Electrocardiogram; LVH = Left ventricular hypertrophy; PPV = positive predictive value.

DISCUSSION

This study represents a reanalysis of previously proposed ECG criteria for LVH in the presence of LAFB. In 1976, Bozzi and Figini were the first investigators to propose specific criteria to detect LVH in the presence of LAFB. They suggested that a QRS voltage sum that included $SV1 + [(RV5 + SV5) \text{ or } (RV6 + SV6)] > 25 \text{ mm}$ demonstrated the best accuracy, sensitivity, and specificity.⁶ This early study, which predated echocardiography, included only 29 patient controls and diagnosed LVH "... on the basis of anamnestic, objective and radiographic criteria." The investigators did

not further clarify exactly how LVH was diagnosed in the study population. Their gold standard was suboptimal by present standards.

In 1988, Gertsch et al. proposed another ECG voltage criterion for diagnosing LVH in the presence of LAFB. In a group of 50 patients, they observed that QRS voltage in which a voltage sum of $S_{III} + \text{maximum } (R + S) \text{ in any of the six precordial leads} \geq 30 \text{ mm}$ or greater demonstrated better sensitivity, specificity, and diagnostic accuracy than previously published LVH criteria in presence of LAFB.⁷ This study included 22 patients as controls and did incorporate M-mode echocardiography as the gold standard for diagnosing LVH. The authors suggested that a less stringent voltage criteria (e.g., a total QRS voltage sum of 28 mm or greater) might be more appropriate to detect LVH in women; however their study population (75% men) did not allow them to test this hypothesis.

Neither of the two aforementioned studies tested their proposed ECG diagnostic criteria in a patient group independent from those in whom the indexes were derived. In 1992, Fragola et al. did so in 70 patients in whom two-dimensional guided M-mode echocardiographic measurements served as the LVH gold standard.⁸ As depicted in Table 5 they demonstrated sensitivities, specificities, and diagnostic accuracies that were lower than what had been reported in the original studies. Using gender-specific Gertsch criteria yielded a slight increase in sensitivity (from 74% to 79%). It is unstated whether this represented a statistically significant difference, but it likely did not.

An overview comparing the chief features of these three studies is provided in Table 5. None

Table 5. Comparison of the Key Data from Publications Studying LVH in Patients with LAFB Cited in the 2009 Multisociety ECG Guidelines

Year	Bozzi et al. 1976	Gertsch et al. 1988	Fragola et al. 1992
LVH criteria	SV1 + (RV5 + SV5) or (RV6 + SV6) > 25	SIII + max (R + S) any precordial ≥30 mm	Bozzi
Controls	29	22	Gertsch Bozzi-30 Gertsch-25
LVH gold standard	X-ray	ECHO	ECHO
Sensitivity	79%	96%	Bozzi-74% Gertsch 74%
Specificity	76%	87%	Bozzi-67% Gertsch 47%
Accuracy	78%	92%	Bozzi-71% Gertsch 62%

LVH = left ventricular hypertrophy; LAFB = left anterior fascicular block; ECHO = echocardiogram.

reported any statistical analyses to test the validity of their conclusions. All were limited by the small number of patients studied, small control groups, and the use of manual measurements of QRS voltage, which is time-consuming and potentially subject to interobservational variability (a potential source of error that was not specifically addressed in any of the three studies). Unlike Bozzi and Figini, we were able to utilize modern echocardiographic methods as the gold standard for LVH. Unlike Gertsch et al. we performed rigorous evaluation of intraobserver agreement in echocardiographic measurements. We also were able to assess the gender-specific ECG voltage criteria for LVH.

Finally, in contrast to all previous studies, we analyzed results with statistical comparisons and we eschewed manual measurement of QRS voltage. To our knowledge this is the first study evaluating the utility of ECG LVH criteria in the presence of LAFB using purely computer-derived measurements of QRS voltage. Such measurements are simpler, faster, and probably subject to less intermeasurement variability.

Since anterior fascicular block shifts the mean QRS vector superiorly, one might anticipate, on theoretical grounds, that it might falsely increase the amplitude of R waves in lead aVL. Hence, one might expect higher sensitivity and lower specificity of the aVL-amplitude-based electrocardiographic LVH criteria in this setting, particularly using the Sokolow criterion. It appears that it was this concern that led the writing committee of Section 5 of the 2009 multisociety ECG guidelines

to eschew aVL-based electrocardiographic LVH criteria in the presence of LAFB.⁴ Despite this hypothetical concern, our results demonstrate the exact opposite of the anticipated results if the above hypothesis were to be true. Our study demonstrates that aVL-based criteria are useful, reliable, and comparable to the non-aVL-based LVH criteria that were selected for inclusion in the 2009 ECG guidelines. All four criteria demonstrated similar overall diagnostic accuracies of 61–65%.

Despite the theoretical concerns regarding the potential effects of the left axis deviation of LAFB on QRS voltage in aVL, we observed that the aVL-based LVH criteria demonstrated lower sensitivity (32–44%) than the non-aVL-based criteria (39–59%), but higher specificity (91–84% vs 84–71%). Schlapfer et al. observed similar findings.¹⁵ Their observations, like ours, suggest that LAFB does not in and of itself cause increased R-wave amplitude in lead aVL. The generation of a tall R wave in this lead probably requires increased myocardial mass, not merely coaxial electrical vector.

The authors of the 2009 ECG guidelines recommended using gender-specific Gertsch criteria to diagnose LVH in the setting of LAFB. In their paper Gertsch et al. offer this suggestion as an aside in their discussion.⁷ Their study population did not allow them to test such gender-specific criteria. Although Fragola et al.,⁸ and Schlapfer et al.¹⁵ studied slightly different patient population than ours, and applied echocardiographic criteria for LVH that were slightly different than ours, neither we nor they found any diagnostic advantage to

applying gender-specific voltage criteria to the criteria of Gertsch et al.

Our observations cannot be generalized, in absolute terms, to other patient populations without LAFB. Our point of emphasis is simply that within a population of patients with LAFB, all four of the ECG voltage criteria that we studied performed in similar fashion. From a practical point of view, the LVH criteria recommended in the 2009 guidelines for usage in the presence of LAFB (the non-aVL-based criteria) are somewhat cumbersome to calculate. They require measurement of R- and S-wave amplitudes in four to seven leads followed by calculation of the maximum cumulative voltages. In contradistinction, the aVL-based criteria are quick and easy to calculate, require examination of only two leads, and yield similar results. This may explain why the aVL-based Sokolow criterion is incorporated in the algorithm for diagnosing LVH in the setting of LAFB in at least one of the commercially available computer-assisted ECG interpretation algorithms (Marquette MUSE, version 7.1.1, GE Medical Systems) presently in use. Also of note, this algorithm incorporates neither the Gertsch criteria nor those proposed by Bozzi and Figini.

LIMITATIONS

This is a modest-sized, retrospective study with potential for sampling error. Nonetheless this study includes more patients than each of the previous studies upon which the 2009 ECG guidelines were based. Some of the echocardiograms and electrocardiograms included in our analysis were not performed on the same day. Although this might change the absolute correlation between ECG and echocardiographic measurements in some of the study subjects, it should not alter the relative diagnostic value of the various ECG criteria. We acknowledge that Youden's index has known limitations, chief among which is its failure to account for predictive values and disease prevalence. Youden's index might theoretically be the same for two tests with different predictive values because Youden's index only takes sensitivity and specificity into account.¹⁶ Hence, in evaluating the relative merits of diagnostic test criteria, it is important to evaluate prevalence and predictive values in addition to the Youden's index. We have done so in our analysis.

CONCLUSIONS

We conclude from this study that LAFB neither "masks" nor "mimics" the ECG diagnosis of LVH. The aVL-based LVH criteria (Sokolow index and the Cornell criteria) identify LVH with accuracy that is comparable to the non-aVL-based criteria. Therefore, in the presence of LAFB, the exclusion of the aVL-based ECG criteria for detection of LVH from the 2009 multisociety ECG guidelines may have been unnecessary. In addition, gender-specific Gertsch voltage criteria (akin to the Cornell criteria), as discussed by Gertsch et al. and included in the 2009 multisociety ECG guidelines, adds little diagnostic discrimination and is thus unnecessary. Neither our analysis nor two other studies^{8,15} support the case for gender-specific voltage cutoffs for the Gertsch criteria.

Clinical Implications

In the presence of LAFB, aVL-based criteria yield similar diagnostic accuracy as non-aVL-based criteria in detecting LVH by ECG. Moreover, the aVL-based criteria are much simpler to calculate and recall than non-aVL-based criteria. In the presence of LAFB, physicians may be approximately 75% certain that fulfillment of any one of the four studied LVH criteria indicates the presence of anatomical LVH. We suggest that the aVL-based criteria for detecting LVH in the presence of LAFB be included in future published ECG guidelines. We would also recommend that a single Gertsch criterion be used in this setting. Gender-specific correction of the Gertsch LVH voltage cutoff does not improve the discriminatory power of the criterion.

Acknowledgments: *We greatly appreciate the assistance of Dr. Yaw Amoateng-Adjepong in performing statistical analyses. We also thank Leslie Segel and Dawn Blaszkia for their expert assistance in obtaining echocardiographic data.*

REFERENCES

1. Koren MJ, Devereux RB, Casale PN, et al. Relation of left ventricular mass and geometry to morbidity and mortality in uncomplicated essential hypertension. *Ann Intern Med* 1991;114:345-352.
2. Boner G, Cooper ME, McCarroll K, et al. Adverse effects of left ventricular hypertrophy in the reduction of endpoints in NIDDM with the angiotensin II antagonist losartan (RENAAL) study. *Diabetologia* 2005;48:1980-1987.
3. Taylor AL. Left ventricular hypertrophy resulting from systemic hypertension: Adaptive advantage and adverse

- consequences. *J Assoc Acad Minor Phys* 1991;2:156-161.
4. Hancock EW, Deal BJ, Mirvis DM, et al. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: Part V: Electrocardiogram changes associated with cardiac chamber hypertrophy: A scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society. Endorsed by the International Society for Computerized Electrocardiology. *J Am Coll Cardiol* 2009;17;53:992-1002.
5. Surawicz B, Childers R, Deal BJ, et al. AHA/ACCF/HRS Recommendations for the standardization and interpretation of the electrocardiogram: Part III: Intraventricular conduction disturbances. A scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society Endorsed by the International Society for Computerized Electrocardiology. *J Am Coll Cardiol* 2009;53:976-981.
6. Bozzi G, Figini A. Left anterior hemiblock and electrocardiographic diagnosis of left ventricular hypertrophy. *Adv Cardiol* 1976;16:495-500.
7. Gertsch M, Theler A, Foglia E. Electrocardiographic detection of left ventricular hypertrophy in the presence of left anterior fascicular block. *Am J Cardiol* 1988;61:1098-1101.
8. Fragola PV, Autore C, Magni G, et al. Limitations of the electrocardiographic diagnosis of left ventricular hypertrophy: The influence of left anterior hemiblock and right bundle branch block. *Int J Cardiol* 1992;34:41-48.
9. Sokolow M, Lyon TP. The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial and limb leads. 1949. *Ann Noninvasive Electrocardiol* 2001;6:343-368.
10. Casale PN, Devereux RB, Kligfield P, et al. Electrocardiographic detection of left ventricular hypertrophy: Development and prospective validation of improved criteria. *J Am Coll Cardiol* 1985;6:572-580.
11. Lang RM, Bierig M, Devereux RB, et al. Recommendations for chamber quantification: A report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. *J Am Soc Echocardiogr* 2005;18:1440-1463.
12. Devereux RB, Phillips MC, Casale PN, et al. Geometric determinants of electrocardiographic left ventricular hypertrophy. *Circulation* 1983;67:907-911.
13. Devereux RB, Casale PN, Eisenberg RR, et al. Electrocardiographic detection of left ventricular hypertrophy using echocardiographic determination of left ventricular mass as the reference standard. Comparison of standard criteria, computer diagnosis and physician interpretation. *J Am Coll Cardiol* 1984;3:82-87.
14. Youden WJ. Index for rating diagnostic tests. *Cancer* 1950;3:32-35.
15. Schlapfer J, Jaussi A, Jaeger M. Is electrocardiographic diagnosis of left ventricular hypertrophy possible in the presence of an anterior hemiblock? *Schweiz Med Wochenschr* 1992;122:554-558.
16. Zhou XH, Obuchowski NA, McClish DK. *Statistical Methods in Diagnostic Medicine*. New York, Wiley & Sons, Inc., 2002, Part 1, 24 p.