Electrocardiographic Predictors of Left Ventricular Hypertrophy in Pediatric Hypertension

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Objective To determine the efficacy of electrocardiography (ECG) in detecting left ventricular hypertrophy (LVH) in pediatric hypertension (HT).

Study design Concomitant echocardiograms and electrocardiograms in 108 children with HT were reviewed. Left ventricular mass (LVM), assessed by echocardiography, was used as a basis for a diagnosis of LVH (echo LVH) using accepted pediatric criteria. Using Wilcoxon's rank-sum test, 14 ECG variables were compared between subjects with and without echo LVH. Spearman correlations were used to examine the linear association between echo LVH and these ECG variables. The sensitivity and specificity of ECG in diagnosing LVH were computed.

Results Of the 108 subjects studied, 35 (32%) met the pediatric criteria for LVH; of these, 8 (7.4%) also met the adult criteria (>51 g/m$^{2.7}$) for LVH. Mean values for only 5 ECG criteria differed significantly among the groups: RI, SaVR, RaVL, RI+SIII, and SVI+RV6 ($P < .05$). Significant correlations were found for several ECG criteria and at least 1 measure of LVM, but the magnitudes were modest. Standard ECG criteria predicted LVH with high specificity (>90%) but low sensitivity (<35%). RI >10 mm was identified as demonstrating a modestly improved positive likelihood ratio of ~3.

Conclusions ECG is not an adequate predictor of LVH for clinical use in HT. *(J Pediatr 2009;154:106-10)*

Left ventricular hypertrophy (LVH) has received much attention in adults with hypertension (HT); it has been recognized as a cardinal sign of preclinical cardiac disease and has been shown to be strongly predictive of myocardial infarction, stroke, and death.[1-4] In pediatric patients, it has been suggested that LVH can be used as a marker to identify hypertensive children at risk for complications later in life.[5] Thus, the early detection of LVH and treatment of HT is widely accepted as a desirable goal. Echocardiography has been shown to be an accurate predictor of LVH;[6] however, electrocardiography (ECG) is less expensive, quicker, and more easily performed. In children, the validity of ECG criteria for diagnosing LVH has been studied in such situations as rheumatic heart disease, human immunodeficiency virus (HIV) infection, hypertrophic cardiomyopathy, aortic stenosis, and ventricular septal defects.[7-10] The purpose of the present study was to identify differences in ECG criteria between children with both HT and LVH detected by echocardiography (echo LVH) and children with HT and no evidence of echo LVH. We also sought to determine the sensitivity and specificity of standard pediatric ECG criteria to diagnose LVH in pediatric HT and to investigate whether the sensitivity may be improved in this condition, as has been reported in conditions with increased afterload.[10]

METHODS

Subjects

A retrospective chart review of data for consecutive children and adolescents identified with HT at the Hypertension Clinic at the Maimonides Infants and Children's Hospital of Brooklyn between 2001 and 2007 was performed. The hospital's Institutional Research Committee approved the study design. The following information was compiled: age, sex, ethnic group, weight, height, body surface area (BSA), and calculated body mass index (BMI). Blood pressure was recorded manually at the time of the echocardio-

AUC	Area under the curve	HIV	Human immunodeficiency virus
BMI	Body mass index	HT	Hypertension
BSA	Body surface area	LVH	Left ventricular hypertrophy
CI	Confidence interval	LVM	Left ventricular mass
ECG	Electrocardiography		

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graphic examination. Subjects were considered to have HT if they fulfilled the criteria for diagnosis of essential HT according to the standards of the fourth report of the National Heart, Lung, and Blood Institute's Task Force on Blood Pressure Control in Children.[11] Patients with both primary and secondary HT were included. Patients with congenital heart disease were excluded.

A comprehensive 2-dimensional Doppler and M-mode echocardiographic examination was performed on each subject on the same day as the ECG, using commercially available ultrasound equipment. Left ventricular mass (LVM), in grams, was calculated following the method described by Devereux et al.[6] The LVM was indexed to BSA and height (in $m^{2.7}$).[12] Subjects were considered to have LVH if they met established pediatric criteria of LVM >36.88 $g/m^{2.7}$ in females and >39.36 $g/m^{2.7}$ in males.[5] Within this group, subjects reaching the adult criteria of LVM >51 $g/m^{2.7}$ also were also examined separately. Measurements of the left ventricular internal dimension and posterior wall and the interventricular septum were done by M-mode echocardiography during diastole, according to methods established by the American Society of Echocardiography.[13] The latter 2 were indexed to the square root of the BSA ($g/m^{1/2}$).[14]

Twelve-lead ECGs were performed using commercially available machines. All studies were performed at a paper speed of 25 mm/s and calibrated to 10 mm/mV. The measurements were made by trained observers who were blinded to the diagnosis. The voltages of the R, S, and Q waves and the QRS duration were measured in all leads. Fourteen criteria considered to reflect left ventriclular forces were tabulated: RI, SIII, SaVR, RaVL, SV1, SV2, SV3, RV5, RV6, q depth in V6, q depth in III, RI+SIII, SV1+RV6, and SV3+RaVL. In addition, all of the electrocardiograms were evaluated to determine whether they met the standard pediatric ECG criteria for diagnosing LVH as reported by Garson,[15] including (1) voltage of the S wave in V1 > 98th percentile for age (SV1), (2) voltage of the R wave in V6 > 98th percentile for age (RV6), (3) sum of the voltages of the S wave in V1 and the R wave in V6 > 98th percentile for age (SV1+RV6), (4) Q wave in V6 > 98th percentile for age, and (5) inverted T wave in V6 (TV6). Three other ECG criteria described in the Bogalusa Study[16] also were used as standard pediatric ECG criteria: RI +SIII > 19 mV, RaVL > 7.5 mV, and RI > 13 mm.

The subjects were divided into 2 groups: those with HT and echo LVH (HT/LVH) and those with HT but no LVH (HT/no LVH). For comparisons of demographic and clinical data by LVH status, unpaired *t*-tests were used for continuous variables, and Fisher exact test was used for categorical variables. Because the distributions of some ECG measures were nonnormal, Wilcoxon's rank-sum test was used to compare all ECG criteria by LVH status. Spearman correlations were used to examine the linear association between measures of echocardiographically determined LVM and the 14 ECG criteria reflecting left ventricular forces. Sensitivity and specificity were computed using relevant standard pediatric ECG criteria and are presented with exact 95% confidence intervals (CIs). The area under the receiver operating characteristic curve (AUC) was used to estimate the accuracy of the ECG criteria in classifying LVH. The AUC values are presented with 95% CIs as well. To determine whether any combination of variables improved the discrimination of subjects with or without LVH (based on pediatric criteria), stepwise logistic regression was used to develop a model that would be optimistic given the data. Because of substantial collinearity among several of the ECG measures, a forward stepwise approach was taken. Liberal cutpoints were applied for variable selection, to allow for broad inclusion of any patient variables or ECG measures that may provide even modest improvement in discrimination. The *P* values were .15 for entry and .20 for removal. All analyses were conducted using Stata version 10.0 (StataCorp, College Station, Texas). Statistical analyses achieving a *P* value of <.05 were considered statistically significant.

Table 1. Demographic and echocardiographic characteristics

Characteristic	HT/LVH (n = 35)	HT/no LVH (n = 73)	*P* value
Age, years	13.74 (2.78)	14.21 (3.51)	.49
Sex, male/female	28/7	58/15	1.0
Race, Caucasian/other	11/24	37/36	.06
BMI, kg/m^2	31.44 (7.32)	26.77 (6.53)	.001
BSA, m^2	1.87 (0.38)	1.76 (0.41)	.19
Weight, kg	84.36 (28.56)	72.98 (26.53)	.04
Height, cm	161.6 (15.14)	162.1 (19.22)	.90
Systolic blood pressure, mm Hg	132.11 (14.64)	136 (15.04)	.18
Diastolic blood pressure, mm Hg	75.06 (9.11)	75.59 (8.96)	.77
LVM, g/m^2	93.62 (18.75)	63.13 (13.22)	.0001
LVM, $g/m^{2.7}$	48.46 (10.47)	29.37 (6.12)	.0001
$IVS/BSA^{1/2}$	0.66 (0.12)	0.53 (0.09)	.0001
$LVPW/BSA^{1/2}$	0.70 (0.11)	0.59 (0.09)	.0001

IVS, interventricular septum; *LVPW*, left ventricular posterior wall.
Values are mean (standard deviation) except for sex and race.

RESULTS

Of the 108 children with HT studied, 35 had LVH as defined by the pediatric criteria (8 of whom also met the adult criteria). and 73 had no LVH. The prevalence of LVH was 32% based on the pediatric criteria and 7.4% based on the adult criteria. Table I summarizes the clinical characteristics of the patient cohort. The preponderance of the subjects were adolescents. The HT/LVH and HT/no LVH groups were comparable in terms of age, sex, and ethnic background. The 2 groups exhibited no significant differences in height and BSA; however, BMI was significantly higher in the HT/LVH group. Of interest, the 2 groups also had no difference in systolic or diastolic blood pressure values.

Table II shows the results of comparison of the ECG variables by LVH status as measured by pediatric echocardio-