Sensitivity and Specificity of the Electrocardiogram in Predicting the Presence of Increased Left Ventricular Mass Index on the Echocardiogram in Afro-Caribbean Hypertensive Patients

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ABSTRACT

Cardiovascular disease is emerging as the leading cause of death in the Caribbean region with hypertension along with diabetes mellitus representing the major causes. Left ventricular hypertrophy associated with hypertension results in a two to fourfold increase in cardiac morbidity and mortality. One hundred and eleven patients, 67% female, mean age 46 years with a mean of seven years since diagnosis, had resting blood pressure, electrocardiogram and sector-focused M-mode echocardiogram performed. The electrocardiograms were analyzed for left ventricular hypertrophy using Sokolow-Lyon, Cornell, Romhilts-Estes, 12 lead sum, QRS duration, 12 lead–QRS product and left ventricular strain pattern. The echocardiograms were analyzed for increased left ventricular mass using the formula of Devereux and Reichek indexed to height. The mean systolic blood pressure was 156 mmHg, mean diastolic blood pressure was 97 mmHg on treatment. At least one electrocardiographic criterion for left ventricular hypertrophy was seen in 47/111 (42%) patients and increased left ventricular mass index was seen in 55/111 (50%) patients. Sensitivity, specificity and positive predictive value of the electrocardiogram in predicting increased left ventricular mass index was best for Sokolow-Lyon (31%, 86%, 76%), Cornell (23%, 96%, 88%) and 12 lead-QRS product (30%, 86%, 72%). Sensitivity ranged from 3 to 31%, specificity from 80 to 96% and positive predictive value from 40 to 88%. The electrocardiogram is insensitive in detecting increased echocardiographic left ventricular mass index, as in patients from developed countries, and is less specific for the finding as in African Americans.

Sensibilidad y Especificidad del Electrocardiograma en la Predicción de la Presencia de Aumento del Indice de Masa Ventricular Izquierda en el Ecocardiograma en Pacientes Afro-caribeños Hipertensos

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RESUMEN

La enfermedad cardiovascular está pasando a ocupar el primer plano como causa principal de muertes en la región del Caribe, siendo la hipertensión junto con la diabetes las causas principales. La hipertrofia del ventrículo izquierdo asociada con los resultados de la hipertensión, trae como consecuencia que la morbilidad y la mortalidad cardíacas aumenten de dos a cuatro veces. A ciento once pacientes – el 67% mujeres, con una edad promedio de 46 años y un promedio de siete años transcurridos desde el diagnóstico – se les midió la presión arterial en reposo, y se les hizo un electrocardiograma, así como un ecocardiograma en Modo-M enfocado por sectores. Los electrocardiogramas fueron analizados en busca de alguna hipertrofia ventricular izquierda, usando los criterios de Sokolow-Lyon, Cornell, Romhilts-Estes, la suma de 12 derivaciones, la duración del QRS, el producto del QRS en las 12 derivaciones, y el patrón de tensión ventricular izquierda. Los ecocardiogramas fueron analizados fueron analizados en busca de un aumento de la masa ventricular izquierda, usando la fórmula de Devereux y Reichek indexada por la altura. La media de la presión arterial sistólica fue 156 mmHg, y la media de la presión arterial diastólica fue 97 mmHg en el tratamiento. Al menos un criterio electrocardiográfico

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de la hipertrofia ventricular izquierda fue visto en 47/111 (42%) pacientes, y el índice de masa ventricular izquierda aumentada, fue visto en 55/111 (50%). La sensibilidad, especificidad y valor predictivo positivo del electrocardiograma en la predicción del índice de masa ventricular izquierda aumentada fue mejor en Sokolow-Lyon (31%, 86%, 76%), Cornell (23%, 96%, 88%) y el producto del QRS en las 12 derivaciones (30%, 86%, 72%). La sensibilidad fluctuó del 3 al 31%; la especificidad, del 80 al 96%; y el valor predictivo positivo, del 40 al 88%. El electrocardiograma es insensible en cuanto a detectar el índice de masa ventricular izquierda aumentada, como en el caso de pacientes de países desarrollados, y es menos específico para el hallazgo, como en el caso de los afro-norteamericanos.

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INTRODUCTION

Cardiovascular disease is emerging as the most frequent cause of death in the Caribbean, with cerebrovascular disease (13.0%), ischaemic heart disease (9.5%), hypertensive disease (4.8%) and diabetes mellitus (8.4%) accounting for 35.5% of the mortality in the region in 1990 (1). The same diseases accounted for 47.2% of the deaths in Antigua and Barbuda in 1998 (2). Available data suggest that hypertension is present in 40% of the Caribbean population by age 40 years and 50% by age 65 years (3). Hypertension has been found to be the leading factor associated with congestive cardiac failure, myocardial infarction, atrial fibrillation and cerebrovascular accident in Afro-Caribbean patients (4–10).

Hypertensive heart disease is defined as the response of the heart to the afterload imposed on the left ventricle by increased arterial pressure and peripheral resistance produced by hypertensive vascular disease. The degree of left ventricular hypertrophy is related to the arterial pressure and is an ominous prognostic sign and independent risk factor for sudden death, ventricular arrhythmias, myocardial ischaemia, coronary artery disease, congestive cardiac failure and cerebrovascular accident (11–15).

Hypertensive patients of African ethnicity in the United States of America (USA) have a higher risk for hypertension related morbidity and mortality, a higher prevalence of hypertension, more left ventricular hypertrophy and more congestive cardiac failure and stroke than patients of European ethnicity (13–16). Although high blood pressure and its consequences had been less of a problem in Africa and the Caribbean for patients of African ethnicity (19–21), changing diet and lifestyles are increasing the risks to the Caribbean patient of African ethnicity (22–24).

The presence of left ventricular hypertrophy may be assessed by electrocardiography and echocardiography, with the newer techniques of computed tomography and magnetic resonance imaging being applied recently (25). The electrocardiogram and echocardiogram have the most substantial support for clinical use (25). The electrocardiogram is relatively insensitive to left ventricular hypertrophy, identifying only 30 to 50% of patients with left ventricular hypertrophy on echocardiogram (26–28).

Electrocardiographic left ventricular hypertrophy is specific for echocardiographic left ventricular hypertrophy in 90 to 95% of persons of European ethnicity but appears less so for Afro-American and Afro-Caribbean patients (29–33). Echocardiographic left ventricular hypertrophy is seen in a majority of mild to moderate hypertensive patients (34), is accurate using necropsy findings for confirmation (35), and is an independent risk factor for cardiovascular complications, increasing risk by a factor of four in patients of European and African ethnicity (36–38).

There are few data concerning the prevalence of left ventricular hypertrophy on electrocardiogram or echocardiogram in Afro-Caribbean patients with hypertension. This study is an attempt to describe the electrocardiographic findings in a sample of treated hypertensive patients in Antigua, and assess the ability of the electrocardiogram to predict echocardiographic left ventricular hypertrophy in this population.

SUBJECTS AND METHODS

Afro-Caribbean patients with hypertension were invited to participate in an evaluation of left ventricular hypertrophy in hypertension in Antigua and Barbuda. Participants were recruited from the district clinics in Antigua as well as from the offices of medical practitioners. All recruited patients were diagnosed previously with hypertension and were receiving medical treatment through their primary caretakers. These medications were continued during the study.

Following the study explanation, informed consent for participation was obtained. Patients with congestive cardiac failure or renal failure were excluded. All patients had age, gender, height, weight, medications and other risk factors such as tobacco and drug use, diabetes and anaemia recorded. Blood pressure was taken with a mercury sphygmomanometer according to recommendations (39). This was followed by an electrocardiogram performed on a Burdick instrument (Burdick, Inc, Milton, Wisconsin USA, 1995) and measured by hand. An echocardiogram was performed by a single investigator (TCM) unaware of clinical or electrocardiographic findings. The echocardiograms were performed on a Toshiba Sonolayer SSA-100 machine (Toshiba, Inc, Tokyo, Japan, 1988) with a 3.25 megaHertz transducer. Sector-focused M-mode images were measured from video images showing the best left ventricular image. Electrocardiograms were analyzed for left ventricular hypertrophy using established criteria (27, 28, 30, 40, 41).

Sokolow-Lyon: S in lead V1 plus R in lead V5 or V6 over 35 millimetres (mm). Cornell: R in lead AVL plus S in lead V3 over 24 min in men, over 20 mm in women.

Romhilts-Estes: R or S in limb lead over 20 mm, S in V1, V2 or V3 over 25 mm or R in V4, V5 or V6 over 25 mm = 3 points; any ST shift = 3 points (with digoxin = 1 point); Left axis deviation less than -15 degrees = 2 points; QRS duration 0.09 second or over = 1 point; intrinsicoid deflection in V5 or V6 over 0.04 second = 1 point, P wave terminal force in V1 over 0.04 second = 3 points. Left ventricular hypertrophy is present if total points equal or exceed 5.

12-Lead sum: sum of all QRS deflections over 179 mm QRS duration: QRS duration in any lead over 0.12 second (120 milliseconds, msec). 12-Lead-QRS product: product of 12-Lead sum multiplied by QRS duration over 17,472 mm-msec. Left ventricular strain: depressed ST segment with upward convexity to negative T wave.

Echocardiographic analysis included measurement of the left ventricular internal diameter (LVID) in diastole, the left ventricular internal diameter in systole (LVIS), the posterior left ventricular wall thickness (PWT), and the intraventricular septal thickness (IVS) according to established criteria (42–44). Patients with decreased left ventricular systolic function, with left ventricular fractional shortening (LVID – LVIS divided by LVID less than 0.25, were excluded. Left ventricular mass was calculated using the method of Devereux and Reichek (45): left ventricular mass (in grams, g) = 1.04 [$(LVID + IVS + PWT)^3 - (LVID)^3$] – 13.6. This value was divided by the height in metres (m) to give the left ventricular mass index. Increased left ventricular mass index was defined as over 143 g/m^2 in men and over 102 g/m^2 in women. Concentric left ventricular hypertrophy was defined as IVS + PWT divided by 0.5 x+ LVID greater than 0.44 with increased left ventricular mass index (46, 47). Concentric remodelling was defined as IVS + PWT divided by 0.5 x LVID greater than 0.44 with normal left ventricular mass index (46, 47).

Using the echocardiographic finding of increased left ventricular mass index as the most definitive diagnostic finding associated with cardiovascular events in hypertension, the sensitivity, specificity, positive predictive value and negative predictive value of each electrocardiographic criterion for left ventricular hypertrophy was assessed. Sensitivity is the number of patients with electrocardiographic left ventricular hypertrophy and echocardiographic left ventricular hypertrophy divided by the number with echocardiographic left ventricular hypertrophy with or without electrocardiographic left ventricular hypertrophy (true positive divided by true positive plus false negative) x 100. Specificity is the number of patients with no electrocardiographic left ventricular hypertrophy and no echocardiographic left ventricular hypertrophy divided by the number with no echocardiographic left ventricular hypertrophy (true negative divided by true negative plus false positive) x 100.

Positive predictive value is the number of patients with electrocardiographic left ventricular hypertrophy and echocardiographic left ventricular hypertrophy divided by the number with echocardiographic left ventricular hypertrophy with or without electrocardiographic left ventricular hypertrophy (true positive divided by true positive plus false positive) X 100. Negative predictive value is the number of patients with no electrocardiographic or echocardiographic left ventricular hypertrophy divided by the number without electrocardiographic left ventricular hypertrophy with or without echocardiographic left ventricular hypertrophy (true negative divided by true negative plus false negative) x 100.

RESULTS

A total of 131 patients were enrolled in the project. There were 111 (85%) with complete data for analysis, the most frequent reason for dropout being technically inadequate transthoracic echocardiographic study. There were 74/111 (67%) women, 37/111 (33%) men, with mean age 46.3 years (range 27 to 69 years). The mean duration of known hypertension was 7.6 years (range 1 to 30 years). The mean systolic blood pressure was 156 ± 22 millimeters of mercury (mmHg) and the mean diastolic pressure was 97 ± 12 mmHg. There were 47/111 (42%) who met at least one criterion for electrocardiographic left ventricular hypertrophy. There were 55/111 (50%) patients who had increased left ventricular mass index on echocardiogram.

The sensitivity of the electrocardiogram for predicting echocardiographic left ventricular hypertrophy varied from 3% for the QRS duration to 31% for the Sokolow-Lyon criterion (Table). There were 7/111 patients (5%) less than the 35 years of age used to validate the Sokolow-Lyon criteria but this did not make a difference to the outcome. The 12-lead QRS product had value of 30% with the Cornell criterion 23%. The specificity of the electrocardiogram for predicting increased left ventricular mass varied from 96% for the Cornell criterion to 80% for the 12 lead sum. The 12 lead QRS product was 86% (Table).

Table: The sensitivity and specificity of various electrocardiographic criteria for left ventricular hypertrophy predicting increased left ventricular mass index on echocardiogram

Criterion	Sensitivity	Specificity
Sokolow-Lyon	31%	86%
Cornell	23%	96%
Romhilts-Estes	27%	84%
12 Lead sum	25%	80%
12 Lead-QRS Product	30%	86%
QRS Duration	3%	94%
Left ventricular strain	21%	62%

The positive predictive value for any of the electrocardiographic criteria predicting increased echocardiographic left ventricular mass index was 57%. The Cornell criteria had the highest positive predictive value, 88%, followed by Sokolow-Lyon at 76% and 12 lead-QRS product at 72%. The negative predictive value (that a normal electro-

cardiogram predicted the absence of increased echocardiographic left ventricular mass index) was 47%.

Of those patients with increased left ventricular mass index, 42/55 (76%) had concentric left ventricular hypertrophy and 13/55 (24%) had eccentric hypertrophy. Of those patients having normal left ventricular mass index, 39/56 (69%) had concentric remodelling and 17/56 (31%) were normal.

DISCUSSION

Although Sokolow-Lyon, Cornell and 12 lead-QRS duration product have some usefulness compared to other criteria for predicting echocardiographic confirmed left ventricular hypertrophy (31, 41, 47), sensitivity is low. This sensitivity is worse for patients of African ethnicity (28–31) and is poor for Afro-Caribbean patients as documented in this study, with maximum sensitivity for any criteria of left ventricular hypertrophy less than 33%. Attempts have been made to improve the sensitivity of the electrocardiogram using more complicated formulae in all patients (28, 48) and Afro-American patients specifically (49), but are not widely used.

Specificity of the electrocardiogram in this sample was in the 80% range for most criteria, with the Cornell criteria at specificity of 96% but with a sensitivity of only 23%. The results of this study do confirm that of the routinely available electrocardiographic criteria for left ventricular hypertrophy, the Sokolow-Lyon, Cornell and 12 lead-QRS product have the best combination of sensitivity, specificity and positive predictive value for predicting increased echocardiographic left ventricular mass.

In addition to lack of sensitivity and, to a lesser extent, specificity, the electrocardiogram had a positive predictive value of 57% and a negative predictive value of 47% in this sample of Afro-Caribbean hypertensive patients. The current recommendation in the Caribbean is to use the electrocardiogram to assess the hypertensive patient for left ventricular hypertrophy (39). Although the left ventricular hypertrophy on the electrocardiogram is an independent predictor of untoward outcome (13, 50), the echocardiographic left ventricular hypertrophy is also an independent predictor (13, 50), one that may have increased usefulness in the Afro-Caribbean hypertensive patient. Echocardiography may be the tool of choice for assessing cardiac involvement in hypertension, despite the cost.

This study has several limitations. The number of patients involved in the study is small. The electrocardiogram is less effective in the elderly (51) and in obese patients (52) in predicting left ventricular mass but the data from these groups were not analysed separately. The left ventricular mass index can be done by different methods (*eg* indexed to body surface area or height to the 2.7 power) but in this study 2/111 (2%) of patients would have been classified differently if values were indexed to body surface area and a recent review suggested that due to high correlation, indexing by any method was nearly equivalent (53). The simplest method was chosen.

In summary, this study demonstrates that the electrocardiogram lacks sensitivity for detecting increased echocardiographic left ventricular mass in a sample of Afro-Caribbean hypertensive patients, as it also does in hypertensive patients in developed countries. In addition, the specificity is similar to that seen in hypertensive patients of African ethnicity overseas, and is less than that for hypertensive patients of European ethnicity. For these reasons, echocardiography appears more accurate than electrocardiography and might be considered the tool of choice for assessing cardiovascular and cerebrovascular risk in hypertensive patients in the Caribbean region.

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