International Journal of Cardiology 120 (2007) 344–350

International Journal of Cardiology

www.elsevier.com/locate/ijcard

# Electrocardiographic prediction of left ventricular geometric patterns in patients with essential hypertension

Meryem Aktoz, Okan Erdogan *, Armagan Altun

*Department of Cardiology, School of Medicine, Trakya University, Edirne, Turkey*

Received 15 May 2006; received in revised form 17 August 2006; accepted 14 October 2006
Available online 13 December 2006

**Abstract**

*Background:* The present study sought to determine the diagnostic value of electrocardiographic voltage criteria in predicting geometry patterns in patients with essential hypertension.
*Methods:* Patients with essential hypertension ($n$=125) according to left ventricular mass index and relative wall thickness as determined by echocardiography were assigned in the following groups: normal geometry (N, $n$=50), concentric remodeling (CR, $n$=12), concentric hypertrophy (CH, $n$=28) and eccentric hypertrophy (EH, $n$=35). Each patient underwent 12-lead ECG followed by determination of conventional voltage criteria as well as peak to peak QRS lengths in each lead.
*Results:* Voltage criteria such as Sokolow–Lyon, Cornell, Cornell product >2440, D1R+D3S >25 mm, and AVL R >11 mm could not significantly predict and discriminate geometric patterns of LVH. However, they all were very specific (range 97–100%) and showed very high positive predictive values (range 94–100%) for detecting abnormal geometry. DI peak >12 mm had a sensitivity 61%, specificity 67%, accuracy 63%, positive predictive value 81%, and negative predictive value 42% in predicting to differentiate CH from CR. Sum of the calculated values from the peak of the R to the nadir of the S wave in all limb leads >60 mm had sensitivity 68%, specificity 75%, accuracy 70%, positive predictive value 86% and negative predictive value 50% in predicting to differentiate CH from CR.
*Conclusions:* Conventional ECG voltage criteria could not significantly discriminate specific geometry patterns observed in patients with essential hypertension.


*Keywords:* Left ventricular hypertrophy; Hypertension; Geometry; Electrocardiography; Echocardiography

## 1. Introduction

Left ventricular hypertrophy (LVH) has been shown to be an extremely strong predictor of cardiovascular morbidity and mortality whether it is diagnosed by electrocardiography (ECG) or transthoracic echocardiography [1]. An increased left ventricular (LV) mass is a major risk factor and a powerful independent predictor of cardiovascular events [2]. Evaluation of LV mass is therefore important in patients with hypertension. It has been reported that cardiovascular mortality and morbidity differ significantly among patients with different LV geometric patterns as determined by echocardiography [3]. Anatomic adaptation of LV to high blood pressure usually ends up with abnormal geometry. Specific patterns of abnormal geometry defined and classified according to left ventricular mass index (LVMI) and relative wall thickness (RWT) are as follows: normal geometry, concentric remodeling, concentric hypertrophy and eccentric hypertrophy [4]. It has been suggested that the concentric type of LVH is associated with poorer prognosis than the eccentric type [5]. In addition, it is well known that left ventricular concentric remodeling is also related to subsequent cardiovascular morbidity and mortality [6]. ECG is a simple, cheap, easy available and interpretable method even by a general practitioner or physician for diagnosing

* Corresponding author. Arseven Sitesi Villa Konutlari, No: 2 D-100 Karayolu, Edirne 22030, Turkey. Tel.: +90 284 226 04 39; fax: +90 284 235 27 30.
*E-mail address:* okanerdogan@yahoo.com (O. Erdogan).

0167-5273/$ - see front matter © 2006 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.ijcard.2006.10.010

LVH and stage the severity of hypertensive heart disease. Although echocardiography is more reliable for this purpose, we think that ECG still might be a reasonable and alternative option if echocardiography is not available. Especially in developing countries due to financial problems echocardiography is only available in certain areas and referral centers. In addition, patients usually wait a long period of time just for having an echocardiographic examination. Cost is also an important issue that must be taken into account, especially in poor countries. Determining abnormal geometry and patterns by echocardiography is also time consuming for places with high patient volume. However, the diagnostic value of ECG is not as good as echocardiography. Given the assumptions and issues mentioned above, if we are able to find a better and reliable method for predicting abnormal LV geometry with the aid of ECG, it will be widely used for this purpose both by general physicians and in places where echo is expensive and not widely available.

Because of limited data on the association between geometric patterns of hypertension and ECG changes, we aimed to investigate the relationship between conventional ECG voltage criteria and LV geometry in patients with essential hypertension.

## 2. Methods

### 2.1. Patients

Essential hypertension is defined as systolic >140 mmHg and/or diastolic blood pressure >90 mmHg or taking regular antihypertensive medications. All subjects with essential hypertension ($n$=210) who were being followed at outpatient clinics of cardiology and internal medicine were prospectively evaluated. Exclusion criteria are poor quality of echocardiographic image, intraventricular conduction abnormalities, pacemaker rhythm, atrial fibrillation, history of ischemic heart disease, evidence of myocardial infarction on ECG, peripheral edema, pericardial effusion, chronic obstructive lung disease, body mass index >35 kg/m$^2$, ejection fraction < 40% and severe valvular heart disease. After exclusion of patients with above mentioned conditions, remaining patients with essential hypertension ($n$=125) who desired to participate in the study underwent routine laboratory check, transthoracic echocardiography and 12-lead ECG. No patient had any evidence of or a history of acute or chronic cardiac, pulmonary, hepatic, or renal diseases. Blood pressure was measured with a standard cuff and a sphygmomanometer after patients had rested for 5 to 10 min in the sitting position. Conventional transthoracic echocardiography was performed after patients had rested for 10 min in the supine position, followed by recording of a standard 12-lead ECG on the same day. The study has been approved by the local ethics committee of our institution. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the institution's human research committee. All patients gave verbal informed consent to participate in the study.

### 2.2. Echocardiography

Transthoracic echocardiography was performed by an experienced echocardiographer with a Hewlett-Packard Sonos 2500 cardiac ultrasound unit. Echocardiographic studies were performed using two dimensionally guided M-mode echocardiograph in standard views with the patient in the partial left decubitus position and three to five measurements were averaged. The LV internal dimension and wall thicknesses were measured at end-diastole according to the recommendations of the American Society of Echocardiography using a leading edge to leading edge convention [7]. The tracings used to determine LV dimensions were recorded at or just below the tip of the mitral leaflets. Ejection fraction was calculated according to the Teichholz method. The left ventricular mass (LVM) was calculated according to the formula described by Devereux et al. [8]: $\mathrm{LVM}=0.8\ [1.04\ (\mathrm{LVDd}+\mathrm{IVSd}+\mathrm{PWd})^3 - (\mathrm{LVDd})^3]+0.6$, where LVDd is the LV internal dimension in diastole, PWd is the LV posterior wall thickness in diastole, and IVSd is the interventricular septal thickness in diastole. LVMI was determined by dividing the LVM to the patient's body surface area. RWT was calculated according to the following formula: RWT=2PWd / LVDd (12). Increased RWT was defined as more than 0.45, and increased LVMI was defined >131 g/m$^2$ for men and >100 g/m$^2$ for women [9]. The subjects were divided into four groups based on their LV geometric pattern, namely normal geometry (N; normal LVMI and normal RWT), concentric remodeling (CR; normal LVMI and increased RWT), concentric hypertrophy (CH; increased LVMI and RWT), eccentric hypertrophy (EH; increased LVMI and normal RWT) [4].

### 2.3. Electrocardiography

Standard 12-lead ECGs were recorded at a paper speed of 25 mm/s and a sensitivity of 1 mV/cm according to the recommendations of the American Heart Association [10]. At the end of the study calculations of several ECG variables were done by the same examiner who was unaware of the patients' echocardiographic data. ECG variables were averaged over five consecutive heart cycles. R and S waves and sum of the R- and S-wave voltages were determined in all 12 leads. Then, the following conventionally used ECG voltage criteria were employed in each patient for detection of LVH: Sokolow–Lyon voltage [11] (V1S+V5R or V6R ≥ 35 mm and V5R or V6R ≥ 26 mm), Cornell voltage [11] (AVL R+V3 S >28 mm for men, and >20 mm for women), Cornell product [12] [(AVL R+V3 S)QRS duration] >2440 mV ms and sum of QRS amplitudes in 12 leads >175 mm [13–15]. In addition, the following criteria calculated from the limb leads were also employed in each subject's ECG [11]: D1R+D3S >25 mm and R >11 mm in AVL.