Hypertension

Change of Body Surface Electrocardiogram is Linked to Left Ventricular Geometric Alteration from Normal, Pre-Hypertension to Hypertension: Comparison of NT-ProBNP and hs-CRP in Determining Ventricular Remodeling

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Background: The presence of echocardiographic left ventricular remodeling and hypertrophy, a potential surrogate of pathophysiology intermediate between hypertension and heart failure, has been strongly linked to increased cardiovascular events. Electrocardiography (ECG) data regarding such a continuous change in pre-hypertension and hypertension subjects and their comparison with biomarkers are still elusive.

Methods and Materials: We studied 364 subjects including 140 normal subjects (mean age 47.6 ± 9.4, 49% female), 136 pre-hypertensives (mean age 50.6 ± 9.6, 32% female) and 88 hypertensives (mean age 58.6 ± 11.5, 44% female). Baseline demographic data and levels of biomarkers [high-sensitivity C-reactive protein (hs-CRP) and N-terminal-pro-B type natriuretic peptide (NT-ProBNP)] were collected, with various 12-lead surface ECG criteria analyzed. Echo-derived left ventricular (LV) geometries were assessed through standardized methods. We used nonparametric trend tests for comparing continuous variables across different groups with receiver-operating characteristic (ROC) curves constructed from both ECG and biomarkers for identifying echo-defined ventricular remodeling and hypertrophy.

Results: Of all 364 subjects under survey, several ECG-based parameters demonstrated continuous changes in an ordered fashion across different groups (all p < 0.05) which paralleled those observed from biomarkers and echo-derived LV geometric changes and function. NT-ProBNP alone identified echo-derived LV hypertrophy (LVH) better than hs-CRP (AUC: 0.72 vs. 0.62, respectively, both p < 0.05) while neither showed satisfactory result in identifying concentric remodeling. The ROC area under curve in identifying LVH showed comparative result between some electrocardiography (ECG) parameters and NT-ProBNP, with Cornell product revealed to have the highest predictive value (AUC: 0.73, p < 0.05).

Conclusion: Surface ECG yielded ability comparable to that of NT-ProBNP in identifying LVH. LV geometric remodeling, when defined by surface ECG, seemed to progress in subjects from normal, pre-hypertension to hypertension. This evidence suggests that aggressive control of blood pressure may be helpful at an earlier stage.

Key Words: Echocardiography • Electrocardiography • hs-CRP • Hypertension • Left ventricular hypertrophy • NT-ProBNP

INTRODUCTION

Hypertension has becoming the leading epidemiologic issue owing to its widely affected population and increasing economic burden. Ventricular hypertrophy, which represents a more severe form of ventricular remodeling following hypertension, denotes a clinical surrogate of target organ damage. Left ventricular hypertrophy (LVH) has been shown to predict cardiovascular events including stroke, myocardial infarction, heart failure and sudden cardiac death. Echocardiography, a
traditional standard clinical tool in determining such cardia
crucial and functional changes, is relatively ex-
pensive and time-consuming. Recently, N-terminal-pro-
B type natriuretic peptide (NT-proBNP) and the inflam-
matory marker high-sensitivity C-reactive protein (hs-
CRP) have been proved to have an increasing risk for
cardiovascular events and altered LV structures. Con-
ventional surface 12-lead electrocardiography (ECG)
such as Cornell voltage and Sokolow-Lyon voltage,
criteria, traditionally used as diagnostic parameters for
the presence of LVH, have lead to various diagnostic
capabilities.

In previous studies, the combined utilization of both
B-type BNP and C-reactive protein in predicting the
presence of LVH has lead to promising results in hyper-
tensive people. However, the data containing both
biomarkers and various 12-lead surface ECG criteria in
diagnosing LVH compared to echocardiography were
lacking in Asian people. The present study was to assess
the clinical value of ECG in diagnosing LVH based on
different criteria and to compare such parameters with
biomarkers and echocardiography in healthy, or pre-
hypertensive (Pre-HTN) and hypertensive (HTN) Tai-
wanese.

METHODS AND MATERIALS

Study setting and subject population

The design of this study was approved by the local
ethics committee in accordance with the Declaration of
Helsinki (IRB No: 09MMHIS037). Participants enrolled
in this study consisted of 1) Normotensive subjects with-
out other known systemic diseases (n = 140, Group A); 2)
Pre-HTN (n = 136, Group B) and 3) HTN subjects (n
= 88, Group C), all of whom underwent general health
evaluation between January 2006 and December 2008. A
detailed review of medical history through structured
questionnaire with physical examination and chest ra-
diography were all performed. All baseline characteris-
tics and related anthropometrics including age, body
height, weight and body mass index (BMI) were ac-
quired, with routine laboratory data including bioche-
mistries (including hepatic, renal and lipid profiles) and
complete blood cell counts taken. Patients with known
cardiovascular surgery or rheumatic heart disease, overt
heart failure symptoms, atrial fibrillation rhythm, pre-
vious implantation of pacemaker and overt renal insuf-
fiency (creatinine > 2.5 mg/dl) were all excluded in our
study. History of diabetes mellitus (DM) was defined as
fasting blood glucose level of more than 126 mg/dL or
any current usage of diabetes medication with previ-
ously diagnosed DM. Patients who had hypertension his-
tory, were taking anti-hypertension agents or had sys-
tolic blood pressure ≥ 140 mmHg and/or diastolic blood
pressure ≥ 90 mmHg were diagnosed as HTN. Pre-HTN
subjects were those with systolic blood pressure > 120
mmHg or diastolic blood pressure > 80 mmHg without
hypertension. Normal group was defined as systolic
blood pressure ≤ 120 mmHg and diastolic blood pres-
sure ≤ 80 mmHg without known cardiovascular or other
systemic diseases. Blood pressures at rest were taken
shortly before the subsequent echo study by medical
staff blinded to the other test results. An average of two
measurements was used as representative data. hs-CRP
level were determined by a highly sensitive, latex par-
icle-enhanced immunoassay using Elecsys 2010 (Hitachi
Corp, Hitachinaka Ibaraki, Japan) with pro-B-type na-
triuretic peptide (pro-BNP) level by electro-hemilu-
minescence immunoassay ECLIA (Roche E17). Serum
samples were collected using standard sampling tubes or
tubes containing separating gel. After ensuring individu-
ized patient samples, calibrators and controls were at
ambient temperature (20-25 °C) and were measured
within 2 hours because of possible evaporation effects.

12-lead surface electrocardiography analysis

All participants underwent standardized 12-lead sur-
face electrocardiography examination. Recordings were
obtained using autonomic instruments (Page Writer Trim
III, Phillip, Andover, USA) with digitized data trans-
ferred and stored for further analysis. Readings were
performed and interpreted by two experienced cardiol-
ogists independently of each other and blinded to
clinical information. Assessment with respect to QRS
duration was measured to the nearest 4 ms as possible,
with R-wave amplitudes in leads aVL, V5, V6, and S
wave amplitudes in leads V1 and V3 measured to the
nearest 0.5 mm (0.05 mV) by use of calipers as proposed
in the LIFE study. Age-adjusted Cornell voltage (RaVL
+ Sv3 > 2.0 mV, plus 0.8 mV in women), Cornell product
((RaVL + Sv3) × QRS duration > 2436 mV.ms), Sokol-

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low-Lyon voltage ($S_{V1} + R_{V5/6} > 3.5$ mV), McPhie criterion (the sum of the tallest R and deepest S in the precordial leads > 4.5 mV) and Framingham score criteria ($R_I + S_{III} > 2.5$ mV, $S_{V1} + R_{V5/6} > 3.5$ mV, $S_{V1/2/3} > 2.5$ mV + $R_{V4/5/6} > 2.5$ mV plus left ventricular strain pattern) were used to determine the left ventricular hypertrophy as defined by previous studies.\textsuperscript{15}

**Determination of LV geometry and function**

A single experienced technician blinded to other study results and details assessed the measures of transthoracic echocardiography (Hewlett Packard Sonos 5500 series equipped with a 2.5-MHz transducer). LV end-diastolic and end-systolic volumes were calculated by the Z-derived method,\textsuperscript{19} which allows accurate quantification of LV volume and mass even in subjects with dilated chambers. LV mass, relative wall thickness and stroke volume (SV) were all derived using such method. The LV concentricity was estimated by relative wall thickness (RWT), with a value > 0.42 being defined as concentric LV geometry. LV concentric hypertrophy was estimated as relative wall thickness (RWT) > 0.42 and LV mass index > 115 gm/m$^2$ male gender and > 95 gm/m$^2$ female gender with eccentric hypertrophy defined to be the same LV mass index criteria with RWT < 0.42. Those patients with RWT > 0.42 with LV mass index within normal rage were classified as concentric remodeling. LV systolic performance by calculating endocardial and mid-wall LV fractional shortening was computed by using a previously described formula.\textsuperscript{20} End-systolic circumferential wall stress was also derived from end-systolic pressure representing mean arterial pressure as in the previously described equation.\textsuperscript{21} Both mid-wall fractional shortening and circumferential wall stress were used to estimate stress-corrected left ventricular after-load. We took a relatively rigorous step to preclude any patient with significant degree valvular heart diseases or existence of significant pulmonary hypertension (defined as estimated systolic pulmonary arterial pressure more than 50 mmHg).\textsuperscript{22}

**Statistical analysis**

Continuous data were shown as mean ± standard deviation and were compared with t-test or Mann-Whitney test for unpaired data as appropriate, and categorical data were presented as ratio and compared by chi-square test or Fisher’s exact test. Data without normal distribution across ordered groups were further compared by using a non-parametric trend test (Wilcoxon rank-sum test). One-way ANOVA test was used for an un-adjusted comparison for three groups, with post hoc Bonferroni correction for multiple comparisons between groups. All p value were two-sided, with value less than 0.05 considered statistically significant.

**RESULTS**

**Baseline characteristics and demographic data**

Baseline demographics and characteristics of these 364 enrolled subjects are listed in Table 1. From normal, pre-HTN to HTN groups, age tended to be older with larger waist circumference, body mass index, waist-to-hip ratio, higher fasting glucose level and biomarker levels including both hs-CRP and NT-ProBNP (all trends p < 0.001). Participants with hypertension were significantly older, had higher waist circumference, higher systolic blood pressure, higher hs-CRP, NT-ProBNP level and worse renal function than both pre-HTN and normal subjects (all p < 0.05). Compared with normal population, pre-HTN group tended to have higher body mass index and fasting glucose level (all p < 0.05).

**ECG criteria of left ventricular hypertrophy in the pre-hypertensive and hypertensive**

In Table 2, value from all electrocardiography (ECG) derived parameters in these three groups were displayed. There was an ordered increase of Sokolow-Lyon voltage, gender-adjusted Cornell voltage, Cornell product, and McPhie and Gubner/Ungerleider voltage criteria across different groups (all trend p < 0.001). ECG criteria including gender-adjusted Cornell voltage, Cornell product and Gubner/Ungerleider in the HTN group all seemed significantly higher than in the pre-HTN and normal group (all p value < 0.05). Compared with the normal group, ECG parameters including Sokolow-Lyon and McPhie voltage were higher in the pre-HTN and HTN groups (both p < 0.05). Finally, PR interval was significantly longer in the HTN group when compared to those in the others (p < 0.05).
Changes of LV structure and function in the pre-HTN and HTN groups

The distribution of LV geometric alteration in terms of remodeling and hypertrophy is shown in Figure 1, while other LV structural and functional parameters based on echocardiography are further displayed in Table 3. The hypertension group had higher percentage of concentric and eccentric hypertrophy and lower ratio of normal LV geometry compared with the normal group, with the pre-HTN group falling in-between. A graded increase in LA diameter, RWT, LV mass with and without indexes and mass-to-volume ratio was observed in a significant trend higher from normal to pre-HTN to HTN groups (all trends *p < 0.001). With a borderline

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Table 1. Baseline demographic characteristics of the study population

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 140)</th>
<th>Pre-HTN (n = 136)</th>
<th>HTN (n = 88)</th>
<th>Trend p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>47.2 ± 9.6</td>
<td>50.6 ± 9.6*</td>
<td>58.6 ± 11.5†</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Gender (female)</td>
<td>69 (49%)</td>
<td>48 (32%)</td>
<td>46 (44%)</td>
<td>0.015</td>
</tr>
<tr>
<td>BW</td>
<td>62.3 ± 12.1</td>
<td>66.9 ± 11*</td>
<td>67 ± 12*</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Waist</td>
<td>78.8 ± 9.7</td>
<td>83.4 ± 9.2*</td>
<td>86.4 ± 10.2†</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Waist-hip ratio</td>
<td>0.85 ± 0.08</td>
<td>0.89 ± 0.07*</td>
<td>0.91 ± 0.07*</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>BMI</td>
<td>22.9 ± 3.2</td>
<td>24.8 ± 3.4*</td>
<td>26 ± 3.7*</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>SBP</td>
<td>105.6 ± 12.1</td>
<td>123.7 ± 6.5*</td>
<td>137.3 ± 17*</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>AC Sugar</td>
<td>91.4 ± 8.5</td>
<td>101.4 ± 23.9*</td>
<td>106.7 ± 27.9*</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>196.9 ± 36</td>
<td>203.2 ± 37.1</td>
<td>199.7 ± 37.6</td>
<td>0.38</td>
</tr>
</tbody>
</table>

BW, body weight; BMI, body mass index; SBP, systolic blood pressure; AC Sugar, fasting blood sugar; eGFR, estimated glomerular filtration rate.

* denotes p < 0.05 compared with normal; † denotes p < 0.05 compared with pre-HTN; ‡ denotes p < 0.1 compared with pre-HTN; * denotes p < 0.1 compared with normal.

Table 2. Various ECG parameters analyzed from the study population

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 140)</th>
<th>Pre-HTN (n = 136)</th>
<th>HTN (n = 88)</th>
<th>Trend p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sokolow-Lyon</td>
<td>19.5 ± 6.5</td>
<td>22.8 ± 6.4*</td>
<td>23.7 ± 8.4*</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Sokolow-Lyon/or strain</td>
<td>8 (5.7)</td>
<td>14 (9.5)</td>
<td>12 (11.4)</td>
<td>0.255</td>
</tr>
<tr>
<td>Cornell (after gender adjust)</td>
<td>14 ± 4.8</td>
<td>14.7 ± 5.6</td>
<td>16.8 ± 5.6†</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Cornell product</td>
<td>1216.2 ± 444</td>
<td>1289.9 ± 538.1</td>
<td>1501.4 ± 548.8†</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Mepchie</td>
<td>22 ± 6.4</td>
<td>25.3 ± 6.8*</td>
<td>27.1 ± 8.1*</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Gubner &amp; Ungerleider</td>
<td>6.1 ± 3.1</td>
<td>7.6 ± 4.1*</td>
<td>8.9 ± 4.4†</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Framingham score</td>
<td>5 (3.6%)</td>
<td>17 (11.5%)</td>
<td>15 (14.3%)</td>
<td>0.009</td>
</tr>
<tr>
<td>QRS duration (max)</td>
<td>87 ± 11.8</td>
<td>87.8 ± 11.3</td>
<td>90.1 ± 15.1</td>
<td>0.10</td>
</tr>
<tr>
<td>P duration (max)</td>
<td>1.67 ± 0.58</td>
<td>1.69 ± 0.54</td>
<td>1.69 ± 0.54</td>
<td>0.55</td>
</tr>
<tr>
<td>PR interval</td>
<td>163.6 ± 19.4</td>
<td>162.6 ± 29</td>
<td>170.9 ± 22.5†</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>HR from RR (1/min)</td>
<td>63.7 ± 8.8</td>
<td>65.5 ± 11.1</td>
<td>66.6 ± 11.1</td>
<td>0.04</td>
</tr>
<tr>
<td>QT interval (max)</td>
<td>382.8 ± 38.8</td>
<td>383.3 ± 32.4</td>
<td>387.8 ± 46</td>
<td>0.85</td>
</tr>
<tr>
<td>QT interval corrected (max)</td>
<td>395 ± 23.7</td>
<td>393.5 ± 36.7</td>
<td>404 ± 40.2†</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>P axis</td>
<td>51.6 ± 26.1</td>
<td>45.9 ± 25.2</td>
<td>50.5 ± 27.9</td>
<td>0.04</td>
</tr>
<tr>
<td>QRS axis</td>
<td>48.4 ± 34.9</td>
<td>41.5 ± 35.9</td>
<td>41.8 ± 43.9</td>
<td>0.01</td>
</tr>
<tr>
<td>T axis</td>
<td>31.8 ± 25.8</td>
<td>33.4 ± 20.7</td>
<td>33.6 ± 32.7</td>
<td>0.58</td>
</tr>
</tbody>
</table>

* denotes p < 0.05 compared with normal; † denotes p < 0.05 compared with pre-HTN; ‡ denotes p < 0.1 compared with pre-HTN; * denotes p < 0.1 compared with normal.
increase of LV end-diastolic volume in the pre-HTN and HTN groups (trend p = 0.06), stress-corrected mid-wall fractional shortening tended to decrease, while LV wall-stress increased (both trends p < 0.05). Compared with normal and pre-HTN groups, subjects in the HTN group had significantly larger RWT, LV mass with and without index, mass-to-volume ratio while showing obviously decreased LV contraction in terms of reduced fractional shortening with or without stress correction (all p < 0.05).

**Table 3.** Various echo-derived cardiac structures and parameters analyzed from the study population

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 140)</th>
<th>Pre-HTN (n = 136)</th>
<th>HTN (n = 88)</th>
<th>Trend p</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA diameter</td>
<td>30.9 ± 4.9</td>
<td>32.9 ± 4.8*</td>
<td>34.4 ± 5.1*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVESV</td>
<td>33.8 ± 9.3</td>
<td>34.7 ± 10.0</td>
<td>34.7 ± 8.7</td>
<td>0.52</td>
</tr>
<tr>
<td>LVEDV</td>
<td>98.6 ± 18.2</td>
<td>104.4 ± 21.1*</td>
<td>103.0 ± 21.1</td>
<td>0.06</td>
</tr>
<tr>
<td>LV EF</td>
<td>65.9 ± 6.0</td>
<td>66.9 ± 5.9</td>
<td>66.2 ± 5.5</td>
<td>0.55</td>
</tr>
<tr>
<td>RWT</td>
<td>0.38 ± 0.06</td>
<td>0.40 ± 0.07*</td>
<td>0.43 ± 0.07*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mass-to-V Ratio</td>
<td>1.38 ± 0.29</td>
<td>1.53 ± 0.3*</td>
<td>1.71 ± 0.36*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV mass</td>
<td>136.1 ± 35</td>
<td>157.1 ± 37.3*</td>
<td>173.6 ± 38.5*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV mass index</td>
<td>75 ± 16</td>
<td>89 ± 18.9*</td>
<td>93.8 ± 18.3*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FS endo</td>
<td>36.4 ± 4.7</td>
<td>37.2 ± 4.7</td>
<td>36.6 ± 4.3</td>
<td>0.5</td>
</tr>
<tr>
<td>FS mmw</td>
<td>0.2 ± 0.02</td>
<td>0.2 ± 0.02</td>
<td>0.19 ± 0.03*</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FS cmw</td>
<td>0.22 ± 0.03</td>
<td>0.22 ± 0.03</td>
<td>0.21 ± 0.03*</td>
<td>0.03</td>
</tr>
<tr>
<td>Cscom</td>
<td>81.3 ± 18.3</td>
<td>86.4 ± 19.1*</td>
<td>87.5 ± 19.5*</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Cscm, circumferential wall stress; EDV, end-diastolic volume; EF, ejection fraction; ESV, end-systolic volume; FS endo, endocardial fractional shortening; FS, midwall fractional shortening; FS cmw, stress-corrected fractional shortening; LA, left atrium/atrial; LV, left ventricular; Mass-to-V, mass to volume; RWT, relative wall thickness.

* denotes p < 0.05 compared with normal; † denotes p < 0.05 compared with pre-HTN; ‡ denotes p < 0.1 compared with normal.

**Role of ECG criteria, NT-ProBNP and hs-CRP levels in the discrimination of LV remodeling and hypertrophy**

In Figure 2, we further demonstrated the diagnostic
accuracy of LV hypertrophy and remodeling from receiver-operating characteristics curves (ROC) by utilizing various ECG parameters and both biomarkers. Generally, diagnostic value tended to be higher in predicting LV hypertrophy but not remodeling by all clinical modalities. Of all ECG-derived parameters, gender-adjusted Cornell voltage and Cornell product seemed to have largest area under curve in predicting LV hypertrophy (AUC: 0.71 vs. 0.73, respectively). NT-ProBNP seemed to have larger area under curve in the discrimination of LV hypertrophy when compared with hs-CRP (AUC: 0.72 vs 0.62). Combined usage of the two biomarkers did not significantly increase the AUC for predicting LV hypertrophy and remodeling, (AUC: 0.72 for LVH and 0.59 for remodeling, respectively), and produced to similar results as NT-ProBNP for hypertrophy and hs-CRP for remodeling.

DISCUSSION

This study revealed that continuous changes in various ECG parameters from normal, pre-HTN to HTN groups were observed which paralleled several echo-derived cardiac structural and functional changes and correlated with some clinical variables. More intriguingly, several electrocardiography parameters had comparable diagnostic accuracy in predicting LVH defined by echo method when compared to the biomarker NT-ProBNP. However, neither ECG-derived parameters nor biomarkers identified the minor form of LV geometric phenotypes in terms of concentric remodeling with satisfactory result.

Left ventricular remodeling and hypertrophy, which represents a clinical feature of target organ damage in hypertensive subjects, denotes the pathophysiologic intermediate between chronic ventricular pressure over-

Figure 2. Biomarkers and various ECG parameters and the corresponding area under curve in the identification of cardiac hypertrophy or remodeling is displayed.
load and heart failure and has been strongly linked to increased cardiovascular events. In terms of concentric remodeling, earlier-stage LV geometric phenotypes when assessed by either relative wall thickness or mass-to-volume ratio, may represent a precursor of LVH, has been reported as a predictor of cardiovascular events and is related to several cardiovascular risk factors. Furthermore, the regression of left ventricular remodeling and LVH indicates improvement of cardiovascular function and prognosis. In this regard, optimal monitoring of the management of hypertensive patients with LVH may thus rely on precise and reproducible echocardiography or electrocardiography methods and medical therapy. Echocardiography as a robust clinical diagnostic tool has been proven to be reliable in differentiating various phenotypes of left ventricular structural and functional changes but is obviously limited by its higher costs and time-consuming procedure. Traditional application of 12-lead surface electrocardiography in assessing various ventricular geometric phenotypes, such as Cornell voltage and Sokolow-Lyon voltage criteria, were not promising in some previous studies. In the LIFE study, Peter et al. observed that anti-hypertensive treatment may result in the regression of electrocardiographic LVH which parallels reduced cardiovascular events and may indicate the validation and feasibility of surface ECG relating to clinical outcomes.

Elevation of NT-proBNP, a biologically inactive peptide from ProBNP precursor in response to increased ventricular wall stress, was proven to be a useful indicator of left ventricular dysfunction after acute myocardial infarction, heart failure, or even in patients with normal blood pressure. More recently, biomarkers such as BNP, NT-ProBNP or their combination usage with C-reactive protein have been adopted as alternative and useful markers in discriminating such cardiac structural changes and functional decay in hypertensive subjects. Furthermore, higher NT-ProBNP levels were proven to be more indicative of ventricular hypertrophy per se rather than the existence of hypertension. Different from the previous study by David et al., our data didn’t show the combination superiority of two biomarkers in assessing echo-defined LVH. Also, we observed a continuous, graded progress of ECG parameters from normal, pre-hypertensive to hypertensive groups, which was in line with the scenario of biomarkers and echocardiographic changes reflecting the clinical continuum of hypertension pathology. Interestingly, while comparable effects were observed for both biomarkers and several ECG-based parameters in identifying echo-defined ventricular hypertrophy, the clinical values for predicting concentric remodeling by these conventional ECG parameters were less impressive which was similar with previous study.

According to JNC VII guidelines, pre-hypertension is the term used to describe intermediate blood pressure value between normotension (< 120/80 mmHg) and traditional hypertension (≥ 140/90 mmHg). In the Framingham study series, the 12-year risk of ischemic heart disease of patients with systolic blood pressure between 130 and 139 mmHg was twice that of those with blood pressure less than 120 mmHg. Previous study in Singapore by Lee et al. illustrated the impact of pre-hypertension on all-cause and cardiovascular mortality. From epidemiologic studies, aging per se was a strong factor contributing to vascular stiffening and subsequent elevated blood pressure. Theoretically, in the aging society of the modern world, the population of pre-hypertension should be increasing and will thus become a major health-care burden in the near future. A more easily applied and clinically feasible tool, such as ECG, may be more helpful in the initial screening for this population.

LIMITATIONS

Although left ventricular remodeling process characterized by surface ECG seemed to progress in subjects from normal, pre-HTN to HTN and correlated with echo-derived parameter and biomarkers, several limitations still need to be acknowledged. First, we only assessed and summed up the ECG criteria for quantitative LVH, which was in line with the scenario of biomarkers and echocardiographic changes reflecting the clinical continuum of hypertension pathology. Interestingly, while comparable effects were observed for both biomarkers and several ECG-based parameters in identifying echo-defined ventricular hypertrophy, the clinical values for predicting concentric remodeling by these conventional ECG parameters were less impressive which was similar with previous study.

CONCLUSION

ECG-based parameters may yield similar capability...
as NT-ProBNP for diagnosing LVH. Further, left ventricular remodeling process, when assessed by surface ECG parameters, seemed to progress in subjects from normal, pre-hypertension to hypertension and correlated with several echo-derived parameters and biomarkers. This evidence suggested that detection and aggressive control of blood pressure may be helpful at an earlier stage.

REFERENCES


30. Talwar S, Siebenhofer A, Williams B, Ng L. Influence of hypertension, left ventricular hypertrophy, and left ventricular systolic dysfunction on plasma N terminal proBNP. *Heart* 2000;83:278-82.


