Study Of The Left Ventricular Myocardial Function In Hypertensive Patients Using Tissue Doppler Image And Speckle Tracking

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Abstract

**Background**: Systolic hypertension causes LV hemodynamic changes ranging from maladaptive hypertrophy to heart failure. (TDI) and 2D strain provides an objective way to quantify global and regional left ventricular (LV) systolic and diastolic function with improved accuracy and greater reproducibility.

**Objectives**: The aim was to assess the systolic and diastolic changes in the myocardium of hypertensive patients and its usefulness in early detection of subclinical dysfunction to determine the parameter that most specifically can represent these abnormalities.

**Methods**: 95 normotensive volunteers (GP A), 45 hypertensive patients without LVH (GP BI) and 47 hypertensive with LVH (GP BII) were examined by standard echocardiography, TDI and speckle tracking.

**Results**: PWD indices were not significantly different among the 3 groups but TDI indices showed statistically significant difference between three groups in E/Em global and IVRT. In GP BII there was slight increase in IVCT, moderate decrease of Sm and significantly increased IVRT and longer MPI. In the hypertension group, mean longitudinal strain was significantly reduced compared with controls and the difference between the 2 subgroups of hypertensive patients was also statistically significant and significant inverse associations between left ventricular mass and global longitudinal systolic strain in hypertensive patients.

**Conclusion**: TDI and speckle tracking were able to detect subclinical heart disease in hypertensive patients without LVH and to demonstrate that E/Em and IVRT can predict early diastolic dysfunction more accurately than Em. IVRT is a more accurate index than MPI in patients without LVH and GLPSS can determine early systolic dysfunction.
Introduction

Hypertensive heart disease is defined as the response of the heart to afterload imposed on the left ventricle by the progressively increasing arterial pressure and total peripheral resistance produced by hypertensive vascular disease (1).

As result of increased hemodynamic demand, the heart becomes able to augment the cardiac output by means of growth of cardiomyocytes. It is known that LVH is in part the result of this morphological adaptation to the chronic pressure-overload and is characterized by thickening of the myocardial walls. The adaptation further increases LV diastolic dysfunction because growth of cardiomyocytes causes increased stiffness of muscular fibers (2).

However, LVH is not a completely adaptive mechanism because it is associated with activation of the molecular program that involves persistent activation of unfavourable signaling pathways. In addition, LVH increases the rate of cardiomyocyte apoptosis and extracellular matrix-deposition, processes that further reduce diastolic compliance and LV systolic impairment (3).

Whether LV diastolic dysfunction is caused directly by raised blood pressure, or by structural changes related to LV hypertrophy remains controversial but hypertensive patients may present with normal transmitral inflow filling patterns or with the more typical presentation is one of diastolic dysfunction. These patterns, however, may be unreliable given their load dependent nature. Given this, to more accurately assess left ventricular diastolic and systolic function, it is necessary to find a less load-dependent method of analysis (4).

Tissue Doppler measures are significantly less affected by changes in loading conditions in the heart and, therefore, provide a more reliable measure of the compliance and diastolic function of the left ventricle under various loading conditions (4).

In addition, patients with hypertension may present with normal-sized LV chamber and normal systolic function so the development of quantitative echocardiographic techniques such as speckle tracking has enhanced our ability to assess myocardial function non-invasively and it can be applied for the detection of structural and functional myocardial abnormalities in hypertensive patients (5).

Hypertensive patients especially those with LVH are extensively studied but the subgroup of hypertension without LVH need more study for early detection of subclinical heart disease.
Aim of the work

The aim of the study was to assess the systolic and diastolic changes in the myocardium of hypertensive patients (with and without hypertrophy) in comparison to control volunteer by tissue Doppler image and speckle tracking to assess its usefulness in early detection of subclinical dysfunction and to determine the parameter that most specifically can represent these abnormalities.

Patients and methods

The study was performed in Benha University Hospital and it included 95 normotensive volunteers ranging in age from 36 to 64 years (Group A) and 92 hypertensive patients with ages ranging from 37 to 71 years (Group B). The hypertensive patients were then divided in two subgroups according to the echocardiographic criteria of LVH: sub-group BI included 45 hypertensive without echocardiographic signs of LVH and sub-group BII constituted the remaining 47 hypertensive with LVH by echocardiography.

All patients had a complete clinical history taken at recruitment. Hypertension was defined by a systolic blood pressure ≥140 mmHg or a diastolic BP ≥90 mmHg, or by antihypertensive drug therapy intake.

Both controls and hypertensive patients were in sinus rhythm with heart rate <100 beats/min and all with normal EF% (>50%) and free of signs or clinical symptoms for heart failure, coronary artery disease, pulmonary disease and not known to have diabetes mellitus.

Conventional echocardiographic Doppler study, as well as tissue Doppler imaging and 2D strain (speckle tracking) were performed using the GE Vingmed (Vivid 7) Ultrasound system.

By 2D echo LVEDV, LVESV and EF% were measured according to the modified Simpson’s method. By M-Mode LV internal systolic and diastolic dimensions and wall thickness were measured. Left ventricular mass (LVM) was calculated using the formula that has been proposed by Devereux (6), and normalized for body surface area to obtain the LV mass index (LVMI). Left ventricular hypertrophy (LVH) was defined as LVMI of 131 g/m² for men and 100 g/m² for women.

\[ \text{LV mass (Penn)} = 1.04 ([\text{LVIDD} + \text{PWTD} + \text{IVSTD}]^3 - [\text{LVIDD}]^3) - 13.6 \text{ g} \]

\[ \text{BSA} = (W^{0.425} \times H^{0.725}) \times 0.007184 \]

By PW Doppler E and A velocity, deceleration time (DT) were measured and E/A ratio was calculated and diastolic dysfunction was diagnosed based on:
- **Normal:** $E/A$ 0.75-1.5 and $DT > 140\text{msec}$
- **Grade 1:** $E/A < 0.75$ and $DT > 140\text{msec}$
- **Grade 2:** $E/A$ 0.75-1.5 and with valsalva $E/A < 0.75$ and $DT < 140\text{msec}$
- **Grade 3:** $E/A > 1.5$ and reversible and $DT < 140\text{msec}$
- **Grade 4:** $E/A > 1.5$ and irreversible and $DT < 140\text{msec}$

TDI was performed by activating the tissue Doppler function. Three major velocities were taken into account: the positive peak systolic velocity ($Sm$) and two negative diastolic velocities ($Em$, $Am$) and two intervals IVCT, IVRT. Then myocardial performance index (MPI) was measured ($IVCT+IVRT/ET$) and $E/Em$ calculated the criteria of diagnosis of dysfunction was:

- $Em$ global $< 8 \text{ cm/s}$
- $Sm$ global $< 10\text{ cm/s}$
- $E/Em > 15$
- $MPI > 0.40$
- $IVRT > 90 \text{ ms}$
- $IVCT > 40 \text{ ms}$

Speckle tracking was measured in the apical four-, two-chamber views as well as long-axis views for quantification of peak systolic strain by automated function imaging speckle-tracking analysis. Global longitudinal peak systolic strain for the complete LV was provided by the software using a 17-segment model in a ‘bull’s eye’ plot calculated as the average of longitudinal peak systolic strain of each view and the mean of the three views the normal value of PLSS is -20%.

**Statistical analysis**

Mean values $\pm$ SD of the indices by 2D, MM and PW Doppler and TDI were measured in Group A and in both hypertensive sub-groups BI, BII and were compared using the Mann-Whitney U test for unpaired data. And average GLPSS of the three views (apical 4ch, apical 2ch and apical long axis) was taken and compared by the same method. The difference was considered significant at $p < 0.05$ correlation between GLPSS and LVMI was done in group BII.

**Results**

**Demographic data of the patients:**

Both groups were comparable in age and gender. Body Mass Index was in the normal range in both groups. The mean values of S.B.P. and D.B.P. were higher in hypertensive than in control (table 1).
Table (1) Demographic data of the patients:

<table>
<thead>
<tr>
<th></th>
<th>Group (A)</th>
<th>Group (B)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=95</td>
<td>N=92</td>
<td></td>
</tr>
<tr>
<td>Mean age</td>
<td>54 ± 16</td>
<td>51 ±15</td>
<td>N.S.</td>
</tr>
<tr>
<td>Male</td>
<td>62</td>
<td>56</td>
<td>N.S.</td>
</tr>
<tr>
<td>Female</td>
<td>33</td>
<td>36</td>
<td>N.S.</td>
</tr>
<tr>
<td>B.M.I. (Kg/m²)</td>
<td>24± 0.7</td>
<td>25±0.3</td>
<td>N.S.</td>
</tr>
<tr>
<td>S.B.P. (mmHg)</td>
<td>122± 13</td>
<td>177±9</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>D.B.P. (mmHg)</td>
<td>79±9</td>
<td>108± 11</td>
<td>P&lt;0.05</td>
</tr>
</tbody>
</table>

B.M.I. = Body Mass Index; S.B.P. = Systolic Blood Pressure; D.B.P. = Diastolic Blood Pressure

**Evaluation of diastolic function:**

When abnormal LV relaxation was defined using PWD-derived indices the difference between the control and two hypertensive subgroups was statistically insignificant but when abnormal LV relaxation was defined according to DTI-derived indices the difference was statistically significant among the three groups (table 2).

Em global velocities demonstrated a stepwise decrease from group BI to group BII that was statistically insignificant P>0.05. Opposite stepwise increase was shown by E/Em global ratio that was statistically significant P<0.05 (table 2).

Isovolumic relaxation time (IVRT) was prolonged in groups BI and BII and the difference was statistically significant between both groups P<0.05 (table 2).
Table (2): Evaluation of diastolic function:

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group BI</th>
<th>Group BII</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PWD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidence of DD</td>
<td>20 %</td>
<td>25 %</td>
<td>30 %</td>
<td>N.S</td>
</tr>
<tr>
<td>E –wave (cm/s)</td>
<td>66±15</td>
<td>71±17</td>
<td>75±21</td>
<td>N.S</td>
</tr>
<tr>
<td>A-wave(cm/s)</td>
<td>62±16</td>
<td>63±20</td>
<td>69±20</td>
<td>N.S</td>
</tr>
<tr>
<td>E/A ratio</td>
<td>1.2±0.3</td>
<td>1.2±0.5</td>
<td>1.1±0.5</td>
<td>N.S</td>
</tr>
<tr>
<td>DT(ms)</td>
<td>210±38</td>
<td>206±37</td>
<td>218±50</td>
<td>N.S</td>
</tr>
<tr>
<td><strong>DTI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidence of DD</td>
<td>16 %</td>
<td>31 %</td>
<td>41 %</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Em global (cm/s)</td>
<td>10±2.1</td>
<td>9.4±3.1</td>
<td>8.2±2.5</td>
<td>N.S</td>
</tr>
<tr>
<td>E/Em global</td>
<td>6.3±1.8</td>
<td>7.4±2.2</td>
<td>8.9±3.2</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>IVRT</td>
<td>75±7</td>
<td>98 ±7</td>
<td>123± 9</td>
<td>P&lt;0.05</td>
</tr>
</tbody>
</table>

**Evaluation of systolic function:**

By MM and 2D echo: The LVEDV, LVESV, LVIDs and LVIDd were within normal values in both groups. LV mass index was significantly greater in group BII. The EF% was significantly lower in the hypertensive group than in controls.
Table (3): 2D and MM echo:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal (group A)</th>
<th>HTN (group B)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEDV (ml)</td>
<td>91± 11</td>
<td>92± 17</td>
<td>N.S.</td>
</tr>
<tr>
<td>LVESV (ml)</td>
<td>32±11</td>
<td>30±14</td>
<td>N.S.</td>
</tr>
<tr>
<td>EF%</td>
<td>61± 5</td>
<td>56 ± 3</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>LVIDd (mm)</td>
<td>50± 4</td>
<td>50±5</td>
<td>N.S.</td>
</tr>
<tr>
<td>LVIDs (mm)</td>
<td>34± 2</td>
<td>36± 2</td>
<td>N.S.</td>
</tr>
<tr>
<td>LV MI (gm/m²)</td>
<td>98± 27</td>
<td>142 ± 32</td>
<td>P&lt;0.05</td>
</tr>
</tbody>
</table>

L.V.E.D.V.=Left Ventricular End-Diastolic Volume; L.V.E.S.V.=Left Ventricular End-Systolic Volume; E.F.%= Percent of Ejection Fraction, L.V.I.D.d.= Left Ventricular internal dimension in diastole L.V.I.D.s.= Left Ventricular internal dimension in systole LV MI= Left Ventricular mass index

By TDI: mean and SD of the tissue Doppler indexes of systolic function were measured and it was found that: in group BI; Sm and IVCT were slightly reduced but MPI were significantly increased p<0.05 vs group A (due to prolonged IVRT). In group BII, Sm decreased and IVCT increased (plus increased IVRT) in respect of group BI therefore, MPI was further increased (table 4).

The difference in the Sm velocity was statistically insignificant among the three groups but the prolongation of the IVCT and MPI was statistically significant (table 4).
Table (4) TDI indices of systolic function:

<table>
<thead>
<tr>
<th>Group</th>
<th>Sm(ms)</th>
<th>IVCT</th>
<th>MPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>group A</td>
<td>309±19</td>
<td>37±6</td>
<td>0.36 ± 0.03</td>
</tr>
<tr>
<td>Group BI</td>
<td>298±17</td>
<td>38±5</td>
<td>0.44±0.02</td>
</tr>
<tr>
<td>Group BII</td>
<td>282±11</td>
<td>44±9</td>
<td>0.53±0.05</td>
</tr>
<tr>
<td>P value</td>
<td>N.S.</td>
<td>P&lt;0.05</td>
<td>P&lt;0.05</td>
</tr>
</tbody>
</table>

By speckle tracking: mean and SD of the peak global longitudinal systolic strain (GLSS) were measured in the three groups. In the hypertension group, mean longitudinal strain was significantly reduced compared with controls: mean and SD were −16.9% ± 2 in the hypertensive patients vs −20.9% ± 1.3 in the control group P < 0.001. The difference between the 2 subgroups of hypertensive patients was also statistically significant -17.9% ± 1.2 for group BI vs -14.7% ± for group BII

In hypertensive patients significant inverse associations were found between left ventricular mass and global longitudinal systolic strain
Discussion:

The study included (187) patients divided into three groups of comparable age and gender and with normal BMI. All patients included in the study had good EF >50%, sinus rhythm and free of signs or clinical symptoms of heart failure, coronary artery disease, pulmonary disease and were not diabetic.

The aim of the study was to assess the systolic and diastolic changes in the myocardium of hypertensive patients (with and without hypertrophy) in comparison to control volunteer by tissue Doppler image and speckle tracking to assess its usefulness in early detection of subclinical dysfunction and to determine the parameter that most specifically can represent these abnormalities.

**Evaluation of the diastolic function:**

The results demonstrated that PWD-derived indices were not significantly different among the 3 groups but TDI derived indices showed the there was statistically significant difference between three groups in E/Em global and IVRT. However the DTI-derived E m global velocities were statistically insignificant.
These results prove that $E/Em$ and IVRT are more important predictors of diastolic dysfunction than Em global in patients with preserved systolic function ($Em$ is prognostic in patients with impaired systolic function with cut off value 3.5cm/s for prediction of poor outcome).

These results are in agreement with Rovner et al. (7). His group found that there were statistically significant differences among all three patient groups (control, hypertensive, hypertensive with hypertrophy) using the tissue Doppler measurement of $E/Em$ global, where $E$ is the transmitral peak early diastolic velocity obtained by conventional Doppler, and $Em$ global is the average of four basal sites obtained by tissue Doppler showed no significant difference.

Likewise, our results are in agreement with Giovanni et al who found that Doppler indices of delayed IVRT can be detected in the presence of normal or supranormal EF in hypertensive patients and be as early sign of diastolic dysfunction (8).

**Evaluation of the systolic function:**

We found that left ventricular volumes and dimensions by MM and 2D echo did not differ both in (Group A) and (Group B). EF% was within the normal range in all patients in the study but it was lower in Group B in comparison with Group A. On the contrary, left ventricular mass was significantly higher in group Group B than in Group A.

In sub-group BI; IVCT and Sm were unchanged in comparison to the healthy controls but IVRT significantly increased. These patterns indicate that in hypertensive not yet affected by LVH, left ventricular diastolic dysfunction is already present independent of systolic function as an early indicator of the increased after-load. It follows that diastolic dysfunction in hypertensive individuals can be caused by increased after load alone and is not purely due to the structural changes that accompany or follow the hypertrophy.

These results are in agreement with reported by Aeschbacher (9) and Federico (10) who also noted that LV diastolic dysfunction in patients with hypertension may occur before the development of hypertrophy.

In our hypertensive subjects with LVH (sub-group BII), the lengthening of IVCT is indicative of LV systolic dysfunction. In these patients, we found a slight increase in IVCT, moderate decrease of Sm and significantly increased IVRT longer MPI. In addition, EF% was further reduced than group BI. These findings provide evidence that LVH is a pathological condition and constitutes a major risk factor for subsequent heart decompensation and chronic heart failure.

Speckle tracking was used to assess the systolic function by evaluating the systolic strain of the longitudinal fibers. It was found that hypertensive patients have significantly ($P<0.05$) lower global longitudinal systolic strain than normal controls. In addition, group BII had
significantly (P<0.05) lower global longitudinal systolic strain than group BI. There was significant inverse correlation between GLPSS and LVMI. These findings are in agreement with that of Belghiti H. et al (11) who found that patients with hypertension and normal EF demonstrated reduced LV systolic strain. They also found that there is a significant association between LV mass index and reduced LV longitudinal contractility.

These results are also in concordance with Narayanan A (12), which was able to detect the mechanical changes in hypertensive patients without clinical finding of heart failure or ischemic heart disease in the form of reduced global systolic strain vs normal control group.

Our study was able to detect these changes early before the development of left ventricular hypertrophy which is unique finding.

The value of MPI:

Myocardial performance is a combined index of systolic and diastolic dysfunction and has been shown to be a predictor of cardiovascular outcome in heart diseases. MPI was normal in the control group and prolonged in group BI due to increased IVRT and significantly prolonged in BII group due to prolonged IVCT and IVRT.

It was reported that MPI was prolonged in hypertensive patients in comparison to control groups and put cut off value of > 0.40 for impaired function. Adeseye et al also found that a significant correlation existed between MPI and LVMI in hypertensive patients (13), they found that MPI was impaired in hypertensive patients compared to the control group and this impairment was correlated with concentric hypertrophy of the left ventricle. Masugata et al (14) found that MPI was prognostic in hypertensive patients for future cardiac events.

Our study found that in group BI the prolongation in MPI was due to prolonged IVRT with normal IVCT whereas in group BII it was due to prolongation of both IVRT and IVCT. This indicates that the IVRT was more important and detrimental to the MPI in hypertensive without left ventricular hypertrophy as early sign of left ventricular dysfunction.

Conclusion:

Tissue Doppler image and speckle tracking were able to detect subclinical heart disease in hypertensive patients without LVH. We were able to demonstrate that E/Em and IVRT can predict early diastolic dysfunction more accurately than Em. IVRT is a more accurate index than MPI in patients without LVH. GLPSS can determine the systolic dysfunction early.

References


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