Echocardiography in hypertension

• Dr Med Athanasios Kranidis FESC

• Director of Cardiology - Athens
In both developed and developing countries, the prevalence of hypertension in adults exceeds 25%.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Rudnick et al.</th>
<th>Danielson et al.</th>
<th>Sinclair et al.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential hypertension</td>
<td>94%</td>
<td>95.3%</td>
<td>92.1%</td>
</tr>
<tr>
<td>Chronic renal disease</td>
<td>5%</td>
<td>2.4%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Renovascular disease</td>
<td>0.2%</td>
<td>1.0%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Coarctation of aorta</td>
<td>0.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary aldosteronism</td>
<td></td>
<td>0.1%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Cushing's syndrome</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Pheochromocytoma</td>
<td></td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Oral contraceptive-induced</td>
<td>0.2%</td>
<td>0.8%</td>
<td>1.0%</td>
</tr>
<tr>
<td>No. of patients</td>
<td>665</td>
<td>1,000</td>
<td>3,783</td>
</tr>
</tbody>
</table>

Staessen JA et al. Lancet 2003; 361:1629
Hypertensive heart disease

*Cardiomyocyte apoptosis*  
- Decreased number  
  - Altered energetics

*Cardiomyocyte hypertrophy*  
- Altered Ca\(^{2+}\) metabolism

*Myocardial fibrosis*  
- Increased stiffness
  - Perivascular compression

*Alterations of the microcirculation*  
- Decreased blood supply

*Impaired systolic contraction*  

*Impaired diastolic filling*  
- Focal re-entry mechanisms
  - Impaired coronary flow reserve

*LV dysfunction/failure*  

*Arrhythmias*  
*Ischemia*

⇒ death

*Figure 3. Pathways linking myocardial remodeling with clinical manifestations in hypertensive heart disease.*

*(Hypertension. 2010;55:1-8.)*
Hypertension & Echocardiography

- Assessment:
  1. Left ventricular hypertrophy – mass - geometry
  2. Left ventricular systolic & diastolic function
  3. Left atrial volume
  4. Thoracic aorta
  5. The co-existence of CAD
Echocardiography - Hyperension

- 1) Left ventricular hypertrophy – mass - geometry
1a) Left ventricular hypertrophy
A. Target-organ damage increases cardiovascular risk

The powerful relation between LV mass and risk of cardiovascular disease in subjects with uncomplicated essential hypertension is continuous over a wide range of LV mass values. The relation remains significant after control for traditional risk factors.

1a) Regression of LVH predicts prognosis


Probability of event-free survival (%)

Regressors (n = 52)

Non-regressors (n = 60)

Rate of events (per 100 patient-years)

$\text{p} = 0.002$
1b) Except hypertrophy the abnormal geometry increase the risk for morbidity and mortality following high-risk myocardial infarction (JACC 2008;1:582)
1a) LV mass -Echocardiography

(non invasive, repeatable, easy, medium cost)

M-Mode is first recommended method for calculating

\[
LVM (g) = 0.8 \times [1.04 \times (D+T)^3 - D^3] + 0.6 \text{ (ASE convention)}
\]

\[
LVM (g) = 1.04 \times [(D+T)^3 - D^3] - 13.6 \text{ g (Penn convention)}
\]
Two methods for estimating LV mass: the area length (AL) formula and the truncated ellipsoid (TE) formula and... Α.Κρανιδης-Ι.Παρασκευαδης. Απεικόνιση στις καρδιαγγειακές παθήσεις.Αθηνα 20012
1a. The final 2D method for calculating LV mass is the biplane method of discs using the modified Simpsons rule. Κρανιδης, Παρασκευαιδης. Απεικόνιση στις καρδιαγγειακές παθήσεις. Αθηνα 20012
**1a. Echocardiographic criteria for LVH**

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>DESCRIPTION</th>
</tr>
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<tbody>
<tr>
<td>LVM / BSA (g/m²)</td>
<td>&gt; 125 (males and females)</td>
</tr>
<tr>
<td>LVM / h (g/m².7)</td>
<td>&gt; 51 (males and females)</td>
</tr>
<tr>
<td>LVM / BSA (g/m²)</td>
<td>≥ 117 (males); ≥ 104 (females)</td>
</tr>
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<td><strong>LVM / BSA (g/m²)</strong></td>
<td><strong>&gt; 125 (males); ≥ 110 (females)</strong></td>
</tr>
<tr>
<td>LVM / BSA (g/m²)</td>
<td>≥ 131 (males); ≥ 100 (females)</td>
</tr>
<tr>
<td>LVM / h (g/m)</td>
<td>≥ 143 (males); &gt; 102 (females)</td>
</tr>
<tr>
<td>LVM / h (g/m)</td>
<td>≥ 149 (males); ≥ 114 (females)</td>
</tr>
<tr>
<td>LVM / h (g/m².7)</td>
<td>&gt; 50 (males); &gt; 47 (females)</td>
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</table>

**ESH 2010 Guidelines:** LVM / BSA (g/m²) > 125 (males) ≥ 110 (females)
A total of 30 studies, including 37 700 untreated and treated patients.

LVH was defined by 23 criteria; its prevalence ranged from 36% (conservative criteria) to 41% (less conservative criteria) in the pooled population.

- LVH prevalence was not different between women and men (range 37.9 -- 46.2 versus 36.0 -- 43.5%, respectively).

- Eccentric LVH was more frequent than concentric hypertrophy (range 20.3 -- 23.0 versus 14.8 -- 15.8, respectively, Po0.05); concentric phenotype was found in a consistent fraction (20%) of both genders.
1a) Limitations (M-Mode, Two -D)

- Validation studies by necropsy were limited in sample size.
- Asymmetric ventricles may not only be accurately measured using linear measurements but also be inaccurately characterized by two orthogonal planes.
- The variability of measurements was not trivial.

Α.Κρανιδης-Ι.Παρασκευαδης. Απεικόνιση στις καρδιαγγειακές παθήσεις. Αθήνα 20012
1b) NON-INVASIVE 3D LV MASS DETERMINATION
strengths and limitations

3D echocardiography

Advantages
High accuracy
Limited anatomic validation
No radiation or claustrophobia

Limitations
Time-consuming
Limited availability
### LV MASS VALIDATION STUDIES USING THE THREE-DIMENSIONAL ECHOCARDIOGRAPHIC MEASUREMENTS

<table>
<thead>
<tr>
<th>Author</th>
<th>3D technique</th>
<th>Subjects</th>
<th>Reference standard</th>
<th>R</th>
<th>SEE (gm)</th>
<th>Mean difference ± 1 SD</th>
<th>Interobserver variability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gopal et al.</td>
<td>Free hand, spark gap locator</td>
<td>15</td>
<td>MRI</td>
<td>0.90</td>
<td>11</td>
<td>−4.9</td>
<td>13</td>
</tr>
<tr>
<td>Gopal et al.</td>
<td>Free hand, spark gap locator</td>
<td>20</td>
<td>Explanted hearts</td>
<td>0.99</td>
<td>11.9</td>
<td>6</td>
<td>23.3</td>
</tr>
<tr>
<td>Lee et al.</td>
<td>RT3D</td>
<td>25</td>
<td>MRI</td>
<td>0.95</td>
<td>6</td>
<td>5±26</td>
<td>0.23</td>
</tr>
<tr>
<td>Mor-Avi et al.</td>
<td>RT3D</td>
<td>21</td>
<td>MRI</td>
<td>0.90</td>
<td>4±14</td>
<td>−14±29</td>
<td></td>
</tr>
<tr>
<td>Takeuchi et al.</td>
<td>RT3D</td>
<td>21 (LVH)</td>
<td>MRI</td>
<td>0.95</td>
<td>20</td>
<td>−14±29</td>
<td>11</td>
</tr>
<tr>
<td>Ven den Bosch et al.</td>
<td>RT3D</td>
<td>20 (CHD)</td>
<td>MRI</td>
<td>0.94</td>
<td>19</td>
<td>10±19</td>
<td></td>
</tr>
<tr>
<td>Jenkins et al.</td>
<td>RT3D</td>
<td>50</td>
<td>MRI</td>
<td>0.90</td>
<td>11</td>
<td>0±38</td>
<td></td>
</tr>
<tr>
<td>Qin et al.</td>
<td>RT3D</td>
<td>27 (COM,AR)</td>
<td>MRI</td>
<td>0.92</td>
<td>29</td>
<td>−9±33</td>
<td></td>
</tr>
<tr>
<td>Caiani et al.</td>
<td>RT3D automated</td>
<td>21</td>
<td>MRI</td>
<td>0.96</td>
<td>11</td>
<td>−2±12</td>
<td>12</td>
</tr>
<tr>
<td>Takeuchi et al.</td>
<td>RT3D</td>
<td>55</td>
<td>MRI</td>
<td>0.95</td>
<td>11</td>
<td>−2±1.9</td>
<td></td>
</tr>
</tbody>
</table>
GUIDELINES
Recommendations for chamber quantification

Roberto M. Lang, Michelle Bierig, Richard B. Devereux et al.,
Eur J Echocardiography 2006

1b) LV geometry

The relative wall thickness (RWT) provides additional prognostic information independent of LV mass.

2 x PWT (d) / LVIDd

a) Concentric hypertrophy carried the greatest stroke risk.
b) Concentric remodeling and LVH conferred a similar significantly increased risk for all cause mortality.
Echocardiography - Hypertension

2. Left ventricular function
2) Heart Failure (HF). Progression from Hypertension to HF

2a) Systolic left ventricular dysfunction in hypertensive patients

- The hazard for developing heart failure in hypertensive subjects was about twofold in men and threefold in women (Framingham Study)

- (JACC 2008;1:582)
2a) Systolic function

The traditional way of measuring systolic function has been the E.F. Patients with essential hypertension and E.F < 50% had a nearly 10 fold risk of hospitalization for CHF (JACC 2008;1:582)
\[ MWFS = \left( \frac{[\text{LVIDd} \pm \text{MWd}] - [\text{LVIDs} \pm \text{MWs}]}{\text{LVIDd} + \text{MWd}} \right) \times 100 \]

where LVIDd, LV internal dimension in diastole; MWd, midwall diastolic thickness; LVIDs, LV internal dimension in systole; MWs, midwall systolic thickness.

- However, we could use mead wall fractional shortening (MWFS) which may be afterload independent flow. This index:
  - is abnormal in the setting of high BP and acute DHF
  - is reduced in pts with diastolic dysfunction
  - can predict LV diastolic abnormalities & the development of CHF (JACC 2008;1:582)
2a) Left ventricular systolic function


- Hypertensive patients without over-systolic dysfunction demonstrate left ventricular long-axis systolic dysfunction, while long-axis diastolic dysfunction always coexists with abnormal diastolic filling patterns.

- This suggests that long-axis systolic dysfunction precedes diastolic dysfunction at the same axis in hypertensive patients.
M-Mode left ventricular systolic function at the long axis
Similarly, patients with hypertension who earlier were considered to have isolated diastolic dysfunction, demonstrated to have reduced left ventricular systolic longitudinal function. Abnormal longitudinal strain (and increased left ventricular Torsion) has also been shown to occur even in the absence of diastolic dysfunction.
In hypertensive patients the development of diastolic dysfunction may precede the development of left ventricular hypertrophy and may be one of the earliest changes associated with hypertensive heart disease. Diastolic dysfunction may be asymptomatic and identified occasionally during a Doppler-echocardiographic examination.
2b) Predictive value of alterations of left ventricular diastolic filling

<table>
<thead>
<tr>
<th>Reference</th>
<th>nº patients</th>
<th>Mean Follow-up (yrs)</th>
<th>Diastolic dysfunction</th>
<th>Relative risk</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurigemma et al., 2000</td>
<td>2671 (CHS)</td>
<td>5.2</td>
<td>E/A &lt; 0.7 or &gt; 1.5</td>
<td>1.88 (95% CI, 1.33-2.68)</td>
<td>CHF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5 (95% CI, 1.8-6.8)</td>
<td></td>
</tr>
<tr>
<td>Bella et al., 2002</td>
<td>3008 (SHS)</td>
<td>3</td>
<td>E/A &lt; 0.6 E/A &gt; 1.5</td>
<td>1.18 (95% CI, 0.7-2.1, p=0.31)</td>
<td>Cardiac death</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.8 (95% CI, 1.196.75, p&lt;0.05)</td>
<td></td>
</tr>
<tr>
<td>Schillaci et al, 2002</td>
<td>1839 (PIUMA study)</td>
<td>4.4</td>
<td>E/A &lt; median value, adjusted for age and HR</td>
<td>1.57 (95% CI,1.1-2.18, p&lt;0.01)</td>
<td>Non fatal CV events</td>
</tr>
</tbody>
</table>
2b) Variables of mitral valve flow which have been used for the assessment of left ventricular function

IVRT_{(ms)}: \begin{align*}
69 \pm 12 &\quad (< 40 \text{ y}) \\
76 \pm 12 &\quad (> 40 \text{ y})
\end{align*}

DT_{(ms)}: 199 \pm 32 \text{ ms}

E_{\text{max}}_{(cm/sec)}: 86 \pm 16

A_{\text{max}}_{(cm/sec)}: 56 \pm 13

E \text{ at A} < 20 \text{ cm/s}
2b) Does echocardiography measure the actual diastolic function of the ventricle?

Numerous studies have correlated echocardiographic parameters of diastolic dysfunction with invasive methods. The single best index to detect diastolic dysfunction was E/E’ (TDI)

Α.Κρανίδης,Ι.Παρασκευαίδης
Απεικόνιση στις καρδιαγγειακές παθήσεις
Εκδόσεις Πασχαλίδης. Αθήνα 2011
Practical Approach of Grade Diastolic Dysfunction

- Septal e'

- Lateral e'

- LA volume

Septal e' ≥ 8
Lateral e' ≥ 10
LA < 34 ml/m2

Septal e' ≥ 8
Lateral e' ≥ 10
LA ≥ 34 ml/m2

E/A < 0.8
DT > 200 ms
Av. E/e' ≤ 8
Ar-A < 0 ms
Val ΔE/A < 0.5

Normal function

Normal function, Athlete's heart, or constriction

Grade I

Grade II

Grade III

E/A 0.8-1.5
DT 160-200 ms
Av. E/e' 9-12
Ar-A ≥ 30 ms
Val ΔE/A ≥ 0.5

E/A ≥ 2
DT < 160 ms
Av. E/e' ≥ 13
Ar-A ≥ 30 ms
Val ΔE/A ≥ 0.5
In hypertensive patients abnormal relaxation appears to have a particular distribution over the myocardial walls. Basal parts are generally more heavily affected.
3) Left atrial size – function
Ambulatory blood pressure, target organ damage and left atrial size in never-treated essential hypertensive individuals
Cesare Cuspidi, Stefano Meani, Cristiana Valerio, Veronica Fusi, Eleonora Catini, Carla Sala and Alberto Zanchetti

a) LA size is shown to be linearly related to filling pressures, LV mass, and BP.

b) Left ventricular hypertrophy, carotid intima–media thickening and metabolic syndrome are independent predictors of left atrial dimension (changes in left atrial size represent an adaptive response when high blood pressure is associated with other cardiovascular or metabolic abnormalities).

J Hypertens 2005 23:1589–1595Q2005
Left atrial diameter/height predicts risk of cardiovascular events independent to other clinical risk factors in hypertensive patients with left ventricular hypertrophy.
3) LA volume

LA volume is superior to LA dimension in predicting outcomes

Methods of measuring LA volume by 2D echocardiography include the biplane A-L method & Simpson's rule (max 22±6 ml/m²).

- MRI IS THE METHOD OF CHOICE
3. Left atrial function

- In hypertensive pts (at risk for left ventricular diastolic dysfunction), a decreased contribution of left atrial contractile function to ventricular filling during diastole is strongly predictive of adverse cardiac events

2D – Strain-LA function
4. Aortic root
The aortic root dilatation is a frequent cardiovascular phenotype in hypertensives referred to echo-labs for detection of hypertensive organ damage. Body surface area, LV mass and age are the most important correlates of this phenotype.
Hypertensive patients with aortic root enlargement have more pronounced alterations in cardiac structure and geometry as well as in carotid artery morphology compared to those without the enlargement. **Aortic root dilatation therefore appears to be a useful marker of high cardiovascular risk**
Echocardiographic appearance of hypertensive patients
Dilatation of aortic root and left ventricular hypertrophy
Echocardiography-Hypertension

- 5. Coronary artery disease
In hypertensive patients stress echocardiography may be somewhat less sensitive to detect and localize mild CAD (in particular when vasodilators are used), but is more specific than perfusion scintigraphy.

The direct prognostic comparisons show that stress echocardiography and perfusion scintigraphy have comparable prognostic value.
Vasodilator stress echo allows coronary flow reserve (CFR) on left anterior descending (LAD) artery.

A CFR ≤ 1.91 was the best value for diagnosing LAD stenosis in hypertensive and normotensive pts.

**However, diagnostic specificity is reduced in hypertensive pts.;**
(hypertension may affect CFR through only coronary microcirculatory damage)
In conclusion: Echocardiography - Doppler is the most useful tool for the assessment of hypertensive patient.
• Altered LV diastolic function, as assessed by MDI but not by deceleration time alone, is independently associated with aortic root dilatation, a phenotype predictive of incident cardiovascular morbidity and mortality.
Inappropriate LV mass

Inappropriate LV mass is the value of LV mass exceeding the amount needed to adapt to stroke work for a given gender and body size.

Predicted value = 55.37 + 6.64 x h^2.7 + 0.64 x SBP x systolic volume − 18.07 x gender
(de Simone et al Hypertension 1998)

Ratio observed / Predicted value *100
LVM in Patients with or without Composite End-Point: LIFE

LV Mass (g)

No Event
Composite End-point

All p<0.05 to <0.001
LV Mass in Patients with or without STROKE : LIFE

P = 0.11  p = 0.17  p = 0.20  p = 0.11  p = 0.02
LVH and CV Risk in Different Populations

LVH diagnosed by echocardiography is a powerful predictor of myocardial infarction, stroke and CV death in:

- Apparently uncomplicated hypertensive patients
- In subjects with or without angiographic coronary heart disease
- In patients with previous myocardial infarction
- In subjects from general populations in epidemiological studies
• Additional information from quantitative echocardiography:
  - LA, Aortic root
  - LV systolic and diastolic dysfunction
  - Stroke work
Διάταση ανιούσης αορτής σε ασθενή με χρονία ΑΥ
Meta-analysis of randomized, controlled trials of LV hypertrophy regression in essential hypertension

80 randomized controlled trials; 4,113 patients
LV Dysfunction: Mechanisms

Diastolic dysfunction
- Hypertension
- Aging
- LVH
- Concentric remodeling

Systolic dysfunction
- MI, CM, volume overload
- Hypertension
- Eccentric remodeling

Mediators: angiotensin II, aldosterone, catecholamines, cytokines
Διαταραχή της διαστολικής λειτουργίας σε νεαρό υπερτασικό ασθενή με διατηρημένη φυσιολογική συστολική λειτουργία.

E/A <1
DT=145msec
IVRT=50msec
Figure 5  Comparison of SR (left panel) and peak systolic strain (right panel) in controls and in LVH patients without and with abnormal LV filling (LVD).

**SR**

- Control (n = 26)
- LVH, no LVD (n = 20)
- LVH, LVD (n = 62)

**Peak systolic strain**

- Control (n = 26)
- LVH, no LVD (n = 20)
- LVH, LVD (n = 62)
Future clinical research

Fibrosis vs Hypertrophy
Videodensitometry
Integrated backscatter

3D Reconstruction
Ultrasound LV mass tissue characterization

**Videodensitometry**

Quantitative analysis of return ultrasound signal
Images converted in a matrix of gray levels, determined by echo amplitude

**Integrated backscatter**

Acoustic quantification of the backscatter signal, i.e. the ultrasound signals that have origin from the myocardial tissue and back scatter towards the transducer
Echocardiography in Low Risk Hypertensives

APROS STUDY RISK RE-CLASSIFICATION

Cuspidi et al, J Hypertension 2002
## Echocardiographic criteria for LVH

<table>
<thead>
<tr>
<th>CRITERIA</th>
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**ESH 2003 Guidelines:** LVM / BSA (g/m²) ≥ 125 (males) ≥ 110 (females)
Hazard Ratio for *Mortality* in 1248 Propensity-Matched Patients by Degree of LV Diastolic Dysfunction

<table>
<thead>
<tr>
<th>Degree of diastolic dysfunction</th>
<th>HR (95% CI)*</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild (n=381)</td>
<td>1.11 (0.85–1.47)</td>
<td>0.45</td>
</tr>
<tr>
<td>60%</td>
<td>(21%)</td>
<td></td>
</tr>
<tr>
<td>Moderate (n=375)</td>
<td>1.58 (1.20–2.08)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4.8%</td>
<td>(24%)</td>
<td></td>
</tr>
<tr>
<td>Severe (n=127)</td>
<td>1.84 (1.29–2.62)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0.4%</td>
<td>(39%)</td>
<td></td>
</tr>
</tbody>
</table>

### Recommendations for chamber quantification

Roberto M. Lang, Michelle Bierig, Richard B. Devereux *et al*

#### Table 4: Reference limits and partition values of left ventricular mass and geometry

<table>
<thead>
<tr>
<th></th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reference range</td>
<td>Mildly abnormal</td>
</tr>
<tr>
<td><strong>Linear method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV mass/BSA (g/m²)</td>
<td>43–95</td>
<td>96–108</td>
</tr>
<tr>
<td>LV mass/height (g/m)</td>
<td>41–99</td>
<td>100–115</td>
</tr>
<tr>
<td>LV mass/height (g/m)²</td>
<td>18–44</td>
<td>45–51</td>
</tr>
<tr>
<td>Relative wall thickness (cm)</td>
<td>0.22–0.42</td>
<td>0.43–0.47</td>
</tr>
<tr>
<td>Septal thickness (cm)</td>
<td>0.6–0.9</td>
<td>1.0–1.2</td>
</tr>
<tr>
<td>Posterior wall thickness (cm)</td>
<td>0.6–0.9</td>
<td>1.0–1.2</td>
</tr>
<tr>
<td><strong>2-D method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>66–150</td>
<td>151–171</td>
</tr>
<tr>
<td>LV mass/BSA (g/m²)</td>
<td>44–88</td>
<td>89–100</td>
</tr>
</tbody>
</table>

Values in bold are recommended and best validated.

*Eur J Echocardiography 2006*
Change in Diastolic Left Ventricular Filling After One Year of Antihypertensive Treatment
The Losartan Intervention For Endpoint Reduction in Hypertension (LIFE) Study
Kristian Wachtell, MD, PhD; Jonathan N. Bella, MD; Jens Rokkedal, MD; Vittorio Palmieri, MD; Vasilios Papademetriou, MD; Bjorn Dahlof, MD, PhD; Tapio Aalto, MD; Eva Gerdts, MD, PhD; Richard B. Devereux, MD

Conclusions —Antihypertensive therapy with significant improvement of diastolic filling parameters

Conclusions — Antihypertensive therapy resulting in LV mass or relative wall thickness regression is associated with significant improvement of diastolic filling parameters related to active relaxation and passive chamber stiffness compared with patients without regression, independent of BP reduction; however, abnormalities of diastolic LV filling remain common.

Circulation. 2002;105:1071-1076
Continuous Relation Between Left Ventricular Mass and Cardiovascular Risk in Essential Hypertension
Giuseppe Schillaci, Paolo Verdecchia, Carlo Porcellati, Olga Cuccurullo, Carmela Cosco, Francesco Perticone

In conclusion, the powerful relation between LV mass and risk of cardiovascular disease in subjects with uncomplicated essential hypertension is continuous over a wide range of LV mass values, even below the current “upper normal” limits. The relation remains significant after control for traditional risk factors, including ambulatory blood pressure.

<table>
<thead>
<tr>
<th>Μελέτη</th>
<th>N</th>
<th>LVH g/m²</th>
<th>LVH(+)</th>
<th>LVH(-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casale 1986</td>
<td>140</td>
<td>&gt;125</td>
<td>4.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Levy 1989</td>
<td>3220</td>
<td>&gt;116</td>
<td>2-3.3</td>
<td>0.8-1.4</td>
</tr>
<tr>
<td>Koren 1991</td>
<td>280</td>
<td>&gt;125</td>
<td>1.4-6.3</td>
<td>0.1-2.2</td>
</tr>
<tr>
<td>Silberberg 1989</td>
<td>119</td>
<td>&gt;125</td>
<td>15.2</td>
<td>9.6</td>
</tr>
<tr>
<td>Partrey 1990</td>
<td>104</td>
<td>IVS&gt;1.4cm</td>
<td>15.3</td>
<td>4.8</td>
</tr>
<tr>
<td>Pittaras 2000,2004</td>
<td>812</td>
<td>&gt;125</td>
<td>RR: 2.0</td>
<td></td>
</tr>
</tbody>
</table>
Target-organ damage increases cardiovascular risk

Left ventricular hypertrophy

2-year age-adjusted incidence (per 1000 patients)

- Stroke
- Heart failure
- Coronary disease

Hypertension
Hypertension + LVH

Incidence of CHF According to LVH Status

Cerebrovascular Events in Hypertensive Patients with and without LVH

Survival of Patients with and Without LVH
N=812, Follow-up: 10 years

ΣΥΜΒΑΜΑΤΑ & ΓΕΩΜΕΤΡΙΑ ΑΡΙΣΤΕΡΗΣ ΚΟΙΛΙΑΣ

Cardiovascular events-free survival curves for patients divided into tertiles LVMI, according to the presence of concentric or eccentric geometry

Muiesan, Agabiti Rosei et al, Hypertension
CV events according to LV geometry changes

n° of patients 424; Follow-up 2-18 yrs, mean 6.4 yrs

1 tertile
(LVMI < 91 g/m2)

2 tertile
(LVMI 91-117 g/m2)

3 tertile
(LVMI > 117 g/m2)

CV ev (%)

RWT < 0.44

RWT ≥ 0.44

* vs eccentric geometry; § vs 1st tertile eccentric geometry

Muiesan, Agabiti Rosei et al, Hypertension 2004
Υποστροφή LVH με αερόβια άσκηση


* p<0.05
Meta-analysis of randomized, controlled trials of LV hypertrophy regression in essential hypertension

80 randomized controlled trials; 4,113 patients

Percent reduction of relative wall thickness during antihypertensive treatment

![Graph showing percent reduction of relative wall thickness for different treatments](image)

Values are adjusted for differences between studies

aDhlof B, Pennert K, Hansson L Am J H 1992; 5:95-110
<table>
<thead>
<tr>
<th>Καταχωρηθείσες Ερευνές</th>
<th>Περιοδικό</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yurenev et al</td>
<td><em>Am J Hypertens.</em> 1992</td>
</tr>
<tr>
<td>Levy et al</td>
<td><em>Circulation</em> 1994</td>
</tr>
<tr>
<td>Muiesan et al</td>
<td><em>Hypertension</em> 1995</td>
</tr>
<tr>
<td>Devereux et al</td>
<td><em>Am J Hypertens.</em> 1996</td>
</tr>
<tr>
<td>Miser et al</td>
<td><em>JACC</em> 1996</td>
</tr>
</tbody>
</table>
### Prognostic Value of Serial Changes in LV Mass (Echo)

<table>
<thead>
<tr>
<th></th>
<th>Persistently Normal LV Mass</th>
<th>LV Hypertrophy Regression</th>
<th>Persistently Increased LV Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>No LVH</td>
<td><img src="image1" alt="Heart Image" /></td>
<td><img src="image2" alt="Heart Image" /></td>
<td><img src="image3" alt="Heart Image" /></td>
</tr>
<tr>
<td>LVH</td>
<td><img src="image4" alt="Heart Image" /></td>
<td><img src="image5" alt="Heart Image" /></td>
<td><img src="image6" alt="Heart Image" /></td>
</tr>
<tr>
<td>Persistently</td>
<td><img src="image7" alt="Heart Image" /></td>
<td><img src="image8" alt="Heart Image" /></td>
<td><img src="image9" alt="Heart Image" /></td>
</tr>
<tr>
<td>Increased LV Mass</td>
<td><img src="image10" alt="Heart Image" /></td>
<td><img src="image11" alt="Heart Image" /></td>
<td><img src="image12" alt="Heart Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>No LVH</th>
<th>LVH</th>
<th>LVH</th>
<th>No LVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koran M. et al</td>
<td>5/98 (5,1%)</td>
<td>1/28 (3,6%)</td>
<td>4/16 (25%)</td>
<td></td>
</tr>
<tr>
<td>Mulasan ML. et al</td>
<td>4/78 (5,1%)</td>
<td>4/32 (12,5%)</td>
<td>13/34 (23%)</td>
<td></td>
</tr>
<tr>
<td>Verdcchia P. et al</td>
<td>15/278 (5,4%)</td>
<td>3/48 (6,2%)</td>
<td>12/68 (21%)</td>
<td></td>
</tr>
<tr>
<td>Cipriano C. et al</td>
<td>6/125 (4,8%)</td>
<td>5/52 (9,6%)</td>
<td>16/109 (15%)</td>
<td></td>
</tr>
</tbody>
</table>

| Total            | 30/579 (5,2%) | 13/160 (8,1%) | 45/217 (20,7%) |

**Koran M. et al**

**Mulasan ML. et al**

**Verdcchia P. et al**

**Cipriano C. et al**
Regression of LVH predicts prognosis


Probability of event-free survival (%)

Rate of events (per 100 patient-years)

Regressors (n = 52)

Non-regressors (n = 60)

Time to event (weeks)

p = 0.002

Regressors

Non-Regressors

Losartan Intervention For End Point Prevention (LIFE)

ECHO LVM CHANGES AND OUTCOME

Echocardiographic Substudy N=960

For 25 g/m2 (1 SD) regression of LVMI there was an independent 20% reduction in the primary composite endpoint, after adjustment for treatment and baseline LVMI (HR 0.80, 95% CI 0.70-0.95, p= 0.009)

Devereux et al- presented at ASH meeting 2002
Estimation of Filling Pressures in Patients with Normal EF

Nagueh et al., JASE 2009

E/e’ < 8 (Sep, Lat, or Av.)

E/e’ 9-14

LA volume < 34 ml/m²
Ar – A < 0 ms
Valsalva Δ E/A < 0.5
PAS <30 mmHg
IVRT/T E-e’ >2

Normal LAP

LA volume ≥ 34 ml/m²
Ar – A ≥ 30 ms
Valsalva Δ E/A ≥ 0.5
PAS >35 mmHg
IVRT/T E-e’ <2

↑ LAP

Sep. E/e’ > 15
or
Lat. E/e’ > 12
or
Av. E/e’ > 13

↑ LAP
Ventricular Structure and Function in Hypertensive Participants With Heart Failure and a Normal Ejection Fraction: The Cardiovascular Health Study
Mathew S. Maurer, MD; Daniel Burkhoff, MD, PHD; Linda P. Fried, MD, MPH

- **Conclusions**

Participants in the population-based CHS with HTN and HFNEF had, on average, increased ventricular dimensions and therefore increased calculated volumes and CO compared with healthy control subjects and participants with HTN without heart failure. Furthermore, they had no greater concentric hypertrophic remodeling than hypertensive participants without heart failure, and they had considerably more frequent comorbidities, particularly ones that may cause volume overload, such as renal dysfunction and anemia. These data suggest that groups exist within the hypertensive HFNEF population and that volume overload states may contribute to the pathophysiology of this important syndrome.

*J Am Coll Cardiol.* 2007
The Strong Heart Study, Circul. 2002
Προγνωστική σημασία μεταβολών διαστολικής πλήρωσης

<table>
<thead>
<tr>
<th>Reference</th>
<th>n° patients</th>
<th>Mean Follow-up (yrs)</th>
<th>Diastolic dysfunction</th>
<th>Relative risk</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurigemma et al., 2000</td>
<td>2671 (CHS)</td>
<td>5.2</td>
<td>E/A &lt; 0.7 or &gt; 1.5</td>
<td>1.88 (95% CI, 1.33-2.68)</td>
<td>CHF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5 (95% CI, 1.8-6.8)</td>
<td></td>
</tr>
<tr>
<td>Bella et al., 2002</td>
<td>3008 (SHS)</td>
<td>3</td>
<td>E/A &lt; 0.6 E/A &gt; 1.5</td>
<td>1.18 (95% CI, 0.7-2.1, p=0.31)</td>
<td>Cardiac death</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.8 (95% CI, 1.196.75, p&lt;0.05)</td>
<td></td>
</tr>
<tr>
<td>Schillaci et al, 2002</td>
<td>1839 (PIUMA study)</td>
<td>4.4</td>
<td>E/A &lt; median value, adjusted for age and HR</td>
<td>1.57 (95% CI,1.1-2.18, p&lt;0.01)</td>
<td>Non fatal CV events</td>
</tr>
</tbody>
</table>
Hazard Ratio for *Mortality* in 1248 Propensity-Matched Patients by Degree of LV Diastolic Dysfunction

<table>
<thead>
<tr>
<th>Degree of diastolic dysfunction</th>
<th>HR (95% CI)*</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild (n=381)</td>
<td>1.11 (0.85–1.47)</td>
<td>0.45</td>
</tr>
<tr>
<td>60%</td>
<td>(21%)</td>
<td></td>
</tr>
<tr>
<td>Moderate (n=375)</td>
<td><strong>1.58</strong> (1.20–2.08)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4.8%</td>
<td>(24%)</td>
<td></td>
</tr>
<tr>
<td>Severe (n=127)</td>
<td><strong>1.84</strong> (1.29–2.62)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0.4%</td>
<td>(39%)</td>
<td></td>
</tr>
</tbody>
</table>

Mortality rate in patients with diastolic dysfunction and normal systolic function.
Change in Diastolic Left Ventricular Filling After One Year of Antihypertensive Treatment
The Losartan Intervention For Endpoint Reduction in Hypertension (LIFE) Study
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Conclusions — Antihypertensive therapy resulting in LV mass or relative wall thickness regression is associated with significant improvement of diastolic filling parameters related to active relaxation and passive chamber stiffness compared with patients without regression, independent of BP reduction; however, abnormalities of diastolic LV filling remain common.

Circulation. 2002;105:1071-1076
Prognostic significance of left ventricular diastolic dysfunction in patients with left ventricular hypertrophy and systemic hypertension

the LIFE Study


In conclusion, antihypertensive treatment in patients with hypertension with electrocardiographic LV hypertrophy resulted in significant improvement in transmitral flow patterns; this was not associated with reduced cardiovascular morbidity and mortality. However, normal in-treatment LV filling was strongly associated with a reduced risk for hospitalization for heart failure

*Am J Cardiol.* 2010 Oct 1;106(7):999-1005.
Conclusion: Left atrial enlargement is not an early echocardiographic finding in relatively young never-treated hypertensive individuals, as its prevalence is lower than that of well-validated markers of target organ damage, and it is unrelated to ambulatory blood pressure. Overweight, left ventricular hypertrophy, carotid intima–media thickening and metabolic syndrome are independent predictors of left atrial dimension, suggesting that changes in left atrial size represent an adaptive response when high blood pressure is associated with other cardiovascular or metabolic abnormalities.
Predictive parameters for the onset of AF

- Age
- Diurnal and nocturnal BP
- Max duration of the depression of P wave in the ECG
- LVMI
- Left atrial dimension
- Velocity of the A wave
- Minimum P wave velocity
New methods in echocardiography

- 2D- Speckle tracking
- 3D
- **Tissue Characterization** (Fibrosis vs hypertrophy)
  - Videodensitometry
  - Integrated backscatter

- **Coronary reserve and myocardial ischemia**
  - Echo contrast media
  - Doppler of LAD flow transesophageal or transtoracic
  - Echo stress
Επίπτωση NSVT σε υπερτασικούς με LVH

<table>
<thead>
<tr>
<th>Μελέτη</th>
<th>N</th>
<th>NSVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loaldi</td>
<td>61</td>
<td>10%</td>
</tr>
<tr>
<td>Aronow</td>
<td>196</td>
<td>15%</td>
</tr>
<tr>
<td>Papademetriou</td>
<td>125</td>
<td>19%</td>
</tr>
<tr>
<td>Mcelenahon</td>
<td>50</td>
<td>28%</td>
</tr>
<tr>
<td>Pringle</td>
<td>90</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Σύνολο</strong></td>
<td>522</td>
<td>15.3%</td>
</tr>
</tbody>
</table>
Υποστροφή LVH και Αρρυθμίες

• Μείωση Αρρυθμιών
  Gonzales-Fernadez et al. Am J Hypert. 1993

• Χωρίς μεταβολές
Can echocardiography identify mildly hypertensive patients at high risk, left untreated based on current guidelines?
Eric Abergel, Gilles Chatellier, Christiane Battaglia and Joel Menard

“**Conclusion** Rigorous application of the WHO/ISH clinical guidelines in a group of mild hypertensive patients led to the treatment of patients with slightly higher LV mass and more concentric LV geometry than were found in those not treated. **However, a high-risk subgroup, with concentric remodelling, was not identified and left untreated.**”

J Hypertens 1999, 17:817-824
Echocardiography for LVH assessment in high risk hypertensive patients?

- better risk assessment
- treatment selection
- evaluation of long term treatment efficacy
Arterial hypertension

Left ventricular hypertrophy

↑ Fibrosis

↑ Media hypertrophy

↓ Coronary flow reserve

Ischemia

Conduction – and depolarization disorders

Re-entry

↑ Wall stress

Stretching of myocytes

Increased automaticity

Triggered activity

Ventricular tachycardia

↑ Heart rate

↑ Sympathetic tone

↑ Catecholamines

Sudden cardiac death

↑ Catecholamines

↑ Heart rate

↑ Sympathetic tone
Ventricular ectopy in patients with normal left ventricular (LV) mass and left ventricular hypertrophy

<table>
<thead>
<tr>
<th>Reference</th>
<th>Criterion</th>
<th>Normal LV-mass</th>
<th>Left ventricular hypertrophy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PVC/24 h</td>
<td>10</td>
<td>475*</td>
<td></td>
</tr>
<tr>
<td>Messerli (1984) [53]</td>
<td>Lown ≥ 2</td>
<td>0</td>
<td>63*</td>
<td></td>
</tr>
<tr>
<td>McLenachan (1987) [8]</td>
<td>Couplets</td>
<td>16</td>
<td>36*</td>
<td></td>
</tr>
<tr>
<td>Lavie (1988) [54]</td>
<td>PVC/h &gt; 1</td>
<td>24</td>
<td>291*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lown ≥ 2</td>
<td>0</td>
<td>35*</td>
<td></td>
</tr>
<tr>
<td>Szlachic (1989) [30]</td>
<td>PVC/h &gt; 30</td>
<td>29</td>
<td>47*</td>
<td></td>
</tr>
<tr>
<td>Ghali (1991) [55]</td>
<td>PVC 1–4/h</td>
<td>1</td>
<td>6*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PVC 5–30/h</td>
<td>0</td>
<td>5*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PVC &gt; 30/h</td>
<td>0</td>
<td>5*</td>
<td></td>
</tr>
<tr>
<td>Galinier (1997) [56]</td>
<td>PVC/24 h</td>
<td>23</td>
<td>826*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lown ≥ 2</td>
<td>4</td>
<td>50*</td>
<td></td>
</tr>
<tr>
<td>Schannwell (1998) [29]</td>
<td>Lown I/II</td>
<td>23</td>
<td>39*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lown ≥ 3</td>
<td>0</td>
<td>29*</td>
<td></td>
</tr>
<tr>
<td>Kulan (1998) [57]</td>
<td>Lown &gt; 2</td>
<td>8</td>
<td>19*</td>
<td></td>
</tr>
</tbody>
</table>
Regression of Hypertrophy

- Calcium channel-blockers
- ACE inhibitors
- Clonidine
- Diuretics
- Beta-blockers
- Improvement of QT-dispersion
- Reduction of ventricular premature beats
- Normalization of ventricular electrophysiology behaviour in animal model

Reduction of sudden cardiac death?
<table>
<thead>
<tr>
<th>Vasodilating Systems</th>
<th>Vasoconstricting Systems</th>
<th>Vascular Growth Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasympathetic Kallikrein-kinin system</td>
<td>Sympathetic Calcium Local renin-angiotensin system Circulating renin-angiotensin system Endothelin Ouabain Vasopressin Superoxide anion</td>
<td>Insulin like growth factor Growth hormone Parathyroid hormone Tissue oncogenes Angiotensin II</td>
</tr>
</tbody>
</table>
**Electrocardiography**

**Advantages**
- High specificity
- LV ischemia
- Arrhythmias and conduction defects

**Limitations**
- Low sensitivity
- No additional information on LV anatomy and function

**Echocardiography**

**Advantages**
- Evaluation of LV anatomy (LV Mass) and function
- High sensitivity and specificity

**Limitations**
- Cost
- Standardization of procedure
- Reproducibility of measurements
ΥΠΕΡΤΑΣΙΚΗ ΚΑΡΔΙΑΚΗ ΝΟΣΟΣ (ΥΚΝ)

Genetic background
Increased blood pressure
Local physico-chemical factors
Environmental factors

Hemodynamic overload
→ Increased LV wall tension
→ Genetic reprogramming and growth of cardiomyocytes
→ LV wall thickening

Systemic and local humoral disregulation
→ Unbalance between pro- and anti-remodeling factors
→ Altered biophysiology of cardiac cells and ECM
→ Myocardial remodeling

Hypertensive heart disease
CV risk stratification – 2007 ESC/ESH Guidelines for the Management of Hypertension¹

<table>
<thead>
<tr>
<th>Other risk factors, OD or Disease</th>
<th>Normal SBP 120-129 or DBP 80-84</th>
<th>High normal SBP 130-139 or DBP 85-89</th>
<th>Grade 1 HT SBP 140-159 or DBP 90-99</th>
<th>Grade 2 HT SBP 160-179 or DBP 100-109</th>
<th>Grade 3 HT SBP ≥180 or DBP ≥110</th>
</tr>
</thead>
<tbody>
<tr>
<td>No other risk factors</td>
<td>Average risk</td>
<td>Average risk</td>
<td>Low added risk</td>
<td>Moderate added risk</td>
<td>High added risk</td>
</tr>
<tr>
<td>1-2 risk factors</td>
<td>Low added risk</td>
<td>Low added risk</td>
<td>Moderate added risk</td>
<td>Moderate added risk</td>
<td>Very High added risk</td>
</tr>
<tr>
<td>3 or more risk factors, MS, OD or Diabetes</td>
<td>Moderate added risk</td>
<td>High added risk</td>
<td>High added risk</td>
<td>High added risk</td>
<td>Very High added risk</td>
</tr>
<tr>
<td>Established CV or renal disease</td>
<td>Very High added risk</td>
<td>Very High added risk</td>
<td>Very High added risk</td>
<td>Very High added risk</td>
<td>Very High added risk</td>
</tr>
</tbody>
</table>

SBP: systolic blood pressure; DBP: diastolic blood pressure; CV: cardiovascular; HT: hypertension. Low, moderate, high and very high risk refer to 10-year risk of CV fatal or non-fatal event. The term “added” indicates that in all categories risk is greater than average. OD: subclinical organ damage; MS: metabolic syndrome; The dashed line indicates how definition of hypertension may be variable, depending on the level of total CV risk.

LVM in Patients with or without Cardiovascular Death: LIFE

All p<0.05 to p=0.001 except year 4

LV Mass (g)

No CV Death
CV Death

Year in LIFE
# Relative Risks According to LV Geometry

<table>
<thead>
<tr>
<th>Patient population</th>
<th>Risk</th>
<th>Concentric remodeling</th>
<th>Eccentric LVH</th>
<th>Concentric LVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTN/nl LVM&lt;sup&gt;35&lt;/sup&gt;</td>
<td>CV Events</td>
<td>2.56</td>
<td>1.2–5.45</td>
<td></td>
</tr>
<tr>
<td>HTN/nl LVM&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Mortality</td>
<td>1.54</td>
<td>1.01–2.47</td>
<td></td>
</tr>
<tr>
<td>General Population&lt;sup&gt;40&lt;/sup&gt;</td>
<td>Mortality</td>
<td>1.99</td>
<td>1.88–2.18</td>
<td>HR = 2.13 (1.89–2.40)</td>
</tr>
<tr>
<td>Stroke&lt;sup&gt;37&lt;/sup&gt;</td>
<td>Stroke</td>
<td>2.4</td>
<td>2.0–4.3</td>
<td>3.5</td>
</tr>
<tr>
<td>CAD&lt;sup&gt;38&lt;/sup&gt;</td>
<td>Mortality/CV events</td>
<td>3.0</td>
<td>1.9–4.9</td>
<td>5.4</td>
</tr>
</tbody>
</table>

HR, hazards ratio; CI, confidence intervals; LVH, left ventricular hypertrophy.

Note: the study by Milani et al. compared concentric remodeling to patients with hypertrophy.
Cardiovascular invents and LV geometry

Event Rate

LVMI

Relative wall thickness

Prevalence of LVH in hypertension

Stage 1: SBP = 140–159; DBP = 90–99

Stage 2: BP = 160–179/100–110

Stage 3: SBP ≥ 180; DBP ≥ 110

Hypertensive patients (%)

Assessment of left ventricular mass by 3D-ECHO
Assessment of left ventricular mass by 3D-ECHO
<table>
<thead>
<tr>
<th>Κριτήρια</th>
<th>Ευαισθησία</th>
<th>Ειδικότητα</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sokolow IRI+SHH≥2.5mV</td>
<td>21%</td>
<td>89%</td>
</tr>
<tr>
<td>Estes ≥5 points</td>
<td>15%</td>
<td>100%</td>
</tr>
<tr>
<td>Framingham LV strain+1 meter</td>
<td>9%</td>
<td>100%</td>
</tr>
<tr>
<td>LV strain</td>
<td>16%</td>
<td>98%</td>
</tr>
<tr>
<td>Cornell volt SV3+RaVL&gt;2.8/2.0mV</td>
<td>16%</td>
<td>97%</td>
</tr>
<tr>
<td>Minnesota 3-1 Voltage</td>
<td>15%</td>
<td>92%</td>
</tr>
<tr>
<td>SV3+RaVL&gt;2.4/2.0mV or LV strain or Estes≥5</td>
<td>34%</td>
<td>93%</td>
</tr>
<tr>
<td><strong>ΕCHO</strong></td>
<td><strong>85-93%</strong></td>
<td><strong>84-97%</strong></td>
</tr>
</tbody>
</table>

Schillaci G. Am. J. Card. 1994;74
There are two neuroendocrine systems that determine BP. The autonomic nervous system and the renin – angiotensin – aldosterone system.
## Table 2. Proposed New Aims for the Clinical Handling of HHD

<table>
<thead>
<tr>
<th>Aim</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>To identify patients prone to develop LVH</td>
<td>24-h monitoring of blood pressure</td>
</tr>
<tr>
<td></td>
<td>Insertion/deletion polymorphism of ACE gene</td>
</tr>
<tr>
<td></td>
<td>Circulating cardiotrophin 1</td>
</tr>
<tr>
<td>To optimize the diagnosis of LVH</td>
<td>3D echocardiography</td>
</tr>
<tr>
<td></td>
<td>MRI</td>
</tr>
<tr>
<td>To detect noninvasively myocardial remodeling</td>
<td>Speckle tracking echocardiography</td>
</tr>
<tr>
<td></td>
<td>MRI</td>
</tr>
<tr>
<td></td>
<td>Nuclear molecular imaging techniques</td>
</tr>
<tr>
<td></td>
<td>ELISA of circulating biochemical markers</td>
</tr>
<tr>
<td>To provide therapeutic benefit beyond reduction of LVM</td>
<td>Agents (i.e., antihypertensive and nonantihypertensive agents) that repair myocardial remodeling</td>
</tr>
<tr>
<td></td>
<td>Antihypertensive agents that preserve cardiac function, electrical activity, and intramyocardial perfusion</td>
</tr>
</tbody>
</table>

*(Hypertension. 2010;55:1-8.)*
Myocardial abnormalities in hypertensive patients with normal and abnormal left ventricular filling: a study of ultrasound tissue characterization and strain
Satoshi YUDA, Leanne SHORT, Rodel LEANO and Thomas H. MARWICK
University of Queensland, Department of Medicine, Princess Alexandra Hospital, Ipswich Road, Brisbane, QLD 4102, Australia

SR in LVH patients with abnormal LV filling was -1.33±0.20 s⁻¹, significantly lower than that both in controls (-1.71±0.31 s⁻¹; $P<0.001$) and in LVH patients without abnormal LV filling (-1.48±0.27 s⁻¹; $P<0.01$). SR in LVH patients without abnormal LV filling was significantly lower than that in controls ($P<0.05$) (Figure 2, upper panels; Figure 5, left panel). Peak systolic strain was also significantly different between the groups. Peak systolic strain in LVH patients with abnormal LV filling was -23.3±3.0%, significantly lower than that in controls (-27.6±4.0%; $P<0.001$), and peak strain in LVH patients without abnormal LV filling was also significantly lower than that in controls ($P<0.05$) (Figure 2, lower panels; Figure 5, right panel).
Ποιος ο ρόλος της υπερηχοκαρδιογραφίας στην ανάδειξη των αλλαγών αυτών στον υπερτασικό ασθενή?

► Στον υπερτασικό πληθυσμό, έχει μεγαλύτερη συχνότητα, η επασβέστωση του μιτροειδικού δακτυλίου – διάταση ανιούσης αορτής- αορτική πάχυνση.

► Στην σοβαρού βαθμού χρόνια ΑΠ, η δευτεροπαθής διάταση της ανιούσης αορτής → εξάλειψη θέσης μετάπτωσης των κόλπων του Valsava→ διεύρυνση θέσης σύγκλεισης αορτικών πτυχών→ δευτεροπαθή AVR.

► Αθηροσκληρυντική αορτή ,συχνά, συνοδεύει την υπερτασική καρδιά.
Predictive parameters for the onset of AF

- Age
- Diurnal and nocturnal BP
- Max duration of the depression of P wave in the ECG
- LVMI
- Left atrial dimension
- Velocity of the A wave
- Minimum P wave velocity
REGRESSION OF LVH BY ANTIHYPERTENSIVE TREATMENT
PATHOPHYSIOLOGICAL AND CLINICAL CONSEQUENCES

- Systolic function → usually improved
- Diastolic function →
- Cardiac rhythm → arrhythmias probably reduced

Coronary blood flow → increased coronary reserve
Autonomic nervous system activity → improved
↓ adrenergic activity
↑ vagal tone
↑ beta-receptor responsiveness
↓ cardiopulmonary reflex
New echocardiographic technologies in the clinical management of hypertensive heart disease
Vitantonio Di Bello, Maurizio Galderisi, Cesare de Gregorio, Gerardo Ansalone, Frank Lloyd Dini, Giovanni Di Salvo, Sabina Gallina, Donato Mele, Susanna Sciomer, Roberta Montisci, Sergio Mondillo and Paolo Nicola Marino, on behalf of the Working Group of Echocardiography of the Italian Society of Cardiology (SIC), Italy
Reversion of LVH με αερόβια άσκηση


* p<0.05
**LV mass measurements by M-mode echo**

Assessment of technical variability
16 centres (2 observer/center); LVM = 56 to 419 grams

<table>
<thead>
<tr>
<th></th>
<th>NT n = 130</th>
<th>HT n = 131</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>38.4 ± 10.4</td>
<td>51.6 ± 11.5</td>
</tr>
<tr>
<td>Male</td>
<td>50 %</td>
<td>50 %</td>
</tr>
<tr>
<td>Prevalence obesity</td>
<td>11%</td>
<td>27%</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>23.95 ± 3.32</td>
<td>25.54 ± 3.66</td>
</tr>
<tr>
<td>Time between examination</td>
<td>4.8 ± 2.36</td>
<td>4.84 ± 2.16</td>
</tr>
</tbody>
</table>

Hypertensive heart disease is a complex entity involving changes to the cardiac system resulting from arterial hypertension and is the major cause of hypertension-related morbidity and mortality.
Diagnostic evaluation of the patient with hypertention

The earliest presentation may be limited to an abnormal vascular response to stress: LV hypertrophy. However, studies have shown increased myocardial fibrosis associated with hypertention related LVH.

Sex-specific upper limits of normality [mean + 1.96 standard deviation (SD)] for left-ventricular mass, left-ventricular mass indexed to body surface area, height and height were the following:

- 213 g, 114 g/m, 51 g/h, 123 g/h in men
- 161 g, 99 g/m, 47 g/h, 101 g/h in women.
- In multivariate analyses, body size measures and ambulatory BP levels were the most important correlates of left-ventricular mass.
# LV mass measurements by M-mode echo

**Assessment of technical variability. The RES Study**

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Day 1 – day 2 within-reader difference (%)</th>
<th>Probability of true biological variation for greater changes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reader 1</td>
<td>Reader 2</td>
</tr>
<tr>
<td>5</td>
<td>-14.92</td>
<td>-13.22</td>
</tr>
<tr>
<td>10</td>
<td>-11.72</td>
<td>-8.73</td>
</tr>
<tr>
<td>12.5</td>
<td>-9.95</td>
<td>-7.76</td>
</tr>
<tr>
<td>15</td>
<td>-8.57</td>
<td>-6.44</td>
</tr>
<tr>
<td>20</td>
<td>-6.51</td>
<td>-5.65</td>
</tr>
<tr>
<td>25</td>
<td>-5.06</td>
<td>-3.83</td>
</tr>
<tr>
<td>30</td>
<td>-3.95</td>
<td>-2.74</td>
</tr>
<tr>
<td>70</td>
<td>4.47</td>
<td>4.31</td>
</tr>
<tr>
<td>75</td>
<td>5.70</td>
<td>5.22</td>
</tr>
<tr>
<td>80</td>
<td>7.22</td>
<td>6.55</td>
</tr>
<tr>
<td>85</td>
<td>8.92</td>
<td>7.82</td>
</tr>
<tr>
<td>87.5</td>
<td>10.24</td>
<td>9.07</td>
</tr>
<tr>
<td>90</td>
<td>11.71</td>
<td>10.35</td>
</tr>
<tr>
<td>95</td>
<td>16.28</td>
<td>14.20</td>
</tr>
</tbody>
</table>

---

Prevalence of LVH in hypertension

Stage 1: SBP = 140–159; DBP = 90–99

Stage 2: BP = 160–179/100–110

Stage 3: SBP ≥ 180; DBP ≥ 110

Hypertensive patients (%)

CV events according to LV geometry changes

n° of patients 424; Follow-up 2-18 yrs, mean 6.4 yrs

1 tertile (LVMI < 91 g/m²)
2 tertile (LVMI 91-117 g/m²)
3 tertile (LVMI > 117 g/m²)

CV ev (%)

RWT < 0.44
RWT ≥ 0.44

75±11 g/m²
79±9 g/m²
104 ± 7 g/m²
104 ± 8 g/m²
141+21 g/m²
149+32 g/m²

* vs eccentric geometry; § vs 1st tertile eccentric geometry

Muiesan, Agabiti Rosei et al, Hypertension 2004
A) Prognostic Value of Serial Changes in LV Mass

### (Echo)

<table>
<thead>
<tr>
<th>Persistently Normal LV Mass</th>
<th>Persistently Increased LV Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>No LVH</td>
<td>LVH</td>
</tr>
<tr>
<td>Koran M. et al</td>
<td>5/98 (5,1%)</td>
</tr>
<tr>
<td>Mulasan ML. et al</td>
<td>4/78 (5,1%)</td>
</tr>
<tr>
<td>Verdcchia P. et al</td>
<td>15/278 (5,4%)</td>
</tr>
<tr>
<td>Cipriano C. et al</td>
<td>6/125 (4,8%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30/579 (5,2%)</strong></td>
</tr>
<tr>
<td>No LVH</td>
<td>LVH</td>
</tr>
<tr>
<td>1/28 (3,6%)</td>
<td>4/16 (25%)</td>
</tr>
<tr>
<td>4/32 (12,5%)</td>
<td>13/34 (23%)</td>
</tr>
<tr>
<td>3/48 (6,2%)</td>
<td>12/68 (21%)</td>
</tr>
<tr>
<td>5/52 (9,6%)</td>
<td>16/109 (15%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13/160 (8,1%)</strong></td>
</tr>
<tr>
<td>LVH</td>
<td>LVH</td>
</tr>
<tr>
<td>4/16 (25%)</td>
<td>45/217 (20,7%)</td>
</tr>
</tbody>
</table>

**Note:** LVH = Left Ventricular Hypertrophy, LV Mass = Left Ventricular Mass
<table>
<thead>
<tr>
<th>Geometric model</th>
<th>Reference</th>
<th>Number of subjects</th>
<th>Reference standard</th>
<th>Cross-sectional views</th>
<th>Convention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolate Ellipsoid</td>
<td>Devereux\textsuperscript{107}</td>
<td>34</td>
<td>Postmortem</td>
<td>M-mode MV tips</td>
<td>Penn</td>
</tr>
<tr>
<td></td>
<td>Devereux\textsuperscript{111}</td>
<td>52</td>
<td>Postmortem</td>
<td>M-mode MV tips</td>
<td>ASEM-mode</td>
</tr>
<tr>
<td></td>
<td>Devereux\textsuperscript{111}</td>
<td>52</td>
<td>Postmortem</td>
<td>M-mode MV tips</td>
<td>Penn</td>
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<tr>
<td></td>
<td>Woythaler\textsuperscript{108}</td>
<td>48</td>
<td>Postmortem</td>
<td>M-mode MV tips</td>
<td>ASE M-mode</td>
</tr>
<tr>
<td></td>
<td>Park\textsuperscript{118}</td>
<td>34</td>
<td>Postmortem</td>
<td>M-mode MV tips</td>
<td>ASE M-mode</td>
</tr>
<tr>
<td></td>
<td>Qin\textsuperscript{195}</td>
<td>27</td>
<td>MRI</td>
<td>M-mode</td>
<td>ASE M-mode</td>
</tr>
<tr>
<td></td>
<td>Takeuchi\textsuperscript{150}</td>
<td>150</td>
<td>MRI</td>
<td>M-mode</td>
<td>ASE M-mode</td>
</tr>
<tr>
<td>Area length</td>
<td>Park\textsuperscript{118}</td>
<td>34</td>
<td>Postmortem</td>
<td>SAX-Pap; 4Ch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Qin\textsuperscript{195}</td>
<td>27</td>
<td>MRI</td>
<td>SAX-Pap; 4Ch</td>
<td></td>
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<tr>
<td>Truncated ellipsoid</td>
<td>Devereux\textsuperscript{111}</td>
<td>9</td>
<td>Postmortem</td>
<td>SAX-Pap; 4Ch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Park\textsuperscript{118}</td>
<td>34</td>
<td>Postmortem</td>
<td>SAX-Pap; 4Ch</td>
<td></td>
</tr>
<tr>
<td>Modified Simpson’s</td>
<td>Helak\textsuperscript{120}</td>
<td>13 in vitro</td>
<td>Direct</td>
<td>6-11 SAX</td>
<td>Wyatt</td>
</tr>
</tbody>
</table>
Inappropriate Left Ventricular Mass Changes During Treatment Adversely Affects Cardiovascular Prognosis in Hypertensive Patients

Maria Lorenza Muiesan, Massirio Salvetti, Anna Paini, Cristina Monteduro, Gloria Galbassini, Bianca Bonzi, Paolo Poisa, Eugenia Belotti, Claudia Agabiti Rosei, Damiano Rizzoni, Maurizio Castellano, Enrico Agabiti Rosei

436 patients, FU echocardiogram after 72 + 38 months, additional 42 + 16 months FU

Event rate (x 100 pts/years)

Persistently Appropriate LVM
0.81

Regression of Inappropriate LVM
0.97

Development of Inappropriate LVM
1.87

Persistence of Inappropriate LVM
*†† 3.18

"...Cox’s proportional hazard model indicated that age, male sex, persistence, or development of inappropriate LVM, in addition to persistence and development of LVH, were independently associated with the occurrence of CV events (p<0.001)."
The Mitral L Wave: A Marker of Pseudonormal Filling and Predictor of Heart Failure in Patients with Left Ventricular Hypertrophy

Carolyn S. P. Lam, MBBS, MRCP, Lin Han, MD, MSc, Jong-Won Ha, MD, PhD, Jae K. Oh, MD, FACC, and Lieng H. Ling, MBBS, FRCP, Singapore; Seoul, Korea; and Rochester, Minnesota