

## Review Article

# Echocardiography in the Evaluation of a Hypertensive Patient: An Invaluable Tool or Simply Following the Routine?

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**H**ypertension is a heterogeneous disorder with a number of well-defined as well as putative etiologies. The World Health Organization estimates that hypertension may cause 7.1 million premature deaths and 4.5% of the disease burden worldwide.<sup>1,2</sup> Hypertension is a major risk factor for stroke and cardiovascular diseases, and is thus associated with significant morbidity and mortality. Hypertensive heart disease is a complex entity that involves changes to the cardiovascular system resulting from arterial hypertension; it is therefore the major cause of hypertension-related complications.<sup>3,4</sup> The development of Doppler echocardiography has offered new approaches regarding both insights into pathophysiology and clinical implications that affect hypertensive patients.<sup>5,6</sup> For these reasons, it is obvious that echocardiographic assessment is very important in the clinical management of a hypertensive patient. We aimed at reviewing "old" and newer data regarding the contributions of echocardiography to the evaluation of a hypertensive patient.

## Echocardiographic evaluation of the hypertensive patient

The heart is the pump of the circulatory system, so it is reasonable that the in-

creased arterial pressure affects it from the early stages of hypertension and it actually suffers the commonest hypertension-related organ damage. Any provoked alterations involving either the anatomy or the functionality of the heart can easily be detected and imaged by echocardiography, which represents a real-time, quick, reproducible, cheap, and widespread method. This is why echocardiography is one of the very first examinations that a hypertensive patient is recommended to undergo. The echocardiographic assessment of the heart of a hypertensive patient is performed on two levels: i) an anatomic approach, which includes measurement of the heart cavities (Table 1), and ii) a functional approach, which includes assessment of indices of function. Overall, to summarize, a global echocardiographic evaluation of a patient with hypertension should include assessment of the following: a) left ventricular hypertrophy, cardiac mass and geometry; b) left ventricular function; c) left atrial volume and function; d) the thoracic aorta; and e) coronary artery patency, to investigate the possible coexistence of coronary artery disease.

## Left ventricular hypertrophy, mass and geometry

Despite many technical limitations (in-

**Table 1.** Anatomic or dimensional echocardiographic approach to a hypertensive patient.

	Tips and Formulas	Normal* and abnormal cutoff values	Advantages	Disadvantages
Linear LV dimensions: LV end-diastolic diameter septal and posterior wall thickness	2D or M-mode measurements should be taken at end diastole and perpendicularly to the axis in left parasternal view Short-axis data overestimate LV dimensions 3D echocardiography provides more accurate data and is well correlated with MRI	LV diastolic diameter: 3.9-5.3 cm for female, 4.2-5.9 cm for male LV diastolic diameter/ BSA=2.4-3.2 cm/m <sup>2</sup> for female, 2.2-3.1 for male Septal and posterior wall thickness, 0.6-0.9 cm for female, 0.6-1.0 cm for male	Simple and easily obtained measurements Calculations are avoided	Normal values for wall thickness have not been corrected for BSA Hypertrophy is not defined according to wall thickness Uniform data for prediction of cardiovascular risk are missing
Left ventricular mass	$0.8 \times 1.04 \times ((LVIDd + PWTd + SWTd)^3 - LVIDd^3) + 0.6 \text{ g}$	88-224 g or <125 g/m <sup>2</sup> for men 67-162 g or <110 g/m <sup>2</sup> for women	Definition of hypertrophy Not appropriate for evaluating patients with LV distortion Predicts cardiovascular risk Follow-up treatment efficacy	Limitations and errors derived from calculations Not widely adopted in clinical practice
Relative wall thickness	$2 \times PWTd / LVIDd$	0.42	Definition of type of hypertrophy: concentric if >0.42 eccentric if <0.42 Concentric hypertrophy has worse prognosis	Not widely adopted in clinical practice
Linear left atrial dimensions	Measurements at end systole 2D anteroposterior linear dimension obtained from parasternal long-axis view LA area: the greatest value obtained in either of 4- or 2-chamber views	LA diameter: 2.7-3.8 cm for female, 3.0-4.0 cm for male LA diameter/BSA: 1.5-2.3 cm/m <sup>2</sup> for both sexes LA area <20 cm <sup>2</sup> for both sexes	Simple and easily obtained measurements Correlate with angiographic measurements Calculations are avoided	Less accurate and reproducible method. LA area underestimates LA dilatation Not well correlated with cardiovascular risk
Left atrial volume	$8/3\pi (A1 \times A2/L)$ A1 and A2: LA areas obtained from 4- and 2-chamber views L: shortest distance from back wall to line across hinge points of mitral valve in either of 4- or 2-chamber views	22-52 ml for female, 18-58 ml for male	More accurate method than linear measurements Predicts cardiovascular risk better than LA linear dimensions	Underestimates left atrial volumes as compared to those obtained by MRI Limitations and errors derived from calculations

\*Values suggested by American Society of Echocardiography and European Association of Echocardiography in Recommendations for Chamber Quantification.<sup>14</sup>

LV – left ventricle; LA – left atrium; BSA – body surface area; LVIDd – left ventricular internal diameter at diastole; PWTd – posterior wall thickness at diastole; SWTd – septal wall thickness at diastole.

terobserver variability, low quality imaging in obese patients, obstructive lung disease, etc.) echocardiography is more sensitive than electrocardiography in identifying left ventricular hypertrophy and predict-

ing cardiovascular risk,<sup>7</sup> thus assisting in the selection of appropriate therapy.<sup>8</sup> Given the relationship between increased left ventricular mass and cardiovascular risk, in its latest guidelines<sup>9</sup> for the management

of arterial hypertension the European Society of Cardiology has included measurement of the dimensions of the left ventricle and further calculation of mass (Table 1). Proper evaluation includes measurement of the interventricular septum, left ventricular posterior wall thickness, and end-diastolic diameter, with calculation of left ventricular mass according to the formula currently approved by the American Society of Echocardiography.<sup>10</sup> This is derived from two-dimensional linear left ventricular measurements, has been validated by necropsy<sup>11</sup> ( $r=0.90$ ,  $p<0.001$ ), and is based on modeling the ventricle as a prolate ellipse of revolution:

$$\text{LV mass} = 0.8 \times 1.04 \times ((\text{LVIDd} + \text{PWTd} + \text{SWTd})^3 - \text{LVIDd}^3) + 0.6 \text{ g}$$

where LVIDd is the left ventricular internal diameter at diastole, PWTd is the posterior wall thickness at diastole, and SWTd is the septal wall thickness at diastole. This formula is appropriate for evaluating patients without major distortions of LV geometry, e.g. patients with hypertension.

Although the correlation between left ventricular mass index and cardiovascular risk is continuous, certain cutoff values for left ventricular mass have been widely accepted for defining left ventricular hypertrophy, namely  $125 \text{ g/m}^2$  for men and  $110 \text{ g/m}^2$  for women. In a multicenter prospective observational study of uncomplicated essential hypertensive patients, it was documented that for any 39 g increase in left ventricular mass there was an independent increase in the corresponding risk of primary hard endpoint events (odds ratio, OR 3.7, 95% confidence interval, CI: 0.5-8;  $p=0.002$ ) and total cardiovascular events (OR 4.0, 95% CI: 1.4-7.3;  $p=0.0013$ ).<sup>12</sup> It has been shown that the therapeutic management of hypertension only has significant beneficial effects on the rate of cardiovascular events when a reduction in left ventricular mass can be achieved.<sup>13</sup>

Furthermore, according to the Recommendations for Cardiac Chamber Quantification that were developed by the European Association of Echocardiography in conjunction with the American Society of Echocardiography,<sup>14</sup> hypertrophy is further classified into concentric and eccentric. This is determined according to the relative wall thickness (RWT), which is defined as the ratio of 2 times the posterior wall thickness to the left ventricular end-diastolic diameter. A cutoff value of 0.42 permits categorization of an increase in left ventricular mass as either concentric ( $\text{RWT}>0.42$ ) or eccentric ( $\text{RWT}<0.42$ ) hypertrophy, and also al-

lows the identification of concentric remodeling, defined as a normal left ventricular mass with increased  $\text{RWT}>0.42$ . All predict an increased incidence of cardiovascular disease, but concentric hypertrophy has consistently been shown to be the condition that most markedly increases the risk.<sup>15,16</sup>

Apart from left ventricular mass, the corresponding geometry provides additional prognostic information about patients with hypertension. Verna et al found that an elevated baseline left ventricular mass and abnormal geometry were associated with a further increase in morbidity and mortality in high-risk patients after a myocardial infarction.<sup>17</sup> Given all this accumulated evidence, it is clear that the assessment of left ventricular mass and geometry by echocardiography contributes significantly to the management of a hypertensive patient.

Both the M-Mode and the 2D technique have been used extensively for the assessment of left ventricular mass and geometry.<sup>18-21</sup> However, despite various modifications to these conventional echo techniques,<sup>18,19</sup> it must be acknowledged that the M-Mode and 2D calculations of left ventricular mass have many limitations.<sup>19</sup> Validation necropsy studies are limited by their small sample size; moreover, only some of them have documented rather poor correlations. Additionally, ventricular asymmetry can interfere with the accuracy of an assessment made by applying linear measurements in two orthogonal planes. Finally, it is well known that the variability of echo measurements is non-trivial.<sup>19,22-24</sup>

Three-dimensional echocardiography has been proved to possess many advantages over 2D echocardiography; it has given good results regarding the assessment of left ventricular mass,<sup>25</sup> though without eliminating the well known limitations.<sup>26</sup> In a study in which 3D echocardiograms were reconstructed from 2D data sets, left ventricular mass measurements showed a high correlation ( $r=0.9$ ) with magnetic resonance imaging (MRI), which has been considered the gold-standard noninvasive method for assessment of left ventricular volumes and mass, given its superior accuracy and reproducibility. However, observer variability was found to be 13%.<sup>26</sup> Assessing left ventricular mass with real-time 3D echocardiography has been shown to reduce the standard error of the estimate.<sup>26</sup> It is notable that if 3D echocardiography is not available, 3D-guided 2D left ventricular mass calculation is a fine alternative, since there is an excellent correlation between the two techniques ( $r=0.95$ ).<sup>27</sup>

## **Left ventricular function**

### *Left ventricular systolic function*

Echocardiography provides a reliable means of assessing left ventricular systolic function. Left ventricular ejection fraction, as well as endocardial and mid-wall fractional shortening, are the most practical systolic indices that have also been proposed as possible additional predictors of cardiovascular events.<sup>28,29</sup> The Framingham study showed that the hazard for developing heart failure in hypertensive as compared with normotensive subjects was about twofold in men and threefold in women,<sup>30</sup> thus documenting the importance of assessing left ventricular function in hypertensive heart disease.

The conventional way of assessing left ventricular function with echocardiography is via the left ventricular ejection fraction, determined by applying Simpson's method of discs.<sup>31</sup> If the left ventricular ejection fraction is initially evaluated to be <50%, there is a nearly tenfold increased risk for hospitalization for congestive heart failure as compared to hypertensive patients with a normal ejection fraction. Despite the widespread clinical use of the left ventricular ejection fraction, it should be kept in mind that it is a load-dependent systolic index. From this point of view, it is clearly very important to identify the slightest initial impairment of left ventricular function, using additional indices apart from ejection fraction that are not load-dependent. This was the reason for the introduction into clinical practice of mid-wall fractional shortening, a systolic index of left ventricular function that is relatively independent of afterload. Notably, hypertensive patients with left ventricular hypertrophy and a normal ejection fraction have been found to have abnormal mid-wall fractional shortening.<sup>32</sup>

Left ventricular function has also been found to be reflected indirectly by the function of long-axis myocardial fibers. Assessing the function of the left ventricular long axis provides a very useful index, which can detect even very slight impairment of left ventricular function that cannot be identified by ejection fraction. Such impairment of left ventricular long-axis function has been shown to occur at the very first stages in many heart diseases, and consequently it has been considered a very useful tool in the evaluation of the hypertensive patient.<sup>33</sup> Older studies based on atrioventricular plane displacement (old method) have demonstrated that hypertensive patients without overt systolic dysfunction exhibit left ventricular long-axis systolic dysfunction, while long-

axis diastolic dysfunction always coexists with abnormal diastolic filling patterns. It has been suggested that long-axis systolic dysfunction precedes long axis diastolic dysfunction in hypertensive patients.<sup>34</sup> Similarly, a newly introduced echocardiographic technique, tissue Doppler imaging has also shown that, in patients with hypertension and a normal ejection fraction, a significant reduction in the systolic tissue velocity of the long axis can be identified, along with left ventricular hypertrophy and diastolic dysfunction.<sup>35</sup> Nishikage et al<sup>36</sup> used tissue Doppler imaging in asymptomatic hypertensive patients and managed to demonstrate an impairment of long-axis left ventricular function in 10% of them, which was closely correlated with a corresponding impairment of diastolic function. They concluded that assessment of left ventricular longitudinal function is a useful tool for identifying diastolic dysfunction and subclinical left ventricular systolic dysfunction in asymptomatic hypertensive patients. Notably, Blendea et al<sup>37</sup> reported a converse finding: alterations in left ventricular long-axis systolic and diastolic function could predict the onset of hypertension.

The implementation of 3D echocardiography in patients with hypertrophy constitutes a new noninvasive method for assessing myocardial mechanics and their relationship with myocardial volumes. Oy et al found that 3D mid-wall left ventricular ejection fraction can discriminate between normal and hypertensive subjects who both have left ventricular hypertrophy and normal systolic function, and is related to the degree of hypertrophy.<sup>38</sup>

Finally, the presence of left ventricular systolic dyssynchrony contributes to systolic dysfunction of the left ventricle. Kırış et al used tissue Doppler imaging to prove that this was also true in hypertension, reporting that left ventricular dyssynchrony is one of the independent predictors of systolic function in newly diagnosed hypertensive patients.<sup>39</sup>

### *Left ventricular diastolic function*

The development of left ventricular diastolic dysfunction may precede hypertrophy and may be one of the earliest changes associated with hypertensive heart disease.<sup>40</sup> Notably, diastolic dysfunction may not be accompanied by symptoms and is usually a chance finding during a Doppler echocardiographic examination.<sup>41</sup> Since left ventricular diastolic dysfunction as assessed by Doppler echocardiography can predict mortality in middle-aged and elderly adults,<sup>42</sup>

this tool has acquired an important clinical position. A comprehensive assessment of diastolic function should include not only a simple classification of diastolic dysfunction progression, but also an estimation of the left ventricular filling pressure, a true determinant of symptoms and prognosis. Although this can be derived via various ultrasound maneuvers or tools, the ratio between the transmitral E velocity and the pulsed tissue-Doppler-derived early diastolic velocity (the E/e' ratio) is the most feasible and accurate. Structural changes in the myocardium, such as altered collagen and myocardial cells, is probably the mechanism of diastolic dysfunction.<sup>40</sup> Kasner et al found that patients with heart failure and a normal left ventricular ejection fraction (diastolic heart failure) have an elevated content of myocardial collagen type I, with enhanced collagen cross-linking and lysyl oxidase expression, which were associated with impaired diastolic tissue Doppler parameters.<sup>40</sup> It is uncertain whether Doppler echocardiography can assess the actual diastolic function of the left ventricle or simply provides indices of left ventricular filling pressures. The above mentioned left ventricular filling index E/e' (lateral) has been identified as the best index, among all echocardiographic parameters investigated, for the detection of diastolic dysfunction in heart failure when the left ventricular ejection fraction is normal; this has been confirmed by conductance catheter analysis.<sup>43</sup>

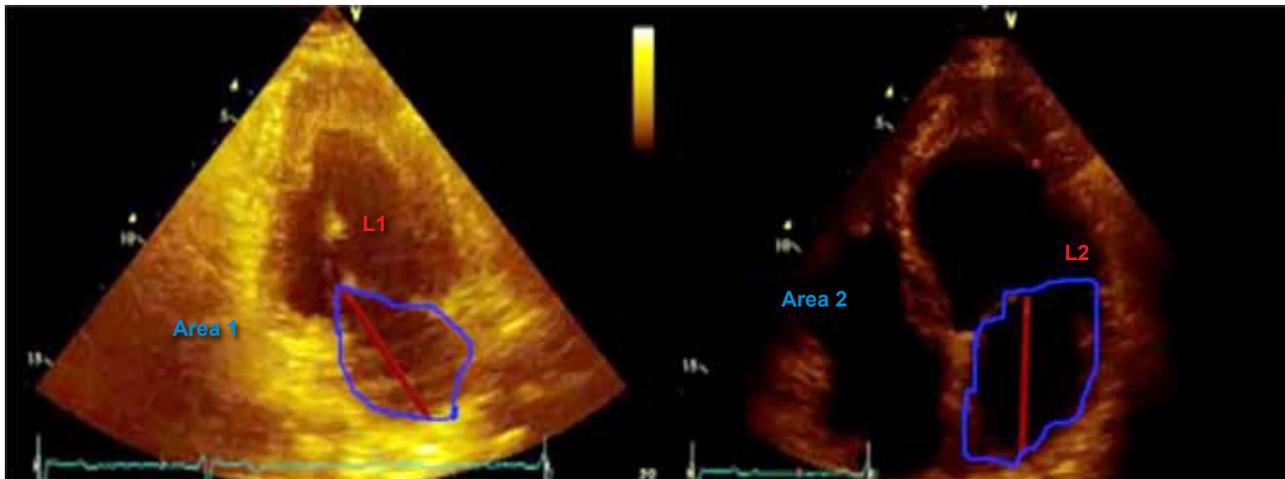
Recently, diastolic dyssynchrony has been proposed as a probable mechanism contributing to pathophysiology in hypertensive heart disease. Findings suggest that left ventricular diastolic dyssynchronous changes may be caused by increased left ventricular mass and arterial stiffness.<sup>6</sup>

### ***Left atrial dimensions, volume and function***

Left atrial size has been shown to be a predictor, not only of atrial fibrillation,<sup>44,45</sup> stroke,<sup>46</sup> and congestive heart failure, but also of overall cardiovascular risk.<sup>47</sup> The left atrium is very sensitive to filling pressures and remodels in response to chronic increased arterial pressure and volume overload. Cuspidi et al<sup>48</sup> found, in a cohort of patients who were mainly hypertensives, that left atrial enlargement was a frequent finding in patients with preserved systolic function seen in clinical practice; this abnormality was found to be strongly related to left ventricular hypertrophy and to diastolic dysfunction. For these reasons, in the European Society of Cardiology's latest guidelines for

the management of arterial hypertension<sup>9</sup> the measurement of left atrial size is strongly recommended (Table 1). Left atrial size is measured at ventricular end-systole along its greatest dimension, trying to avoid foreshortening of the left atrium. The base of the atrium should be at its greatest size, indicating that the imaging plane passes through the maximal short-axis area, and the length of left atrium is maximized, thus ensuring alignment along its true long axis. It is well known that left atrial volume and left atrial anteroposterior dimension are not linearly related, so that when left atrial size is measured in clinical practice, volume determinations are preferred over linear dimensions because they allow accurate assessment of the asymmetric remodeling of the left atrial cavity.<sup>49</sup> Furthermore, not only is left atrial volume a more accurate and reproducible estimate of left atrial size compared to reference standards such as MRI,<sup>50</sup> but also the relationship with cardiovascular disease is stronger for left atrial volume than for linear dimensions.<sup>51</sup> Left atrial volumes are best calculated<sup>14</sup> using either an ellipsoid model or Simpson's rule. Calculation of left atrial volume from the area-length method is more usually applied (Table 1), using the formula  $8/3\pi (A1 \times A2/L)$  (Figure 1), where A1 and A2 represent the maximal planimetered left atrial areas acquired from the apical 4- and 2-chamber views, respectively, and L is the long-axis length, determined as the shortest distance from the back wall to the line across the hinge points of the mitral valve in either of the 4- or 2-chamber views.<sup>14</sup> However, all echocardiographic methods significantly underestimate left atrial volumes as compared to those obtained by MRI. Some minor non-significant improvement in the estimation of left atrial volume has been gained by implementation of 3D echocardiographic methods.<sup>52</sup>

Apart from the dimensions and volume of the left atrium, left atrial function has attracted particular interest.<sup>53</sup> Progressive left ventricular diastolic dysfunction due to hypertension alters left atrial contractile function in a predictable manner. In hypertensive patients 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 and death.<sup>53</sup> However, there are significant limitations to the clinical application of echocardiographic methods of assessment of left atrial function, including dependence on altered left ventricular hemodynamics, image quality, single plane assessment, and the tethering effect. Strain rate imaging is a novel echocar-



**Figure 1.** Calculation of left atrial volume by the area-length method, using the formula  $8/3\pi (A1 \times A2/L)$ , where A1 and A2 represent the maximal planimetered left atrial area acquired from the apical 4- and 2-chamber views (blue lines), and L is the long-axis length, determined as the shortest distance from the back wall to the line across the hinge points of mitral valve in either of the 4- or 2-chamber views (red lines).

diographic technique that enables quantification of left atrial function in patients with hypertension, even in the absence of left atrial dilation or functional left atrial impairment assessed by conventional Doppler echocardiography. Similarly, two-dimensional speckle-tracking echocardiography (see below) has been used as a noninvasive, simple, and reproducible technique for assessing left atrial function in patients with either physiological or pathological left ventricular hypertrophy.<sup>54</sup> Left atrial function can also be evaluated indirectly by assessment of the function of the left atrial appendage. Notably, non-dipper hypertensive patients exhibit impaired indices of left atrial appendage function, such as filling and ejection flow rates, as compared to dipper hypertensives and control group. According to this finding, non-dipper hypertensive patients detected by ambulatory blood pressure monitoring require a more aggressive treatment approach.<sup>55</sup> Maintenance of left atrial appendage function may prevent potential complications secondary to its dysfunction.<sup>56</sup>

### **Thoracic aorta**

Aging and hypertension have been shown to significantly increase aortic diameter, thickness and stiffness. Aortic root dilatation is a frequent cardiovascular phenotype in hypertensive patients who are referred to echo laboratories for identification of hypertensive organ damage, and is actually predictive of increased cardiovascular morbidity and mortality.<sup>57</sup>

Body surface area, left ventricular mass, and age are the most important correlates of this phenotype. It is of note that the echocardiographic assessment of the aortic root is correlated with left ventricular diastolic function. Altered left ventricular diastolic function, as assessed by the ratio of deceleration time to early mitral wave velocity, has been found to be independently associated with aortic root dilatation. This could be attributed to the fact that the aortic and mitral annulus exhibit a close anatomic continuity. As a result, the aortic annulus, with its attached aortic root, moves simultaneously with the rigidly attached mitral annulus. The M-mode traced motion of the aortic root in diastole mimics the motion of the mitral annulus, thus indirectly reflecting left ventricular diastolic function. In one study, hypertensive patients and normal subjects were screened for left ventricular diastolic dysfunction by measuring mitral inflow velocities, employing tissue Doppler imaging of the mitral annulus and M-mode examination of aortic root motion. The easily obtained and less complex M-mode aortic root motion was as accurate as tissue Doppler imaging in detecting or ruling out left ventricular diastolic dysfunction.<sup>58</sup> From this point of view, aortic root dilatation has been considered a useful marker of subclinical left ventricular diastolic dysfunction.<sup>59</sup>

### **Coronary artery disease**

It is well known that there is significant association between coronary artery disease and hypertension.

Moreover, a relationship with stress-induced myocardial ischemia, decreased coronary flow reserve, and incipient diastolic dysfunction has been documented in asymptomatic young hypertensive patients.<sup>60</sup> From this point of view, the detection of myocardial ischemia in asymptomatic subjects with hypertension, with or without other risk factors for coronary artery disease, is very important.<sup>60</sup>

Stress echocardiography is a significant tool in the detection of coronary artery disease in everyday clinical practice. One study reviewed the accuracy of stress myocardial perfusion scintigraphy and stress echocardiography for diagnosis of coronary artery disease in patients with arterial hypertension.<sup>61</sup> Pooled summary estimates showed that stress myocardial perfusion scintigraphy and stress echocardiography had sensitivities of 0.90 and 0.77 and specificities of 0.63 and 0.89, respectively in detecting coronary artery disease in hypertensive patients.<sup>61</sup> The specificity of stress myocardial perfusion scintigraphy was comparable to that reported in the general population, whereas stress echocardiography showed higher specificity but substantially lower sensitivity as compared to myocardial perfusion scintigraphy.<sup>61</sup> Furthermore, dobutamine stress echocardiography yielded satisfactory diagnostic accuracy for identifying coronary artery disease, particularly in hypertensive women.<sup>61</sup>

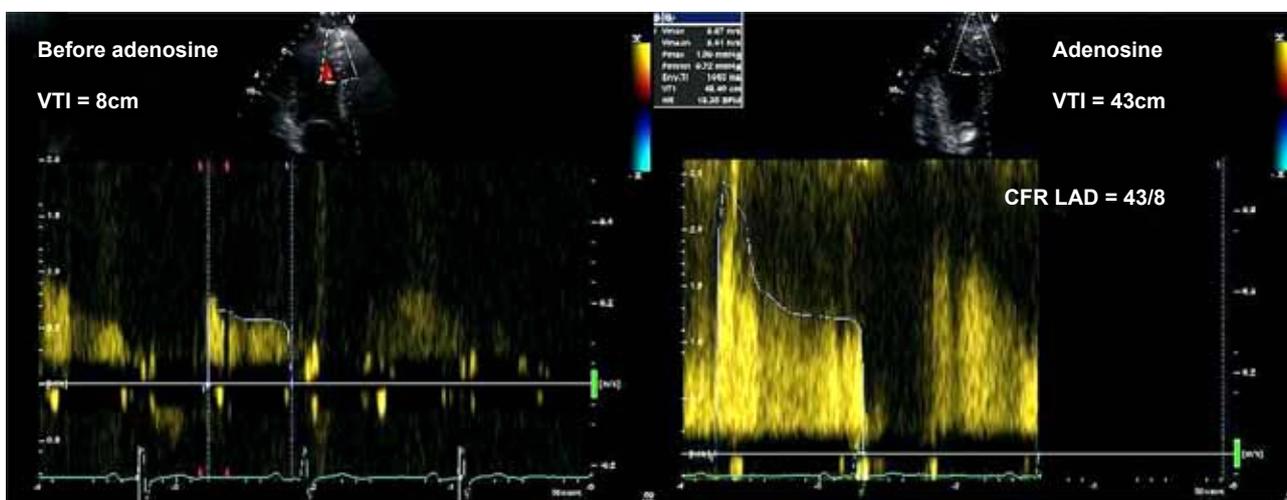
Vasodilator stress echocardiography allows dual imaging of both regional wall motion and coronary flow reserve in the left anterior descending artery ter-

ritory (Figure 2). Hypertension may affect coronary flow reserve independently of obstructive coronary artery disease, through a mechanism involving dysfunction of the coronary microcirculation. Employing receiver operating curve analysis, a coronary flow reserve  $\leq 1.91$  was the best cutoff value for diagnosing left anterior descending artery stenosis in both hypertensive patients (sensitivity 87%, specificity 76%) and normotensive subjects (sensitivity 89%, specificity 80%).<sup>48</sup> Assessment of coronary flow reserve in the left anterior descending artery provides useful information for both vessel stenosis and prognosis, in both hypertensive and normotensive patients, despite the fact that the specificity was found to be lower in the hypertensive group.<sup>62</sup>

The prognostic implication of stress echocardiography was studied in a large cohort of hypertensive and normotensive subjects with known or suspected coronary artery disease.<sup>4</sup> It seems that stress echocardiography provides an effective prognostic tool in hypertensive and normotensive patients. It is of note that a non-ischemic stress test result predicts better survival in normotensive than in hypertensive patients with no resting wall motion abnormalities.<sup>4</sup>

### The role of newer techniques

In recent years, echocardiography has been enriched by very refined newer techniques that are capable of studying hypertensive heart disease more thoroughly, providing new insights to be taken into account



**Figure 2.** Estimation of coronary flow reserve (CFR) in the left anterior descending artery (LAD) territory in a young hypertensive patient with a negative dobutamine stress test. In the 3-chamber apical view, the LAD flow is detected at the apex, and the velocity time integral (VTI) of diastolic coronary flow is measured before (8 cm) and after (43 cm) adenosine infusion. CFR is estimated to be normal ( $43/8 = 5.3$ ).

when clinically managing these patients. These newer techniques include mainly real-time three-dimensional echocardiography, coronary flow reserve, and the concepts of strain and strain rate assessed by either tissue Doppler or speckle-tracking echocardiography.<sup>63</sup> We have already reported above the great contribution of 3D echocardiography to the evaluation of hypertensive patients, since it allows a more precise evaluation of left ventricular volumes and mass. In addition, we have already pointed out the significance of coronary flow reserve as a non-interventional tool for quantification of the vasodilatory response of coronary velocities. The concepts of strain or strain rate have been incorporated into the group of the newest techniques for evaluating left ventricular function.<sup>64</sup> This technique assesses myocardial mechanics by measuring the relationship between two points within the myocardium as if they were connected by a rubber band. Strain and strain rate can be derived from either tissue Doppler or speckle-tracking two- or three-dimensional echocardiography. Because of the many limitations to the Doppler-based strain and strain rate method, speckle-tracking-derived strain and strain rate seem to have prevailed. Conventional transthoracic echocardiography and pulsed wave tissue Doppler imaging are usually unable to reveal very early subtle abnormalities in left ventricular systolic function caused by hypertension, prior to the manifestation of hypertrophy. It has been proposed that strain and strain rate, particularly when derived from speckle-tracking echocardiography, provide more insight into early hypertension-induced left ventricular systolic dysfunction. However it must be emphasized that, although very promising, this technique has mainly been applied for research purposes and has not been adopted as a standard tool in every day clinical practice for the evaluation of hypertensives.

In many studies, systolic and early diastolic strain and strain rate were measured in longitudinal, circumferential and radial directions using two-dimensional speckle-tracking echocardiography, whereas left ventricular twist and twist rate curves were calculated from rotation curves. It seems that longitudinal systolic strain has been found to be diminished in hypertensive patients, even before hypertrophy occurs.<sup>65-67</sup> It has been concluded that speckle-tracking echocardiography provides more detailed information than conventional echocardiography, since it can reveal systolic dysfunction before hypertrophy occurs and can identify some early left ventricular mechanical changes that might improve the clinical

management of these patients. However results regarding other measured systolic strains, such as radial have been rather controversial.<sup>65-67</sup> Regarding systolic strain rate, it has been measured either along the longitudinal or circumferential axis, and all have been found to be lower in hypertensives with hypertrophy as compared to those without hypertrophy.<sup>68</sup> Other studies<sup>68,69</sup> have documented that diastolic strain and strain rate have a significant trend towards a lower value in hypertensives with hypertrophy, particularly in those with concentric hypertrophy rather than other geometric patterns.<sup>68</sup> In contrast, data regarding left ventricular twist and twist rate have not given clear messages: some studies<sup>68,70</sup> have shown reduced torsion in patients with hypertension and hypertrophy, but others<sup>67</sup> have not confirmed these findings.

Two dimensional speckle-tracking echocardiography has also been applied for the assessment of left atrial function<sup>55</sup> in hypertensive patients. In another study,<sup>71</sup> the authors investigated the effects of the dipper or non-dipper status of hypertension on the longitudinal systolic and diastolic function of left atrial myocardial tissue by means of two-dimensional speckle-tracking echocardiography in hypertensive patients. They found decreased values of mean peak left atrial strain and strain rate in dippers versus non-dippers and they concluded that non-dipping in treated hypertensive patients was associated with adverse cardiac remodeling and impaired left atrial mechanical function. Finally, another study<sup>72</sup> evaluated the impact of arterial stiffness on regional myocardial function assessed by speckle-tracking echocardiography in patients with hypertension. It was shown that, in hypertensive patients with a normal ejection fraction, arterial stiffening contributed to diminished compensatory increases in ventricular twist, particularly in those with an advanced stage of vascular stiffening.

## Conclusions

Despite its technical limitations, echocardiography is really a significant tool for the evaluation of a hypertensive patient. Assessing a hypertensive patient echocardiographically does not simply represent adherence to a routine examination procedure that has limited clinical value. Conventional echocardiography, alongside newer, richer techniques, provides invaluable information about the extent of heart damage related to hypertension and cardiovascular risk, thus helping us to achieve better management and apply better treatment.

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