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Annals of Clinical and Experimental Hypertension

Case Report

The Role of Echocardiography for Evaluation Patients with Arterial Hypertension

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Submitted: 15 October 2014
Accepted: 18 November 2014
Published: 28 November 2014

INTRODUCTION

Arterial hypertension is a major risk factor for stroke andcardiovascular diseases, and is thus associated with significant morbidity and mortality. Hypertensive heart disease is a complex entity that involves changes to thecardiovascular system resulting from arterial hypertension; it is therefore the major cause of hypertension-related complications [1]. The development of Doppler echocardiography has offered newapproaches regarding both insights into pathophysiology and clinical implicationsthat affect hypertensive patients [2,3] . For these reasons, it is obvious that echocardiographic assessment is very important inthe clinical management of 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 echocardiographic assessment of the heartof a hypertensive patient is performed ontwo levels: an anatomic approach, whichincludes measurement of the heart cavities, and a functional approach, which includes assessment of indices offunction. Overall, to summarize, a globalechocardiographic evaluation of a patienwith hypertension should include assessment of the following:

a) left ventricularhypertrophy, cardiac mass and geometry;

b) left ventricular function;

c) left atrialvolume and function;

d) the thoracic aorta;and

e) coronary artery patency,

to investigate the possible coexistence of coronaryartery disease.

Left ventricular hypertrophy, mass and geometry

Despite many technical limitations (interobserver variability, low quality imaging in obese patients, obstructive lung disease, etc.) echocardiography is more sensitive than electrocardiography inidentifying left ventricular hypertrophy and predicting cardiovascular risk, thus assisting in the selection of appropriate therapy [4-6]. Given the relationship beween increased left ventricular mass and cardiovascular risk, in its latest guidelinesfor the management of arterial hypertension the European Society of Cardiology has included measurement of the dimensionsof the left ventricle and further calculation of mass [10]. Proper evaluation includes measurementof the interventricular septum, left ventricular posterior wall thickness, and end-diastolic diameter, withcalculation of left ventricular mass according to theformula currently approved by the American Societof Echocardiography [7,12]. This is derived from two-dimensional linear left ventricular measurements, hasbeen validated by necropsy($r=0.90$, $p<0.001$), andis based on modeling the ventricle as a prolate ellipseof revolution:

$$\text{LV mass} = 0.8\times1.04\times((\text{LVIDd} + \text{PWTd} + \text{SWTd})^3 - \text{LVIDd}^3) + 0.6\ \text{g}$$

where LVIDd is the left ventricular internal diameterat diastole, PWTd is the posterior wall thickness atdiastole, 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[8]. Although the correlation between left ventricularmass index and cardiovascular risk is continuous, certain cutoff values for left ventricular mass have beenwidely accepted for defining left ventricular hypertrophy, namely 125 g/m^2 for men and 110 g/m^2 for women. In a multicenter prospective observational studyof uncomplicated essential hypertensive patients, itwas documented that for any 39g increase in leftventricular mass there was an independent increasein the corresponding risk of primary hard endpointevents (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) [11]. It has beenshown that the therapeutic management of hypertension only has significant beneficial effects on the rateof cardiovascular events when a reduction in left venricular mass can be achieved[13]. Furthermore, according to the Recommendationsfor Cardiac Chamber Quantification that were developed by the European Association of Echocardiography and American Society oEchocardiography, [12] hypertrophy is further classified intoconcentric and eccentric. This is determined according to the relative wall thickness (RWT), which is defined as the ratio of two times the posterior wall thicknessto the left ventricular end-diastolic diameter. A cutoffvalue of 0. 42 permits categorization of an increase inleft ventricular mass as either concentric (RWT>0. 42)or eccentric (RWT<0. 42) hypertrophy, and also allows the identificationof concentric remodeling, defined as a normal left ventricular mass with increased 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. [13] Apart from left ventricular mass, the corresponding geometry provides additional prognostic information about patients with hypertension. *Verna et al*[14]. found that an elevated baseline left ventricular massand abnormal geometry were associated with a further increase in morbidity and mortality in high-riskpatients after a myocardial infarction[15]. **Given all this accumulated evi-**dence, it is clear that the assessment of left ventricular mass and geometry by echocardiography contributes significantly to the management of a hypertensive patients. Both the M-Mode and the 2D technique have been used extensively for the assessment of left ventricular mass and geometry [16-18].

However, despite various modifications to these conventional echo techniques, [19] itmust be acknowledged that the M-Mode and 2D calculations of left ventricular masshave many limitations. 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 echomeasurements is non-trivial. 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, [20] though without eliminating the well known limitations. [21]. In a study in which 3D echocardiograms were reconstructedfrom 2D data sets, left ventricularmass 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 andreproducibility. However, observer variability was found to be 13%. [21]. Assessing left ventricular mass with real-time 3D echocardiography has been shown to reduce the standard error of the estimate. [21]. It is notable that if 3D echocardiography is not available, 3D-guided 2 dimensional left ventricular mass calculation is a fine alternative, since there is an excellent correlation between the two techniques (r=0. 95) [21].

Left ventricular systolic function

Echocardiography provides a reliable assessment of left ventricular systolicfunction. Left ventricular ejection fraction, as well as endocardial andmid-wall fractional shortening, are the most practical systolic indices that have also been proposed as possible additional predictors of cardiovascular events [23]. The Framingham study showed that the hazard for developing heart failure in hypertensive as compared with normotensive subjects was about twofold in menand threefold in women, 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 [23]. 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 initialimpairment 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 [22]. 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 inthe evaluation of the hypertensive patient [24]. 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 longaxis diastolic dysfunction always coexists with abnormal diastolic filling patterns. It has been suggestedthat long-axis systolic dysfunction precedes long axisdiastolic dysfunction in hypertensive patients [25].

Similarly, a newly introduced echocardiographic technique, tissue Doppler imaging has also shown that, in patients with hypertension and a normal ejectionfraction, a significant reduction in the systolic tissuevelocity of the long axis can be identified, along withleft ventricular hypertrophy and diastolic dysfunction [26-28]. *Nishikage et al. [*29] used tissue Doppler imagingin asymptomatic hypertensive patients and managed to demonstrate an impairment of long-axis left ventricular function in 10% of them, which was closelycorrelated with a corresponding impairment of diastolic function. They concluded that assessment ofleft ventricular longitudinal function is a useful toolfor identifying diastolic dysfunction and subclinicalleft ventricular systolic dysfunction in asymptomatic hypertensive patients. Notably, *Blendea et al.* [30]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 inpatients with hypertrophy constitutes a new noninvasive method for assessing myocardial mechanics andtheir relationship with myocardial volumes. *Jenkins 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. [31]Finally, the presence of left ventricular systolicdyssynchrony contributes to systolic dysfunction ofthe left ventricle. Kırışet al used tissue Doppler imaging to prove that this was also true in hypertension, reporting that left ventricular dyssynchrony is oneof the independent predictors of systolic function innewly diagnosed hypertensive patients [32,33].

Left ventricular diastolic function

The development of left ventricular diastolic dysfunction may precede hypertrophy and may be one of theearliest changes associated with hypertensive heartdisease [34]. Notably, diastolic dysfunction may not beaccompanied by symptoms and is usually a chancefinding during a Doppler echocardiographic examination [35]. Since left ventricular diastolic dysfunctionas assessed by Doppler echocardiography can predict mortality in middle-aged and elderly adults, [36] his 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, are probably the mechanism of diastolic dysfunction [35]. Kasner et al found that patients with heart failure and a normalleft 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 withimpaired diastolic tissue Doppler parameters [35]. It is uncertain whether Doppler echocardiography can assess the actual diastolic function of the left ventricleor simply provides indices of left ventricular fillingpressures. The above mentioned left ventricular filling index E/e' (lateral) has been identified as the bestindex, among all echocardiographic parameters investigated, for the detection of diastolic dysfunction inheart failure when the left ventricular ejection fraction is normal; this has been confirmed by conductance catheter analysis [36]. Recently, diastolic dyssynchrony has been proposed as a probable mechanism contributing topathophysiology in hypertensive heart disease. Findings suggest that left ventricular diastolic dyssynchronous changes may be caused by increased left ventricular mass and arterial stiffness [37].

Left atrial dimensions, volume and function

Left atrial size has been shown to be a predictor, not only of atrial fibrillation, [40,42] stroke, [43] and congestive heart failure, but also of overall cardiovascular risk [38].

The left atrium is very sensitive to filling pressures and remodels in response to chronic increased arterial pressure and volume overload. Cuspidi et al. [41] found, in a cohort of patients who were mainly hypertensive, 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 forthe management of arterial hypertensionthe measurement of left atrial size is strongly recommended. Left atrial size is measured at ventricular end systole along its greatest dimension, trying to avoid foreshortening of the left atrium. The baseof the atrium should be at its greatest size, indicatingthat the imaging plane passes through the maximalshort-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 antero -posterior dimension are not linearly related, so that when left atrial size is measured in clinical practice, volume determinations are preferred overlinear dimensions because they allow accurate assessment of the asymmetric remodeling of the left atrial cavity [42]. Furthermore, not only is left atrial volume amore accurate and reproducible estimate of left atrialsize compared to reference standards such as MRI [43], but also the relationship with cardiovascular diseaseis stronger for left atrial volume than for linear dimensions [44]. Left atrial volumes are best calculated[12]using either an ellipsoid model or Simpson's rule. Calculation of left atrial volume from the area-lengthmethod is more usually applied , using theformula $8/3\pi$ $(A_1 \times A_2/L)$, where A_1 and A_2 represent the maximal plan metric left atrial areas acquired from the apical four- and two-chamber views, respectively, and L is the long-axis length, determinedas the shortest distance from the back wall to the lineacross the hinge points of the mitral valve in either ofthe four- or two-chamber views [12].

However, all echocardiograph 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 [45]. Apart from the dimensions and volume of the left atrium, left atrial function has attracted particular interest [46]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 [46]. However, there are significant limitations to the clinical application of echocardiographic methods for 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 echocardiographic technique that enables quantification of left atrial function in patients with hypertension, even in the absence of left atrial dilatation or functional left atrial impairment assessed by conventional Doppler echocardiography. Similarly, two-dimensional speckle-tracking echocardiography 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. 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 [48-49]. Maintenance of left atrial appendage function may prevent potential complications secondary to its dysfunction [47].

The role of new 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 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. [50]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 vasodilator 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. [51] 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 hypertensive. 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 [52,53]. 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. [55]. Regarding systolic strain rate, it has been measured either along the longitudinal or circumferential axis, and all have been found to be lower in hypertensive with hypertrophy as compared to those without hypertrophy [56]. Other studies [57] 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. In contrast, data regarding left ventricular twist and twist rate have not given clear messages: some studies [57] have shown reduced torsion in patients with hypertension and hypertrophy. Two dimensional speckle-tracking echocardiography has also been applied for the assessment of left atrial function [55] in hypertensive patients. In another study 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 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 any technical.

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Cite this article

Hristova K, Shiue I (2015) The Role of Echocardiography for Evaluation Patients with Arterial Hypertension. Ann Clin Exp Hypertension 3(1): 1016.