Echocardiography in Hypertension
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Abstract

Hypertension (HTN) is a treatable risk factor for cardiovascular diseases. Accurate diagnosis of HTN along with the assessment of cardiovascular risk is essential for proper treatment in hypertensive patients. Echocardiography provides prognostic factors in HTN including left ventricular mass, systolic function, diastolic function, left atrial function, and size. Apart from routine echo methods, tissue Doppler, three-dimensional echo, and strain imaging are newer echo techniques in the evaluation of hypertensive patients. Familiarity with routine and newer echo parameters is helpful for risk stratification in HTN.

Key words: Left ventricular mass, echo parameters, cardiovascular risk

Introduction

Echocardiography is the simple routine investigation which provides information regarding pathophysiology and complications of hypertension (HTN). Anatomical and physiological changes in heart can be detected with this reproducible imaging technique [Figure 1]. Early target organ dysfunction can be detected by echo as a predictor of risk.

Indications of Echocardiography in HTN[1]

- In patients with mid-diastolic HTN (90–94 mmHg) with no other cardiovascular risk factors or evidence of end-organ damage (including lack of or equivocal signs of the left ventricular hypertrophy [LVH] on electrocardiography [ECG])
- The demonstration of LVH by echo is generally an indication for medical therapy, while non-pharmacological modalities alone can be used if the left ventricle (LV) mass is normal
- In patients who have no evidence of end-organ damage, who have either severe or refractory HTN or HTN that is present in the doctor’s office, but not at home or work. The absence of LVH in this setting suggests either HTN of recent onset or white coat HTN. The presence of the latter can be confirmed by ambulatory blood pressure (BP) monitoring
- Similarly, the presence of significant LVH on echocardiography, with normal clinical BP recordings, mandates ambulatory BP monitoring, to detect masked HTN
- In patients with known or suspected concomitant heart disease in whom the heart disease itself needs further evaluation or in whom the type of heart disease might suggest a particular form of antihypertensive therapy. As an example, an angiotensin-converting enzyme inhibitor or angiotensin receptor blocker would be preferred in a patient with systolic dysfunction or mitral regurgitation
- In patients who have a bundle branch block on ECG.

In contrast, performance of an echocardiography for the purpose of measuring LV mass is not recommended for the selection of antihypertensive therapy or for the assessment of LV mass in patients without adequate BP control.[2]

The European Society of Cardiology HTN guidelines in 2013 mention echocardiography as the second approach after routine history, clinical examination, and laboratory tests. Echocardiography detects LVH, left atrial (LA) dilatation, or associated heart diseases (Class IIb). Canadian HTN Education Programme in 2014 suggested echo evaluation in selected patients with HTN. Echo is not routinely indicated in all hypertensive patients [Table 1 and Figure 2]. If cardiac failure or coronary disease is suspected clinically, LV mass, systolic and diastolic function should be assessed by echo.[2]
**Figure 1:** Staging of hypertensive heart disease

- **Degree I:**
  - LV diastolic dysfunction
  - No LV hypertrophy

- **Degree II:**
  - LV diastolic dysfunction and
  - LV hypertrophy

- **Degree III:**
  - Clinical heart failure with
  - Preserved LV ejection fraction

- **Degree IV:**
  - Eccentric LV hypertrophy
  - Reduced LV ejection fraction

LV = left ventricular.

**Figure 2:** Clinical flow chart for echocardiographic evaluation in hypertension

- **SYMPTOMS**
  - DYSPNEA, CHEST PAIN, CHANGE IN SYMPTOMS, SWELLING OF FEET

- **PHYSICAL EXAMINATION**

- **EDEMA, MURMUR**

- **CXR, ECG**

- **CXR ABNORMALITIES**
  - (CARDIOMEGALY, PULMONARY EDEMA, PLEURAL EFFUSION)

- **ECG ABNORMALITIES**
  - (LVH, LAE, RVH, RAE, LBBB, Q WAVES, ATRIAL FIBRILLATION)

- **ECHOCARDIOGRAPHIC EVALUATION**
Echocardiographic Evaluations

LV Mass\(^{(3)}\)

Echo is more sensitive than ECG for the assessment of LVH. Echo helps in cardiovascular risk assessment and in selection of proper antihypertensive treatment [Figures 3-5]. LV mass can be measured with the equation from the American Society of Echocardiography, using two-dimensional (2D) linear LV measurements [Figure 6].

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

(LVIDD-LV internal diameter - end diastole, PWTd posterior wall thickness - end diastole, and SWTd Interventricular septal wall thickness - end diastole). Small variations in calculation can cause significant changes in values. Relative wall thickness (RWT), measured as \((2 \times \text{PWTd})/\text{LVIDd}\), classifies LVH into concentric type (RWT > 0.42) or eccentric type (RWT < 0.42). Cutoff levels of LV mass, suggesting LVH – are 125 g/m\(^{2}\) in men and 110 g/m\(^{2}\) in women.\(^{(5)}\) Concentric hypertrophy correlated with mortality risk for patients with suspicion of coronary artery disease (CAD). Three-dimensional (3D) echocardiographic assessment of LV mass correlated well with magnetic resonance imaging (MRI).

LV Systolic Function

Ejection fraction (EF) can be assessed with modified Simpson’s method. Normal EF is >55%. Echo suggests evidence of CAD along with the assessment of LV function. 3D echo measurement has advantages for calculation of LV volumes in patients with regional wall motion abnormalities (RWMA) or LV aneurysms. 3D echo correlates well with MRI assessment. 3D echo has significant reproducibility. Tissue Doppler imaging (TDI) assesses mitral annular movement. Mitral annular velocity is less in HTN with normal EF. Hence, it predicts subclinical LV systolic dysfunction. Myocardial function assessment by strain echo has advantages over routine LVEF measurement by echo. Global and regional myocardial functions are well assessed. 2D speckle tracking echo assesses myocardial deformation by tracking of natural acoustic markers formed between ultrasound and myocardium. These markers are described as speckles. Angle independent and multidirectional (longitudinal, radial, and circumferential) strain values can be derived. Inter- and intra-observer variability with 2D strain echo is much less than

<table>
<thead>
<tr>
<th>Table 1: Clinical indications for echocardiography in hypertension</th>
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<td><strong>Management of hypertension</strong></td>
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<td>Suspected heart failure</td>
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<td>Suspected coronary artery disease</td>
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RAE: Right atrial enlargement, LAE: Left atrial enlargement, LVH: Left ventricular hypertrophy, RVH: Right ventricular hypertrophy, ECG: Electrocardiogram, LBBB: Left bundle branch block

Figure 3: Effect of LVH on incidence of sudden cardiac death

Figure 4: Effect of LV mass on cardiovascular events

Figure 5: Comparative efficacy of antihypertensive drugs to reduce LV mass
tissue Doppler assessment. Subclinical target organ damage can be assessed early. Longitudinal strain is less in patients with HTN, having normal LV systolic function, and it correlates with serum tissue inhibitor of matrix metalloproteinase-1 value, a biomarker for myocardial fibrosis.

3D strain echocardiography can assess the motion of myocardial speckles. Assessment of the whole LV from a single volume data can be done with 3D strain echocardiography.\(^\text{[2]}\)

**LV Diastolic Function [Table 2]\(^\text{[2]}\)**

Echocardiography assesses LV diastolic function. LV filling pressure is estimated. Increased LA size and volume suggest increased LV filling pressure. Increased LA diameter was seen in 20% of hypertensive patients. Enlarged LA indicates elevated LV filling pressure and increased LA size and volume correlate with morbidity and mortality.

Mitral inflow pattern assessed by pulsed-wave Doppler technique estimates diastolic dysfunction. Isovolumetric relaxation time, ratio of E and A velocities, deceleration time of E velocity, and duration of A wave can be used to assess diastolic dysfunction. However, these velocities can be influenced by multiple factors including age, heart rate and rhythm, cardiac output, mitral annular size, and LA function.

Mitral annular velocity can be assessed by pulsed-wave Doppler of mitral annulus from TDI [Figure 7].

The ratio E/\(e')\ can be a good indicator of LA pressure and it is the most feasible marker for estimation of LA filling pressure. This ratio correlates well with LA filling pressure. If E/\(e')\ is <8 correlation is better. Ratio >15 indicates elevated LA filling pressure.

E/\(e')\ ratio may not always correlate with LA filling pressure. In patients with systolic heart failure, there is poor correlation. In patients with tachycardia, valvular heart disease, and left bundle branch block, the ratio may be inaccurate.

Diastolic stress echo with exercise stress identifies hemodynamic effects of exercise-induced rise in diastolic filling pressure, as a non-invasive method. Subclinical diastolic dysfunction can be diagnosed in patients having dyspnea.

**LA Assessment**

LA enlargement is seen in systemic HTN, in the absence of valvular heart disease, and it is usually seen along with obesity, LVH, and metabolic syndrome. The LA size is measured with parasternal long axis view – end systole at its maximum dimension, avoiding foreshortening. Normal value is 2.7–3.8 cm in female and 3.0–4.0 cm in male.\(^\text{[2]}\)

LA volume is measured by 2D echo [Figure 8]. Normal value is <28 ml/m\(^2\) and enlarged LA predicts prognosis. Rise in LA size and volume indicates diastolic dysfunction in HTN and suggests morbidity and mortality. Volume >34 ml/m\(^2\) marks poor prognosis predicting death, heart failure, atrial fibrillation (AF), and ischemic stroke. LA volume does not change fast with treatment, it is not a good marker of treatment response.

LA strain with strain rate identifies subclinical dysfunction of atria in HTN.

LA appendage function provides clue of LA function. Reduced function is seen in non-dipper than dipper patients with HTN. 3D echo also measures size and function of LA.

**Associated EchoCharacteristics in HTN\(^\text{[4]}\)**

Secondary pulmonary artery pressure (PAH) occurs due to raised LA pressure being transmitted into pulmonary vasculature. Heart failure with preserved left ventricular ejection fraction leads to PAH. Echo measures pulmonary artery pressure
Table 2: Echo parameters for LV Diastolic function (Based on European Society of Cardiology guidelines)\(^5\)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Abnormal value</th>
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<td>LV mass index (g/m(^2))</td>
<td>&gt;95 in women, &gt;115 in men</td>
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<tr>
<td>Relative wall thickness (RWT)</td>
<td>&gt;0.42</td>
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**Diastolic function**

- Septal e’ velocity (cm/s) <8
- Lateral e’ velocity (cm/s) <10
- LA volume index (ml/m\(^2\)) ≥34

**LV filling pressures**

- E/e’ (averaged) ratio >13

LA: Left atrium, LV: Left ventricle, RWS: Relative wall thickness

stenosis or sclerosis may be found. RWMA or LV aneurysm may be found in CAD patients. Stress echo by dobutamine or exercise is more sensitive for CAD. Ascending aorta dilatation is seen along with increased arterial stiffness and LV mass, in about 17% of patients with HTN. Aortic valve calcification is a common finding, suggesting atherosclerosis. Aortic valve sclerosis predicts clinical events.

**Dipper and Non-dipper BP**

BP reduction at night time <10% suggests non-dipper pattern of BP. Non-dipper BP pattern is usually seen with high LV mass, reduced LV and RV function. Hence, it predicts cardiovascular events.

**Stress Echocardiography**

LVH leads to false-positive results in exercise tests by ECG or single-photon emission computed tomography. It does not change the results of stress echo. Exercise echo is thus a better method to diagnose CAD in patients with HTN.\(^6\)

**Acute Chest Pain and HTN**\(^6\)

In the setting of equivocal ECG changes and negative biomarker, echo evidence of RWMA indicates acute coronary syndrome (ACS). No RWMA by echo rules out significant ACS and points toward HTN as a cause of chest pain. HTN raises intracavitary end-diastolic pressures, which compresses the subendocardial region, inducing ischemia resulting in chest pain, an effect exaggerated by the presence of LVH. Normalizing BP will lead to relief of chest pain and save unnecessary diagnostic workup for ACS in emergency. Bedside echo easily diagnoses aortic stenosis in the presence of chest pain and high BP may reveal dissection of aorta involving ascending aorta and its extent. In young hypertensive patients, echo can reveal coarctation of aorta or aortoarteritis.

**Arrhythmias and HTN**\(^6\)

Slow progression of HTN results in dilatation of LA. Large LA provides ripe situation for looping sinus rhythm within itself resulting in AF. The LV is increasingly dependent on atrial
contraction for adequate filling. Sudden onset of AF offsets this filling, leading not only to inadequate LV filling but also elevated LA pressure which transmits to pulmonary vasculature. Fibrotic area can act as a substrate for ectopic rhythm generation which results in chronic intractable AF and lead to clot formation with the risk of systemic embolization.

Excessive LVH causes smaller LV cavity with low stroke volume. It also leads to disorganization of the LV contraction of different layers. This can be measured by strain imaging. Excessive LVH results in different areas achieving peak contractions at different times. This mechanical dispersion can be measured by strain imaging. Evidence is emerging that dispersion beyond standard deviation can cause ventricular arrhythmias and sudden cardiac death (SCD). Prediction of subsets of such patients likely to develop ventricular fibrillation and SCD may be possible in future by the use of strain imaging echo technology.[6]

**Conclusion**

According to the most recent guidelines, initiation and monitoring of the response to the treatment of HTN are based on clinical findings. Echocardiography is the second-line approach in evaluating selected patients. It provides valuable assessment of cardiovascular risk at clinical and subclinical levels. Standard 2D and 3D echo techniques detect end-organ damage at clinical level. New techniques like strain imaging help to diagnose dysfunction at subclinical level. Early detection and treatment can prevent progression of hypertensive heart disease.

**References**