# The detection of left ventricular hypertrophy and diastolic dysfunction

**Norton GR**, MBBCh, PhD
Professor of Physiology, Faculty of Health Sciences, University of the Witwatersrand
**Correspondence to**: Gavin Norton, e-mail: gavin.norton@wits.ac.za
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## Introduction

All guidelines for the diagnosis and management of hypertension recommend that electrocardiographic (ECG) evidence of left ventricular hypertrophy (LVH) is sought for accurate risk assessment. The presence of ECG patterns that fulfill the criteria for LVH suggest a > 20% absolute 10-year risk of developing cardiovascular disease, and is a compelling indication for the use of antihypertensives that block the renin angiotensin system.[1] Many guidelines also suggest that an echocardiogram is performed to confirm or refute the presence of LVH suggested by ECG criteria. However, in South Africa, access to echocardiography is costly and limited. However, echocardiography may be a critically important tool in the care of the hypertensive patient with LVH who presents with dyspnoea, when the cause is not obvious. These patients may have heart failure caused by diastolic dysfunction.

A major cardiovascular consequence of LVH in hypertension is progression to heart failure, in part through the effects on diastolic, rather than systolic (pump), function.[2] In these cases, the LV develops an inability to relax adequately, or a reduced compliance (increased stiffness) occurs. Consequently, this increases filling pressures in the left ventricle (LV) and left atrium (LA). These patients have heart failure with a preserved pump function, as indexed by a normal ejection fraction (EF) (HFpEF). In contrast to patients with heart failure with a reduced EF (HFrEF) who have an attenuated pump function that is easily detected by using a number of approaches, the presence of HFpEF often poses a considerable diagnostic challenge.

## Recognising heart failure in the primary care setting

While clinical signs, symptoms and abnormalities noted on a chest X-ray are specific features of heart failure, they are very insensitive.[3,4] Thus, although the presence of these clinical features indicate a heart failure diagnosis, their absence does not preclude the presence of heart failure. Identifying the presence of LVH, Q waves, left bundle branch block, atrial fibrillation and ST and T wave abnormalities on ECG are sensitive methods of detecting the presence of heart failure.[3] However, these ECG changes are not specific,[3] and their presence rather suggests that further investigation is required. Circulating brain natriuretic peptide (BNP) concentrations, a substance released from the heart when filling pressures in the LV increase, may assist with the diagnosis of heart failure. A BNP concentration < 100 pg/ml will rule out heart failure, while a BNP concentration > 400 pg/ml confirms a heart failure diagnosis.[4] These thresholds will differ according to geographic region, whether N terminal pro-brain natriuretic peptide (NT-proBNP) or BNP is being used, and a number of other factors. (Consult your own laboratory for appropriate thresholds.) However, when BNP concentrations lie in the grey zone (100-400 pg/ml in the consensus document),[4] echocardiography is required to make a diagnosis.

## Recognising heart failure caused by diastolic dysfunction

On echocardiography, the presence of a reduced EF (< 50%), together with a dilated ventricle (> 97 ml/m$^2$) in a patient with dyspnoea is likely to indicate HFrEF. Furthermore, a multitude of anatomical defects (e.g. valve abnormalities, pericardial abnormalities, and a thick-walled septum in hypertrophic cardiomyopathy) may indicate a cause of heart failure. However, if EF is preserved (> 50%), if the LV volume is < 76 ml/m$^2$ and no obvious anatomical defects are noted, a diagnosis of HFpEF should be considered.

To make this diagnosis, noninvasive approaches to detect LV diastolic dysfunction have been proposed as follows:[5,6]

Firstly, using Doppler imaging, the velocity of blood flow across the mitral valve in early diastole (E wave) before atrial contraction (see Figure 1) is measured. This velocity is determined by left atrial driving pressure and LV relaxation. As shown in the figure, the velocity is normally high during this phase, as this is when most LV filling occurs. In contrast, the velocity during atrial contraction (A wave) is much lower, as only a minor portion of LV filling is usually determined by atrial contraction.

Secondly, using tissue Doppler imaging (TDI), the velocity of tissue movement (lengthening) in the myocardium next to the mitral annulus (lateral and septal wall) during early diastole (e' wave) (see Figure 1) is measured. This velocity is determined by LV relaxation, and not by left atrial driving pressures.

Thirdly, from the above measurements, E/e' is calculated, which represents the effects of left atrial driving force independent of LV relaxation. The value is closely related to the measurements of left atrial pressures, and hence represents filling pressures in the left side of the heart. If there is left heart failure, this value will be raised. As summarised in Table I, there are also clear upper and lower values or E/e'[5,7] whereby a diagnosis of heart failure can be made or excluded with relative certainty. However, there is also a grey zone for E/e'. If E/e' lies between 8-15, additional tests may be performed, or considerations taken into account (Table II).

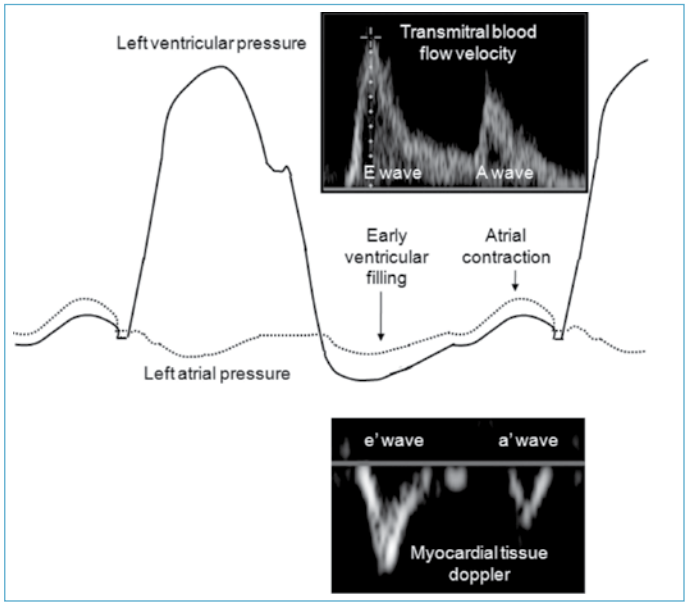


**Figure 1**: Relationship between the cardiac cycle and the velocity of blood flow across the mitral valve in the early (E wave) and the late (atrial) (A wave) periods of diastole, as well as the velocity of tissue lengthening in the lateral wall of the left ventricle next to the mitral annulus in the early (e' wave) and the late (atrial) (a' wave) periods of diastole

**Table I**: Sensitivity and specificity of echocardiographic measurements that may be employed to diagnose heart failure with a preserved pump function in patients with dyspnoea, without obvious clinical evidence of heart failure, and who have an E/e' that lies in the grey zone (> 8 and < 15)[7]

| Measurement | Sensitivity[a] | Specificity[a] |
|---|---|---|
| BNP > 200 pg/ml or NT-proBNP > 220 pg/ml | 38% | 94% |
| Left atrial volume index > 40 ml/m$^2$ | 30% | 94% |
| Left atrial volume index ≥ 34 ml/m$^2$ | 49% | 81% |
| LV mass index > 122 g/m$^2$ for women and > 149 g/m$^2$ for men | 33% | 94% |
| Ard-Ad[b] > 30 milliseconds | 33% | 92% |
| E/A[c] < 0.5 and E wave deceleration time > 280 milliseconds | 7% | 100% |

a = The higher the sensitivity, the more likely that the absence of these changes will exclude the possibility of heart failure, while the higher the specificity, the more likely the chances are that the presence of these changes will truly reflect the presence of heart failure; b = Difference between the duration of reverse pulmonary vein atrial systolic flow and the duration of the A wave; c = Ratio of transmitral blood flow velocities during early (E) and late (atrial-A) left ventricular filling

## Additional measures to assist with identifying diastolic heart failure

BNP > 200 pg/ml or NT-proBNP > 220 pg/ml have been suggested as being useful in contributing toward a diagnosis decision of HFpEF.[5] The lower thresholds for circulating BNP concentrations in HFpEF, as compared to heart failure, are because it is now recognised that HFpEF produces increases in circulating BNP concentrations that are not as high as those noted in patients with HFrEF.[4] Although the specificity of BNP concentrations for the diagnosis of HFpEF is high, the sensitivity is very low (Table I).[7]

A left atrial volume index (LAVI) > 40 ml/m$^2$[2,5,6] is a highly specific index of heart failure (Table I).[7] In this regard, the increased filling pressures in the LA cause the LA to dilate. However, the sensitivity of the threshold of LAVI for the diagnosis of heart failure is low (Table I).[7] Nevertheless, a value of ≥ 34 ml/m$^2$ provides a better sensitivity (Table I).[7]

An increased LV mass indexed to body surface area (> 122 g/m$^2$ for women and > 149 g/m$^2$ for men) is a highly specific index of the presence of HFpEF (Table I).[7] However, again the sensitivity for diagnosing HFpEF is low (Table I).[7]

**Table II**: Decisions to be taken based on the ratio of the velocity of blood flow across the mitral valve in early diastole (E wave) to the velocity of tissue movement in the myocardium, next to the mitral annulus, during early diastole (e' wave), obtained using tissue Doppler imaging (TDI) (E/e') (see Figure 1). Sensitivity and specificity values are provided.[7]

| Position of TDI[a] | E/e' value | Decision | Sensitivity[b] | Specificity[b] |
|---|---|---|---|---|
| Septal and lateral wall | > 15 | Heart failure[5,6] | 36% | 96% |
| Lateral wall | > 12 | Heart failure[7] | 56% | 94% |
| Septal and lateral wall | < 8 | Heart failure excluded[5,6] | | |
| Septal and lateral wall | > 8 and < 15 | Requires additional measures (see Table I) | | |

a = tissue Doppler imaging; b = the higher the sensitivity, the more likely that the absence of these changes will exclude the possibility of heart failure, while the higher the specificity, the more likely the chances are that the presence of these changes will truly reflect the presence of heart failure

A difference between the duration of reverse pulmonary venous flow during atrial systole and the duration of the A wave (Ard-Ad) of > 30 ms[5,6] is also a highly specific index of the presence of HFpEF (Table I).[7] To understand this index, it is important to remember that there are no valves between the pulmonary veins and the LA. Consequently, when the LA contracts (which generates the transmitral A wave), a small amount of blood will flow backward from the atrium to the pulmonary veins (reverse flow). If the volumes in the LA are high, such as when filling pressures in the LV are elevated, then there will be more reverse flow, which occurs for a longer period. As with other indexes of HFpEF, the sensitivity for diagnosing HFpEF from Ard-Ad is low (Table I).[7]

A value for the ratio of early-to-late (atrial) transmitral velocity (E/A) < 0.5 and a E wave deceleration time > 280 milliseconds is a highly specific diagnostic, criterion,[5,6] but with a high chance of missing the presence of HFpEF (very low sensitivity) (Table I).[7] Normally, most filling of the LV occurs during early diastole, and hence the velocity of blood flow across the mitral valve is highest in early (E), as opposed to late (atrial-A) diastole (see Figure 1).

Thus E/A is normally > 1.0. When relaxation of the ventricle decreases, ventricular filling will rely more heavily on atrial contraction. Hence, transmitral blood flow will decrease in early, and increase in late, diastole, and E/A will decrease, producing E/A values often < 0.5. However, as diastolic function decreases, relaxation is not the only factor that restricts LV filling. Indeed, LV stiffness increases, which limits the ability of the ventricle to fill in late diastole. Consequently, more filling begins to occur in early diastole, and the E/A ratio may return to normal. This is called pseudonormalisation, and is the main reason why the use of E/A is very insensitive as a diagnostic criteria for HFpEF (Table I).

## Conclusion

Patients with hypertensive LVH and HFpEF may frequently present with dyspnoea, where specific clinical symptoms and signs of heart failure are not detected, and circulating BNP concentrations lie in the grey zone. In these patients, pump function as assessed from EF will be normal, and the diagnosis of heart failure requires the identification of diastolic dysfunction. In this regard, E/e', a measure of left atrial pressures (filling pressures) may be elevated. However, E/e' may also have a grey zone. To diagnose HFpEF when E/e' is in the grey zone, increases in left atrial volume, left ventricular mass, the extent of reverse pulmonary venous flow, and BNP concentrations with lower thresholds are required, or the characteristics of the transmitral blood flow velocity during early filling must change. Although all of these measures have a high specificity for diagnosis, none are sensitive measurements.

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