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# Echocardiography in heart failure

*A guide for general practice*

## Background

Echocardiography is an essential investigation in patients with suspected heart failure. An echocardiogram provides assessment of cardiac chamber size and structure, ventricular function, valvular function and key haemodynamic parameters.

## Objective

This article explains the principles of echocardiography and how general practitioners can use echocardiograms to manage patients with heart failure.

## Discussion

Echocardiography can provide diagnostic information about the cause of heart failure, and may indicate what further investigations are required and what therapy is indicated. It may also provide important prognostic information. It can be used for noninvasive quantitative monitoring. Identification of impaired systolic function is important as there is evidence based therapy which can improve prognosis in this condition.

**Keywords:** heart diseases; heart failure; echocardiography



Heart failure is the inability of the heart to provide sufficient cardiac output for the body's needs without an increase in filling pressures. Heart failure can be difficult to diagnose as the symptoms and signs can be nonspecific – it is important to confirm a clinical diagnosis by demonstrating cardiac dysfunction.

All major heart failure guidelines, including the Australian guidelines developed by the National Heart Foundation and Cardiac Society of Australia & New Zealand, recommend echocardiography as an essential first line investigation in the evaluation of suspected heart failure.<sup>1</sup> Retrospective studies suggest that patients with a clinical diagnosis of heart failure who have had an echocardiogram have a better outcome than those who have not, presumably due to more appropriate evidence based management.<sup>2</sup> This article will discuss why assessment of cardiac structure and function is critical in evaluating heart failure, the specific information gained from an echocardiogram and how to interpret an echocardiogram report. It will concentrate on the use of transthoracic echocardiography as this is typically the first line investigation with transoesophageal echocardiography reserved for specific situations.

In Australia, ischaemic heart disease accounts for about 50% of patients with heart failure.<sup>1</sup> Other common causes include hypertension and dilated cardiomyopathy. Underlying valvular heart disease and pericardial disease are less common but important as they may be amenable to surgical treatment. Less common but identifiable by echocardiogram are hypertrophic cardiomyopathy, a cause of left heart failure and pulmonary hypertension, a cause of right heart failure (*Table 1*).

Previously left ventricular failure was considered a disease of reduced left ventricular systolic function. However, recent studies suggest up to 50% occur in the setting of a normal ejection fraction, particularly in the elderly. This is thought to be partly due to impaired cardiac filling, with similar symptoms to systolic dysfunction. Traditionally called diastolic heart failure, evidence for subtle abnormalities of systolic contraction means 'heart failure with normal ejection fraction' (HFNEF) is the preferred term.



**Table 1. Important causes of heart failure with reduced and normal ejection fraction**

Reduced ejection fraction	Normal ejection fraction
<ul style="list-style-type: none"> <li>• Coronary artery disease</li> </ul>	<ul style="list-style-type: none"> <li>• Hypertension</li> </ul>
<ul style="list-style-type: none"> <li>• Hypertension</li> </ul>	<ul style="list-style-type: none"> <li>• Coronary artery disease</li> </ul>
<ul style="list-style-type: none"> <li>• Dilated cardiomyopathy               <ul style="list-style-type: none"> <li>– idiopathic</li> <li>– familial</li> <li>– toxic (drugs, alcohol)</li> <li>– metabolic (thyroid abnormalities)</li> <li>– myocarditis</li> <li>– peripartum</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Valvular heart disease</li> <li>• Hypertrophic cardiomyopathy</li> <li>• Restrictive cardiomyopathy               <ul style="list-style-type: none"> <li>– amyloidosis</li> <li>– iron deposition</li> </ul> </li> <li>• Infiltrative cardiomyopathy               <ul style="list-style-type: none"> <li>– amyloidosis</li> <li>– iron deposition</li> </ul> </li> <li>• Constrictive pericarditis</li> </ul>
<ul style="list-style-type: none"> <li>• Valvular heart disease</li> </ul>	

## Principles of clinical cardiac ultrasound

Echocardiography uses ultrasound in the 2–7 MHz range to provide detailed information about the structure and function of the heart. Ultrasound machines have become smaller, more portable and with improved image quality, permitting easier use within the community. The major ultrasound modalities used are M-mode, two dimensional (Figure 1) spectral Doppler and colour Doppler echocardiography (Figure 2). Using traditional ‘grey scale’ two dimensional ultrasound, cardiac chambers and major blood vessels can be measured. Left ventricular wall thickness and mass can be estimated to document the presence of left ventricular hypertrophy. Function of the left and right ventricles and motion of cardiac valves may be assessed in real time. The integration of Doppler ultrasound techniques allows additional information from estimation of blood flow velocities within the heart. Doppler ultrasound relies on the shift in sound frequency that occurs when a sound wave is reflected from a moving object, such as a red blood cell, and provides information about the direction and velocity of blood flow.

Doppler ultrasound can be used to make quantitative haemodynamic measurements such as cardiac stroke volume and output, and to quantify the severity of valvular lesions. Doppler echocardiography may be used to estimate intracardiac pressures such as the pulmonary artery systolic pressure (which can become elevated in response to heart failure). Colour Doppler, in which blood flow velocities are represented on a two dimensional image by different colours, can be useful to demonstrate patterns of flow and is particularly useful for valvular regurgitation (Figure 2).

Windows available for ultrasound evaluation of the heart within the thorax are limited and vary between individuals. Air within the lungs conducts ultrasound poorly, ribs may obscure views of the heart and body habitus can affect the quality of images. However, echocardiography should still be ordered as image quality is often adequate for assessment, or may be enhanced with intravenous contrast agents.

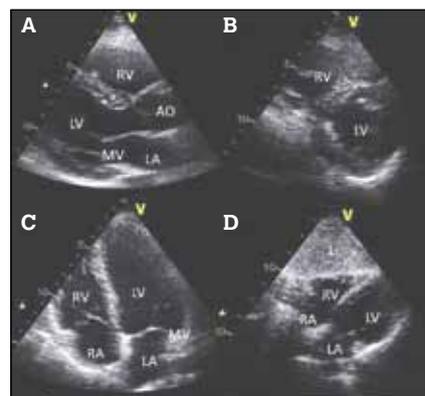


Figure 1. Common two dimensional echocardiographic views of the heart. A) Parasternal long axis view; B) Parasternal short axis view; C) Apical four chamber view; D) Subcostal view. LV = left ventricle, LA = left atrium, RV = right ventricle, RA = right atrium, MV = mitral valve, AO = aorta, Li = liver

## Assessment

### Left ventricular systolic function

One of the critical pieces of information to be gained from an echocardiogram is whether left ventricular systolic function is normal or reduced (Figure 3). When systolic function is reduced, proven heart failure therapies such as angiotensin converting enzyme inhibitors (ACEIs) and beta blockers improve cardiac symptoms and prognosis.<sup>1</sup> The degree of reduction in systolic function provides prognostic information – lower left ventricular ejection fraction (LVEF) is associated with worse prognosis. The degree of systolic dysfunction can determine additional therapies – for example, an implantable defibrillator (AICD) is recommended if the LVEF is below 35%.<sup>3</sup> In contrast, the evidence for treatment in HFNEF where LVEF is normal is unclear and no specific pharmacologic therapy has been shown to improve mortality, although candesartan may reduce hospitalisations.<sup>4</sup> The pattern of diastolic filling contributes to the severity of symptoms in heart failure in both systolic heart failure and HFNEF and provides incremental prognostic information<sup>5</sup> as discussed below.

Systolic function may be assessed using a number of methods. LVEF is the most widely used quantitative measure of systolic function, and measures what fraction of the left ventricular diastolic blood volume is ejected during each cardiac cycle. The normal LVEF is 50–70% and a LVEF below 50% reflects reduced systolic function. Current practice uses two dimensional measurement to calculate LVEF with the Simpson’s Biplane method; tracing the endocardial border at end diastole and end systole to estimate left ventricle (LV) volumes and LVEF. If adequate tracing of the endocardium is impossible, a visually estimated LVEF may be reported, although the accuracy is highly operator dependent. Three dimensional echocardiography provides more reproducible quantification of LVEF but is not available on all echocardiographs.

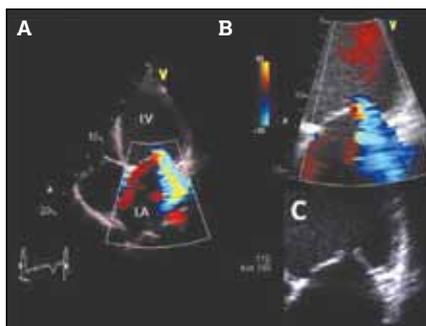


Figure 2. Secondary mitral regurgitation in dilated cardiomyopathy demonstrated using colour Doppler. A) Coloured jet of mitral regurgitation into the LA. The mitral regurgitation; (B) occurs because LV enlargement restricts the mitral leaflets from closing completely during systole (C)

Segmental (or regional) variation in wall thickening is suggestive of underlying coronary artery disease, and areas of thinning are commonly seen at the site of previous myocardial infarction (Figure 3). Further evaluation including stress echocardiography or coronary angiography may be indicated. More global dysfunction should prompt a search for other causes of a dilated cardiomyopathy (Table 1). The detection of mural thrombus within the LV in the setting of regional or global systolic dysfunction is a strong indication for anticoagulation.

### Left ventricular diastolic function

Filling of the LV during diastole is a critical component of cardiac function independent of LVEF. It is influenced by left atrial (LA) pressure which drives filling and active LV relaxation which provides suction into the ventricle. In sinus rhythm, inflow through the mitral valve occurs in two phases; an early phase producing an E wave on Doppler examination and an atrial filling phase producing an A wave (Figure 4). Normally, the E wave is larger than the A wave so that their ratio is  $>1.0$ . An impaired relaxation pattern is a mild form of diastolic dysfunction. It indicates an abnormality of active, energy dependent LV relaxation and is associated with a decreased E/A wave ratio ( $<1.0$ ). However, this is a common finding in people over the age of 60 years due to age related reduction in LV relaxation.

The amplitude of the E wave is largely dependent on the efficiency of LV relaxation and the LA pressure. As relaxation worsens and LA pressure increases, a 'pseudonormal' pattern occurs, characterised by an E/A wave ratio between 1.0 and 2.0. This pattern can be differentiated from a normal diastolic filling pattern by the addition of tissue Doppler imaging, which directly measures the reduced relaxation of the myocardium. Severe diastolic dysfunction is

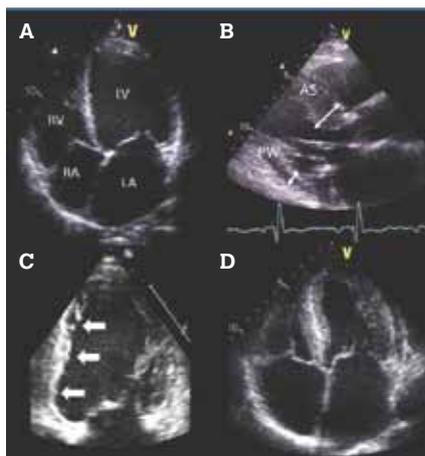


Figure 3. Possible causes of heart failure on echocardiography. A) Dilated cardiomyopathy with dilation of all cardiac chambers (2.5 cm markers on left). Left ventricular ejection fraction is reduced; B) Hypertrophic cardiomyopathy with normal left ventricular cavity size, but marked hypertrophy of the anterosseptum (AS) which is asymmetric compared to the posterior wall (PW), LVEF is preserved; C) The inferior wall (arrows) is thinned and bright due to scarring from previous infarction. LVEF is reduced; D) Marked increase in left ventricular wall thickness due to infiltration with amyloid protein in cardiac amyloidosis. The LA and RA are enlarged and LVEF may be normal or reduced

characterised by a restrictive filling pattern, with an elevated E/A wave ratio (typically  $>2.0$ ), and occurs in the setting of markedly reduced LV compliance and markedly elevated LA pressure. This pattern points to an adverse prognosis largely independent of the underlying LVEF.<sup>6</sup>

Several other parameters also suggest elevated LV filling pressures, including LA enlargement in response to chronically elevated LV filling pressures, and abnormalities of tissue Doppler imaging. In the setting of diastolic or systolic dysfunction, LV filling pressures can be approximated using a ratio of the E wave and the early diastolic motion of the mitral annulus (the E' wave, Figure 4). The E/E' ratio increases with increasing LA pressure and an E/E' ratio  $>15$  makes elevated LA pressure highly likely.<sup>7</sup> Elevated filling pressures leads to dyspnoea from pulmonary congestion.

### Valvular disease

Valvular heart disease is an important correctable cause of heart failure and may be a cause or consequence of abnormal ventricular function. Structural information about the four cardiac valves from two dimensional imaging includes thickening, calcification, restriction or redundancy

of valve leaflets. Doppler ultrasound is the predominant method to assess the severity of valve disease. Spectral Doppler, which assesses the direction and velocities of blood flow, can be used to quantify the severity of valvular stenosis or regurgitation. Blood travelling through a narrowed orifice, such as a stenotic aortic valve, must increase in velocity to maintain constant forward flow. The increase in blood velocity across the valve is used to calculate the pressure gradient across the valve, and the valve area. Colour flow imaging, by displaying patterns of blood flow superimposed on the normal grey scale image, aids in localising sites of turbulent flow or regurgitation (Figure 2). In the context of left ventricular enlargement or systolic dysfunction, quantitative evaluation of valvular pathology is important to establish whether chronic volume or pressure overload may be a contributing factor.

### Other cardiac findings associated with heart failure

Atrial fibrillation commonly coexists with heart failure. Echocardiography may identify underlying cardiac structural and functional abnormalities that may predispose to atrial fibrillation. Transthoracic echocardiography does not identify or exclude LA

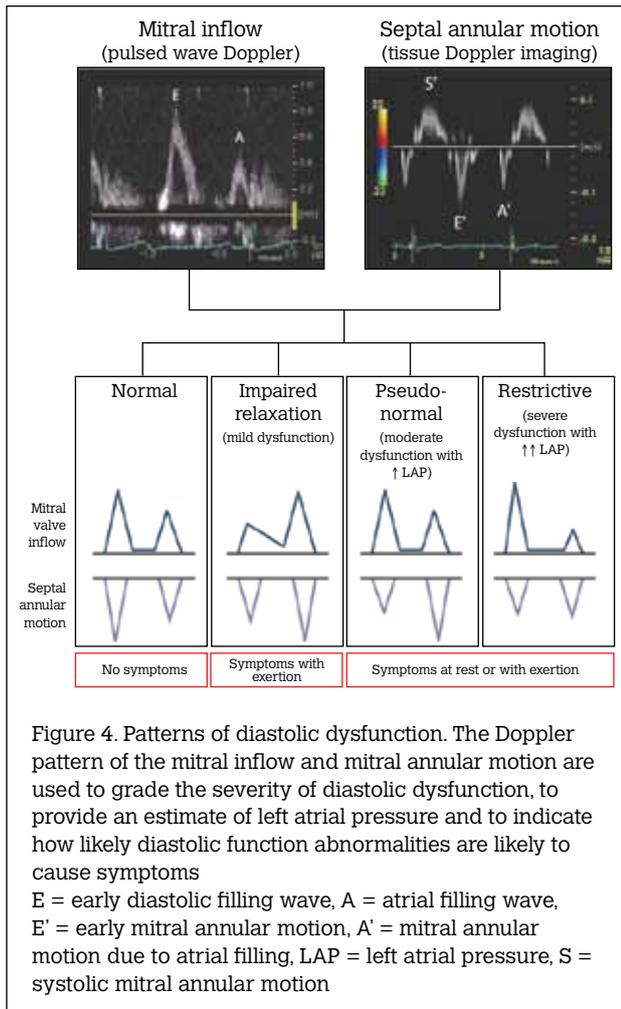


Figure 4. Patterns of diastolic dysfunction. The Doppler pattern of the mitral inflow and mitral annular motion are used to grade the severity of diastolic dysfunction, to provide an estimate of left atrial pressure and to indicate how likely diastolic function abnormalities are likely to cause symptoms  
 E = early diastolic filling wave, A = atrial filling wave, E' = early mitral annular motion, A' = mitral annular motion due to atrial filling, LAP = left atrial pressure, S = systolic mitral annular motion

thrombus in most cases because the left atrium is a structure in the far (low resolution) field of the echocardiogram. Echocardiography is able to identify other conditions which give rise to symptoms and signs of heart failure. The presence of a pericardial effusion can be seen on ultrasound and echocardiography can be used to assess the severity of the associated haemodynamic disturbance. The more chronic entity of constrictive pericarditis has characteristic echo features. In the context of right heart failure, echocardiography can identify pulmonary hypertension (secondary to pulmonary arterial disease or chronic lung disease). The right ventricular systolic pressure (RVSP) can be estimated by Doppler echocardiography, as can the effect of the elevated RVSP on the structure and function of the right ventricle.

### Interpreting an echocardiogram report

Despite the existence of guidelines for structured echocardiography reporting, reports come in many formats.<sup>8</sup> Most provide quantification of cardiac chamber size and function, key Doppler parameters of valve function and important haemodynamic parameters, often in tabular format. Figure 5 provides a sample echocardiogram report which also includes normal values. There is generally an interpretation of cardiac chamber structure and ventricular function, both systolic and diastolic,

valve structure and function and other important findings such as pericardial abnormalities. A summary of the clinically important findings will be provided with an interpretation in the context of the indication provided on the request form. It is important that the request contains sufficient clinical details to allow the echocardiographer to conduct and report the study to ensure the clinical question is addressed.

A 'technically difficult study' usually means that the patient was obese, had lung disease or was unable to cooperate fully so that some aspects of the examination may be unclear or unanswered. If a finding on a technically difficult examination does not fit with the clinical picture, it is useful to discuss this with the reporting clinician.

After ensuring the report concerns the correct patient, begin reading from the end summary to ensure the key clinical question has been answered. However, do not to stop here; go back to the body of the report to check it supports the conclusions. If the left ventricle is reported as enlarged, the chamber dimensions on M-mode should be greater than the normal range, allowing for patient size. If left ventricular hypertrophy is reported, the left ventricular wall thicknesses (septal and posterior) or left ventricular mass will be above the normal range. Left ventricular systolic function will usually be quantified by fractional shortening (M-mode) or LVEF, and impaired systolic function is a key clinical finding

<b>Name:</b> Patient name	<b>DOB:</b> 10/12/1950	<b>Date:</b> 08/10/2010	
<b>M-mode measurements</b>			
LV diastolic diam:	6.7 cm (N<5.7)	<b>2-D measurements</b>	
LV systolic diam:	5.2 cm	LVEF: 35% (N>50)	
Septum:	1.1 cm (N<1.1)	LVEF method: Biplane Simpson's	
Posterior wall:	1.0 cm (N<1.1)	LA area: 26 cm <sup>2</sup> (N≤20)	
Fractional shortening:	22% (N>26)	LAVI: 40 mL/m <sup>2</sup> (N<29)	
Left atrium:	4.8 cm (N<4.0)	RA area: 23 cm <sup>2</sup> (N<18)	
Aortic root:	3.2 cm (N<3.6)		
<b>Doppler measurements</b>			
<b>Doppler velocity (m/sec)</b>		<b>Valve gradients (mmHg)</b>	
Peak	Normal	Peak	Mean
Aortic:	1.0 (1.0-1.7)		
Pulmonary:	0.7 (0.6-0.9)		
Tricuspid:	E = 0.9 A = 0.3 (0.3-0.7)		
Mitral:	E = 0.9 A = 0.3 (0.6-1.3)		
Mitral decel time:	140 msec		
MV area:	cm <sup>2</sup>	RV pressure:	33 mmHg + RA
AR half time:	msec	RVSP:	43 mmHg (N<36)
AoV area:	cm <sup>2</sup>	E/E' septal:	16
<b>Indication:</b> ? heart failure			
<b>ECG:</b> Sinus rhythm			
<b>Left ventricle:</b> Mildly dilated left ventricle with moderate systolic dysfunction. The pattern is segmental with thinning and akinesis of all apical segments. No mural thrombus evident. The estimated LVEF = 35 ± 5%. Restrictive diastolic filling and an E/E' of 16 indicate elevated filling pressures			
<b>Right ventricle:</b> Normal right ventricular size and function			
<b>Left atrium:</b> Mildly dilated left atrium			
<b>Right atrium:</b> Mildly dilated right atrium. The inferior vena cava is not dilated			
<b>Aortic valve:</b> Normal trileaflet aortic valve which opens widely. No aortic regurgitation			
<b>Mitral valve:</b> The mitral valve leaflets are normal, however posterior leaflet closure is restricted by LV dilation. There is moderate mitral regurgitation which is directed posteriorly			
<b>Pulmonary valve:</b> Normal pulmonary valve with trivial regurgitation			
<b>Tricuspid valve:</b> Normal tricuspid leaflets with trivial regurgitation			
There is mild pulmonary hypertension with an estimated RV systolic pressure of 43 mmHg			
<b>Conclusion</b>			
1. Mildly dilated LV with moderate segmental systolic dysfunction. The presence of apical infarction is suggestive of underlying coronary disease			
2. Mild biatrial enlargement with features of elevated LA pressure			
3. Moderate functional MR due to LV enlargement			
4. Mild pulmonary hypertension			
Cardiologist			

Figure 5. Sample echocardiography report including normal values for important parameters  
 N = normal value, LV = left ventricular, LVEF = left ventricular ejection fraction, LA = left atrium, LAVI = left atrial volume index, RA = right atrium, MV = mitral valve, RV = right ventricular, RVSP = right ventricular systolic pressure, AR = aortic regurgitation, AoV = aortic valve



in heart failure. Left ventricular diastolic function will often be graded. It is uncommon to have clinically significant diastolic dysfunction without concomitant left atrial enlargement; a 'barometer' of long term trends in left atrial pressure. If diastolic function is abnormal but the left atrium is not enlarged consider other causes for the symptoms.

Sometimes there is no demonstrated specific cause for left ventricular systolic dysfunction. However, regional wall thinning, hypokinesis or akinesis are strongly suggestive of underlying coronary artery disease. When present, the degree of valvular dysfunction is usually quantified and the mechanism of dysfunction is determined if possible. Important supporting parameters are typically included such as valve gradient or valve area for aortic and mitral stenosis. In the context of significant mitral or tricuspid regurgitation the report should specify whether this is due to a valve leaflet problem or is secondary to chamber dilation (often seen with cardiomyopathies).

### Correlation of echocardiogram findings with symptoms

While an echocardiogram provides assessment of cardiac structure and function, consider whether abnormal findings identified on the study are the cause of the patient's symptoms. Symptoms of heart failure can occur at any LVEF and their severity correlates best with the degree of any associated diastolic dysfunction rather than the LVEF. However, significant

symptoms at rest are unusual in mild diastolic dysfunction prompting consideration of other causes for dyspnoea. Mild diastolic dysfunction may be associated with symptoms during activity and may require exercise testing to unmask them.<sup>9</sup> Similarly, mild valvular lesions are usually asymptomatic and should not be regarded as the cause of dyspnoea.

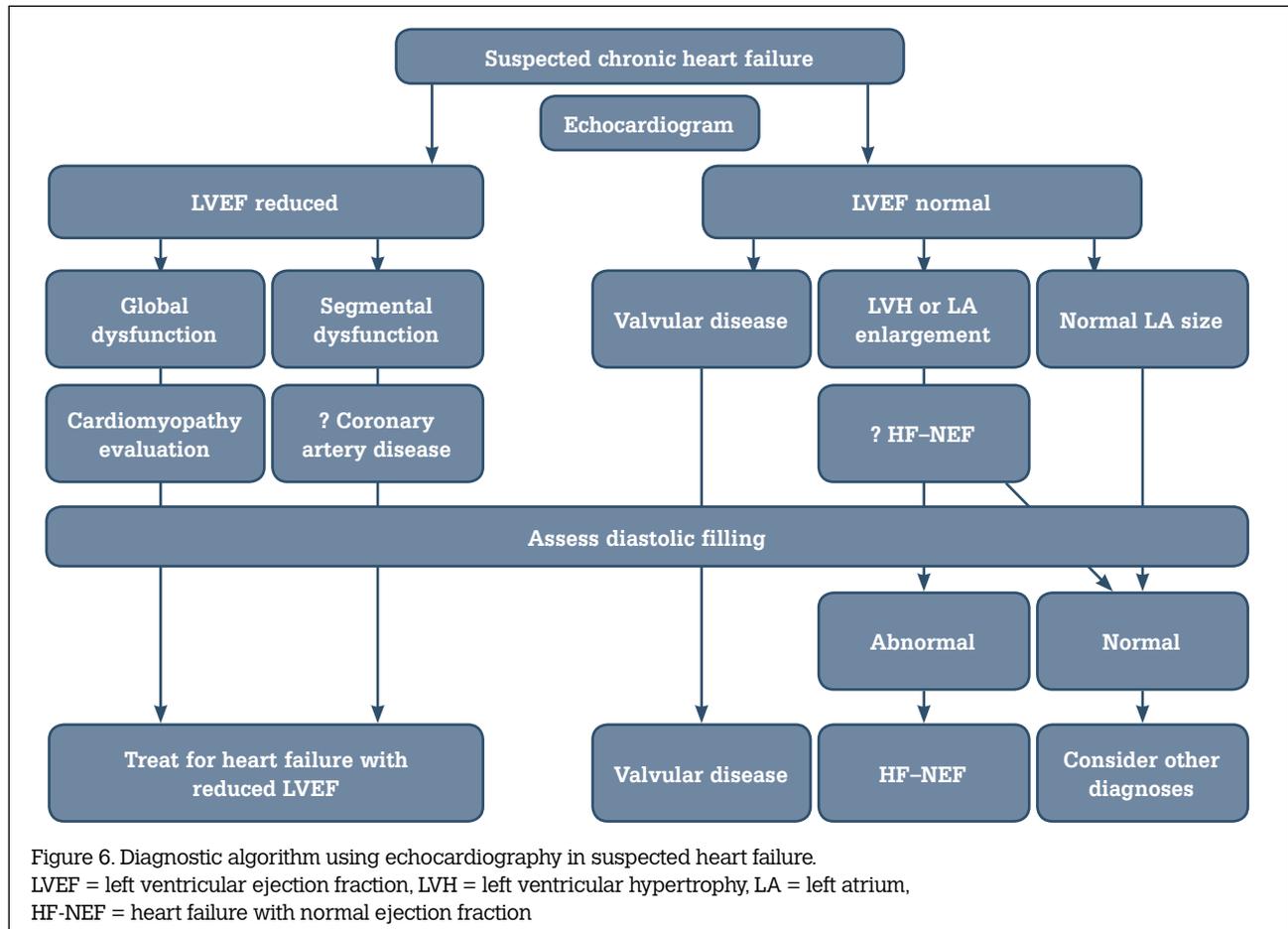
### How frequently should echocardiography be repeated?

Transthoracic echocardiography is mandatory in the initial assessment of suspected heart failure. Evidence suggests routine annual echocardiography is inappropriate to monitor heart failure or mild stenotic or regurgitant valve lesions unless symptoms or signs change.<sup>10</sup> If there is a significant change in the severity of symptoms, re-assessment of systolic, diastolic or valvular function is appropriate and moderate and severe lesions may require more frequent evaluation.

Routine assessment can be useful to measure the effect of changes in therapy on cardiac structure and function.

### Summary

Transthoracic echocardiography is recommended in all cases of suspected heart failure to confirm the clinical diagnosis, identify the aetiology and guide further investigation and therapy. Figure 6 shows a useful diagnostic algorithm in suspected heart failure. Important





findings include the presence or absence of left ventricular systolic dysfunction, the presence and severity of valvular dysfunction and key haemodynamic features such as diastolic filling patterns and pulmonary artery pressure.

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### References

1. Krum H, Jelinek MV, Stewart S, et al. Guidelines for the prevention, detection and management of people with chronic heart failure in Australia 2006. *Med J Aust* 2006;185:549–57.
2. Senni M, Rodeheffer RJ, Tribouilloy CM, et al. Use of echocardiography in the management of congestive heart failure in the community. *J Am Coll Cardiol* 1999;33:164–70.
3. Bardy GH, Lee KL, Mark DB, et al. Amiodarone or an implantable cardioverter-defibrillator for congestive heart failure. *N Engl J Med* 2005;352:225–37.
4. Yusuf S, Pfeffer MA, Swedberg K, et al. Effects of candesartan in patients with chronic heart failure and preserved left-ventricular ejection fraction: the CHARM-Preserved Trial. *Lancet* 2003;362:777–81.
5. Redfield MM, Jacobsen SJ, Burnett JC Jr, Mahoney DW, Bailey KR, Rodeheffer RJ. Burden of systolic and diastolic ventricular dysfunction in the community: appreciating the scope of the heart failure epidemic. *JAMA* 2003;289:194–202.
6. MeRGE collaborators. Independence of restrictive filling pattern and LV ejection fraction with mortality in heart failure: an individual patient meta-analysis. *Eur J Heart Fail* 2008;10:786–92.
7. Ommen SR, Nishimura RA, Appleton CP et al. Clinical utility of Doppler echocardiography and tissue Doppler imaging in the estimation of left ventricular filling pressures *Circulation* 2000;102:1788–94.
8. Gardin JM, Adams DB, Douglas PS, et al. Recommendations for a standardized report for adult transthoracic echocardiography: a report from the American Society of Echocardiography's Nomenclature and Standards Committee and Task Force for a Standardized Echocardiography Report. *J Am Soc Echocardiogr* 2002;15:275–90.
9. Burgess MI, Jenkins C, Sharman JE, Marwick TH. Diastolic stress echocardiography: hemodynamic validation and clinical significance of estimation of ventricular filling pressure with exercise. *J Am Coll Cardiol* 2006;47:1891–900.
10. TTE/TEE Appropriateness Criteria Writing Group, Douglas PS, Khandheria B, et al. ACCF/AHA/ACEP/ASNC/SCAI/SCCT/SCMR 2007 appropriateness criteria for transthoracic and transesophageal echocardiography: a report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group, American Society of Echocardiography, American College of Emergency Physicians, American Society of Nuclear Cardiology, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, and the Society for Cardiovascular Magnetic Resonance. Endorsed by the American College of Chest Physicians and the Society of Critical Care Medicine. *J Am Soc Echocardiogr* 2007;20:787–805.

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