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. 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. 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. 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

<table>
<thead>
<tr>
<th>Reduced ejection fraction</th>
<th>Normal ejection fraction</th>
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<tr>
<td>• Coronary artery disease</td>
<td>• Hypertension</td>
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<tr>
<td>• Hypertension</td>
<td>• Coronary artery disease</td>
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<tr>
<td>• Dilated cardiomyopathy</td>
<td>• Valvular heart disease</td>
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<td>– idiopathic</td>
<td>• Hypertrophic cardiomyopathy</td>
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<tr>
<td>– familial</td>
<td>• Restrictive cardiomyopathy</td>
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<tr>
<td>– toxic (drugs, alcohol)</td>
<td>• Infiltrative cardiomyopathy</td>
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<tr>
<td>– metabolic (thyroid abnormalities)</td>
<td>– amyloidosis</td>
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<tr>
<td>– myocarditis</td>
<td>– iron deposition</td>
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<tr>
<td>– peripartum</td>
<td>• Constrictive pericarditis</td>
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<tr>
<td>• Valvular heart disease</td>
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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.

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.1 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%.2 In contrast, the evidence for treatment in HFNHF where LVEF is normal is unclear and no specific pharmacologic therapy has been shown to improve mortality, although candesartan may reduce hospitalisations.3 The pattern of diastolic filling contributes to the severity of symptoms in heart failure in both systolic heart failure and HFNHF and provides incremental prognostic information4 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.
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 LV EF. 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 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 LV EF.

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. 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
Interpreting an echocardiogram report

Despite the existence of guidelines for structured echocardiography, interpreting an echocardiogram report involves understanding 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 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.

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.

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. 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 value lesions unless symptoms or signs change. 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

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**Figure 6. Diagnostic algorithm using echocardiography in suspected heart failure.**

LVEF = left ventricular ejection fraction, LVH = left ventricular hypertrophy, LA = left atrium, HF–NEF = heart failure with normal ejection fraction.
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.

Authors
David Prior MBBS, PhD, FRACP, is Director of Non-invasive Cardiac Imaging, Department of Cardiology, St Vincent’s Hospital, Melbourne, Victoria. david.prior@svhm.org.au

Jennifer Coller MBBS, FRACP, is Research Fellow, Department of Cardiology, St Vincent’s Hospital, Melbourne, Victoria.

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References


