Investigating the patient with cardiac failure

Each month we present authoritative advice on the investigation of a common clinical problem, specially commissioned for family doctors by the Board of Continuing Medical Education of the Royal Australasian College of Physicians.

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Cardiac failure is the pathophysiological state in which the heart is unable to pump blood at a rate commensurate with the requirements of the metabolising tissues or when it can do so only from an elevated filling pressure. Systolic heart failure results from a defect in expulsion of blood, whereas diastolic heart failure results from a defect in ventricular filling. Cardiac failure is a symptom complex, not a disease.

Management of cardiac failure includes early intervention and, if possible, therapy directed at the underlying condition, with the aims of controlling symptoms and, ultimately, prolonging life. The choice of investigations will depend on the clinical situation and the information being sought. This article will describe investigations that are helpful to:

- confirm the clinical diagnosis
- identify the underlying cardiac condition and precipitating factors
- monitor the patient's progress.

A list of key prognostic indicators that may be determined by appropriate investigation is given in the box on page 56.

Confirming the clinical diagnosis

A diagnosis of cardiac failure will generally be clinically obvious on the basis of a patient's history and examination. However, confusion may arise in the presence of airways disease, which can mimic the signs and symptoms of cardiac failure and can, of course, coexist with it.

Chest x-ray

Chest x-ray provides excellent contrast between the air-filled lungs and the adjacent soft tissue and osseous structures. It is the investigation of choice to confirm a clinical impression of cardiac failure.

Features of cardiac failure

Increases in pulmonary venous pressure from any

IN SUMMARY

- **A chest x-ray is the investigation of choice to confirm a clinical impression of cardiac failure.**
- **The cardiothoracic ratio is a valuable parameter for estimating the size of the heart. Echocardiography has become the investigative tool of choice for assessing the thickness and function of ventricular walls and the dimensions of individual chambers.**
- **Ageing has a greater impact on diastolic than systolic function, and diastolic cardiac failure becomes more common with increasing age.**
- **Measurement of plasma B-type natriuretic peptide (BNP) may prove to be the long awaited 'blood test' for the diagnosis and management of heart failure.**
- **Echocardiography is one of the few investigations that can enable an initial assessment of ventricular systolic and diastolic function to be made and provide helpful information for establishing the cause and determining prognosis.**
- **For a patient with known cardiac failure, serial monitoring of renal function and potassium is essential.**

cause (including left ventricular failure, mitral stenosis or vascular obstruction) will initially cause blood to be diverted to the upper lobes of the lungs when the patient is in the erect position. In patients without heart failure, the upper lobe vessels are smaller than the lower lobe vessels (on average, only two-thirds of the diameter). Interstitial oedema will occur if the venous pressure is elevated further, resulting in a typical honeycomb appearance that is most prominent at the bases and perihilar region. Alveolar oedema and, eventually, pleural effusions follow.

The radiological changes that are seen in cardiac failure are most marked in the bases and, unlike infective pulmonary changes, are symmetrical. However, if the patient has lain on one side for some time, the changes may become asymmetrical and be confused with infection.

Heart size

Overall heart size is best estimated by the cardiothoracic ratio, which is calculated using a chest film in the posterior, anterior view (Figure 1a). If the ratio is not reported, you should calculate it yourself by dividing the maximum cardiac transverse diameter by the maximum thoracic diameter at the inside edge of the rib margin. In a person without heart failure, the cardiothoracic ratio is normally 0.50 or less and tends to remain constant throughout his or her life.

Resting ECG

The resting ECG can be expected to reveal sinus tachycardia and, frequently, arrhythmias such as atrial fibrillation and ventricular or atrial ectopic beats. Other features may be noted, such as ventricular hypertrophy, ischaemic ST or T wave changes, evidence of previous infarction (Q waves or lack of R wave progression across the precordial leads), or a left bundle branch pattern.

Serum urea, creatinine and electrolyte levels

It is prudent to have a measurement of renal function prior to commencing therapy, both to help with the dosages of medications (such as digoxin and ACE inhibitors) and to monitor hydration over time. Generally, serum electrolyte levels should be normal; however, hyponatraemia may be noted in severe cardiac failure, often as a result of intensive diuretic therapy and rigid sodium restriction. Diuretic therapy may also cause hypokalaemia and hypomagnesaemia, both of which will aggravate pre-existing propensities to arrhythmias.

B-type natriuretic peptide levels

Measurement of plasma B-type natriuretic peptide (BNP) may prove to be the long awaited 'blood test' for the diagnosis and management of heart failure. (The peptide is also known as 'brain natriuretic peptide' because it was originally isolated from brain tissue.) The major storage sites of BNP are the cardiac ventricles, and release of the peptide appears to be directly proportional to ventricular volume expansion and pressure overload. The fact that the ventricles are the major source of plasma BNP suggests that it may be a better indicator of ventricular

Prognostic indicators in patients with cardiac failure

Overall prognosis of patients with cardiac failure has improved considerably with modern treatment. Selection of patients for maximal therapy implies an understanding of the prognostic indicators.

Ejection fraction

- An ejection fraction of more than 50% predicts better survival after acute myocardial infarction and better outcome after valve surgery for aortic and mitral regurgitation.
- An ejection fraction of more than 40% predicts better five-year event-free survival after coronary artery bypass grafting (80% *v.* 30%).
- An ejection fraction of more than 35% predicts improved mortality in cardiac failure (one-year all-cause mortality of 6% *v.* 11%).

Systolic function

Prognosis is better if the systolic function of the right ventricle is preserved relative to that of the left ventricle.

Left ventricular mass and thickness

Preservation of overall mass in cardiomyopathy is associated with an improved outlook.

Sinus rhythm

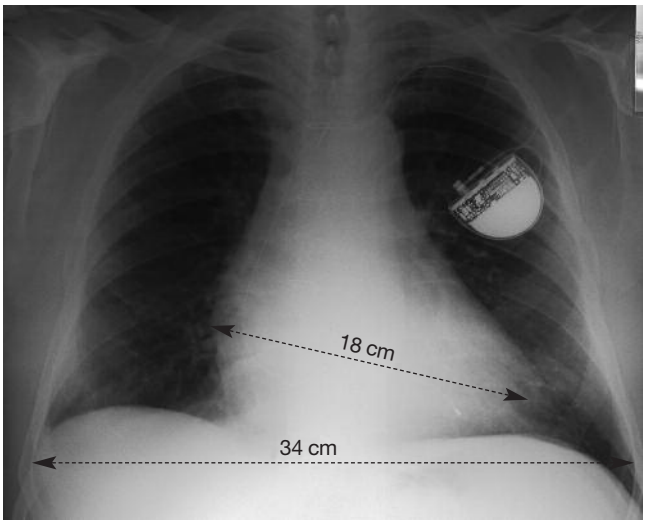
Atrial fibrillation, ventricular arrhythmias and heart block are associated with a poorer prognosis.

Heart size

Reduction in heart size over time is associated with an improved outlook.

Effort tolerance

Ability to perform at a level of at least six 'metabolic equivalents' (METs) on a Bruce protocol (with the patient not holding the handrail) or covering a distance of more than 300 m on a six-minute walking test is associated with a better prognosis in patients with ischaemic heart disease or heart failure. The use of METs is described in the box on page 58.



Figures 1a (above) and b (right). Chest x-rays taken of a 76-year-old man shown in the posterior–anterior (a) and lateral (b) views. The heart is enlarged in its transverse diameter and the cardiothoracic ratio is 0.53. Evidence of cardiac surgery (sternal wires) and a pacemaker *in situ* are visible, and the lung fields are clear.

disorders than other natriuretic peptides – the major storage sites of A-type natriuretic peptide, for example, include the atria and ventricles.

Pilot studies with a commercially available assay have found BNP to be a highly sensitive and specific indicator for heart failure. BNP levels do rise with age, possibly reflecting age-related decrease in ventricular compliance; however, at the level of 80 pg/mL the results show a clear difference between subjects with and without heart failure (98% sensitivity, 92% specificity). The BNP assay has been approved in the USA, and may prove to be an excellent screening tool for subsequent echocardiography, which is not always available and is more expensive.

Echocardiography

Echocardiography remains one of the few investigations that can enable an initial assessment of ventricular systolic and diastolic function to be made and provide helpful information for establishing the cause and determining prognosis. The procedure is readily available and cost effective, and an understanding of its potential will put a GP in a strong position to ask for specific information from the echocardiographer and result in a more useful report.

Systolic function can be measured quantitatively using various formulas, and is usually recorded as an ejection fraction or fractional shortening. A qualitative assessment can also be made and will give more accurate information about overall contraction in the presence of abnormalities of regional wall motion. Global hypokinesis generally indicates a dilated cardiomyopathy, but in the presence of ischaemic heart disease it would suggest multivessel disease. Abnormalities of regional wall motion in the absence of a left bundle branch pattern generally suggest an ischaemic cause.

In most cases, diastolic failure can be assessed accurately with echocardiography. The interpretation of echo reports for patients in whom diastolic dysfunction is suspected was discussed in the October 2001 issue of *Medicine Today*.[1]

Finding the cause

Finding the cause of heart failure involves identifying the underlying pathology (if possible) and then determining the precipitating factor for the current bout. Common underlying conditions are listed in the Table. Precipitating factors include:

- inappropriate reduction in diuretic and/or vasodilator therapy
- arrhythmias
- acute myocardial ischaemia

Table. Cardiac failure: common underlying pathologies

- Coronary artery disease
- Hypertension
- Diabetes
- Valvular heart disease (degenerative, rheumatic, congenital)
- Dilated cardiomyopathy (idiopathic, related to alcohol or substance abuse, myocarditis, familial, peripartum, amyloid, other)
- Hypertrophic cardiomyopathy

- systemic infection
- pulmonary embolism
- physical or emotional stress
- administration of salt-retaining drugs (for example, NSAIDs)
- development of an additional form of cardiac disease
- a high output state (such as anaemia, pregnancy or thyrotoxicosis).

Resting ECG

A resting electrocardiograph may show evidence of previous infarction or of chronic ongoing ischaemia by Q, ST and T wave changes. The underlying rhythm can be determined; occasionally, typical changes associated with drug toxicity or abnormal potassium levels may be noted. The ECG may be able to support a clinical impression of valvular disease, hypertrophic cardiomyopathy or pericardial disease.

Chest x-ray

Chest x-ray is a useful investigation in identifying individual chamber enlargement, although echocardiography has increasingly superseded this role. A careful look at the cardiac outline in both posterior–anterior and lateral views can often identify the enlarged chambers – the ventricles and left atrium can confidently be identified if they are enlarged significantly. An enlarged heart makes a diagnosis of cardiac failure more likely.

Calcification of cardiac structures also helps in the assessment. Coronary calcification has a typical tram track pattern. Calcification of the mitral or aortic valvular annulus – the fibroskeleton of the heart – represents a degenerative process that occurs particularly in women over the age of 40 years. Valvular calcification suggests the presence of haemodynamically significant stenosis. Aortic calcification, a curvilinear calcification near the lateral border, is common after the age of 50 years and is usually degenerative.

The presence of prosthetic heart valves or evidence of previous cardiac surgery revealed by radiography may also help in the assessment (Figures 1a and b).

Echocardiography

Echocardiography has become the investigative tool of choice for assessing the thickness and function of ventricular walls and the dimensions of individual chambers.

Valves can be assessed accurately by echocardiography – the method is a very sensitive way of detecting calcification, valvular vegetations, valvular stenosis and regurgitation, and of establishing whether the cause is rheumatic, congenital or degenerative. The presence of so-called functional mitral regurgitation, which will mask the severity of left ventricular dysfunction, should be assessed accurately – the masking effect is due to the ejection fraction not representing forward movement of blood because a significant quantity of blood is being expelled into the left atrium. The mitral regurgitation may be primary, for which repair would result in dramatic improvement.

Thrombosis may be observed in the ventricle and is more likely in the presence of abnormalities of regional wall motion, particularly in aneurysmal or akinetic regions. Atrial thrombosis may occur, particularly in the presence of atrial fibrillation, mitral stenosis or dilated atria. The atrial appendages cannot be visualised adequately on transthoracic echocardiography, and a transoesophageal echo should be considered if thrombus is suspected. Spontaneous echo contrast indicates sluggish flow of blood – with an associated increased risk of thrombosis – and implies a poorer prognosis.

Exercise stress testing

Exercise stress testing can reveal the presence of significant ischaemia and provides objective information about the patient's effort tolerance that is useful in assessing prognostic group and monitoring progress. Ability to perform at a level of at least six metabolic equivalents (METs) – i.e. six minutes or more of the standard Bruce protocol – is associated with a better prognosis in patients with ischaemic heart disease or heart failure. Note that in order to obtain an accurate reading the patient should not be allowed to hold the handrail during the exercise test. Examples of energy expenditure in terms of MET units are given in the box on this page.

In the case of a patient who has more severe heart failure, a six-minute walking test is useful. The test can be performed by asking the patient to walk at his or her own pace along a corridor of known distance and measuring the total distance covered in six minutes. Covering a distance of 300 m or more is associated with fewer subsequent cardiac events (death or hospitalisation). The test is a useful predictor of prognosis and a visual indicator for the GP of the patient's actual ability and limiting factors that can be used for serial monitoring.

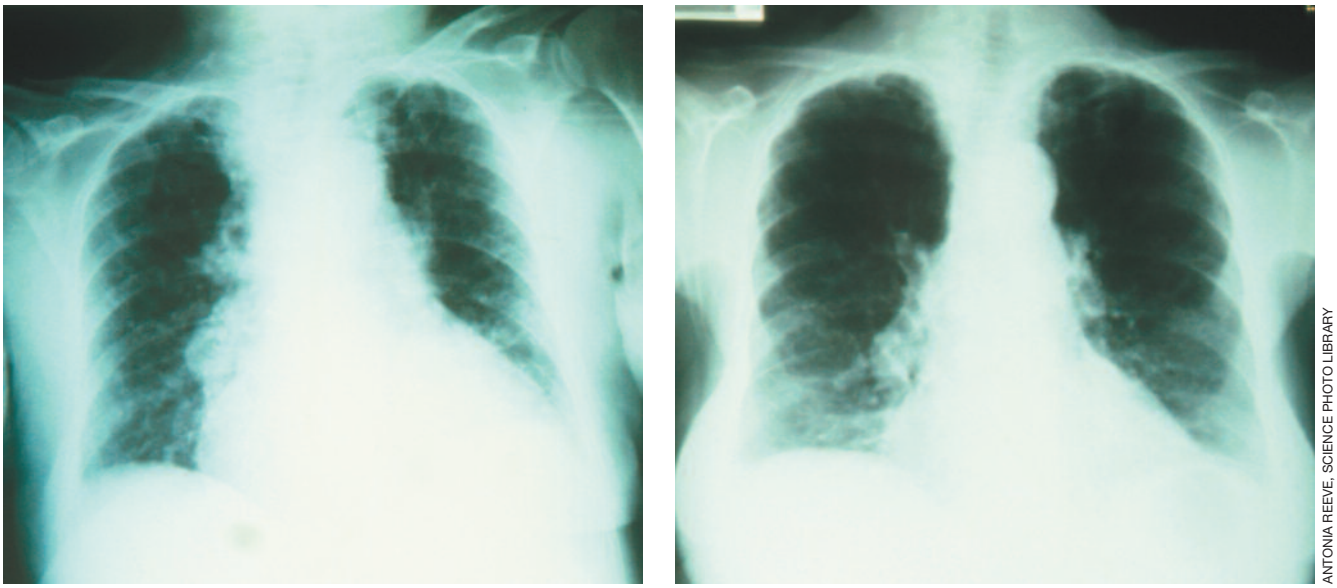
Stress testing is also a useful first line investigation to detect coronary artery disease and give an indication of its severity. False positives are more likely in women and in patients who are unable to exercise to a level to achieve 85% or greater of the

What is a MET?

A MET or 'metabolic equivalent' is a unit for expressing the rate of energy expenditure. By definition, 1 MET is equal to consumption of 3.5 mL of oxygen per kg of body weight per minute at rest.

Examples of energy consumption in METs for some common activities are:

- 3 to 5 METs – consistent with raking leaves, performing light carpentry, playing golf or walking at approximately 5 km/hour.
- 5 to 7 METs – consistent with playing singles tennis or light backpacking
- 7 to 9 METs – consistent with playing squash or walking at a rate of 7 to 9 km/hour.



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Figures 2a and b. Chest x-rays taken of a patient before (left) and after (right) treatment for cardiac failure. Therapy has led to a reduction in the heart size, reduced diameter of the upper lobe vessels (noted in the left apex) and reduction of hilar congestion.

maximum predicted heart rate for age. Nevertheless, a negative result is associated with a better prognosis.

Stress testing is contraindicated in the presence of significant aortic valvular disease, hypertrophic cardiomyopathy with significant left ventricular outflow tract obstruction, and severe hypertension. Relative contraindications include:

- left ventricular hypertrophy
- a left bundle branch block
- digoxin therapy
- pre-excitation syndrome
- intraventricular conduction disturbances
- resting ST segment depression from a variety of causes.

All of these contraindications prevent accurate interpretation of the ECG for ischaemia; however, information on effort tolerance and limiting symptoms can still be obtained.

The main value of stress testing may be as the initial test for excluding coronary artery disease in patients with a low pre-test likelihood (based on age and gender) and in those who have a normal resting ECG or very atypical chest pain.

Sestamibi SPECT imaging

Single-photon emission computed tomography (SPECT) using sestamibi is an imaging technique that can be performed with exercise or, if the patient is unable to exercise adequately, with pharmacological stress using dipyridamole (Persantin Ampoules) or dobutamine (Dobutamine Hydrochloride Injection, Dobutex). It has greater sensitivity and specificity than standard exercise testing, and is the investigation of choice when:

- stress testing is relatively contraindicated (see the discussion of exercise stress testing above)
- an index of suspicion remains after a negative exercise stress test, or
- a patient is unable to achieve 85% of the predicted maximum heart rate with no ST depression on standard exercise stress testing.

Compared with exercise testing, diagnostic changes seen on imaging and ECG appear earlier at a lower peak heart rate. False positives can occur in obese people and in women who have breast attenuation artefacts that will need to be distinguished from inducible ischaemia or myocardial scarring.

Sestamibi SPECT using dipyridamole is the test of choice in the presence of a left bundle branch block because this agent gives the lowest false positive rate. Note that dipyridamole is contraindicated in patients with asthma.

ECG-gated SPECT, which is now performed routinely, yields important information about regional and global left ventricular function. This procedure is able to measure the left ventricular ejection fraction accurately, adding supplementary information.

Exercise and dobutamine stress echocardiography

This investigation can be performed in some centres. Its role is very similar to that of sestamibi SPECT exercise testing, but exercise and dobutamine stress echocardiograhy has the extra advantage of being able to screen for coexisting valvular disease, left ventricular hypertrophy and pericardial abnormalities. Sensitivity and specificity are both highly dependent on the operator.

Blood tests

In the majority of cases, the diagnosis will be obvious with the investigations already described. However, in the presence of an idiopathic cardiomyopathy, it is prudent to conduct some extra tests to help elucidate a treatable cause. Iron studies, thyroid function tests, antinuclear factor, thiamine levels and angiotensin-converting enzyme may each reveal a treatable cause of heart failure. Blood sugar levels and the lipid profile may reveal evidence of the metabolic syndrome contributing to an ischaemic cause.

Monitoring the patient's progress

Patients should monitor their own weight every day and record their observations. They – or their GP – should note their ability to walk a known distance (e.g. the number of stops they need to make on a daily walk) or their ease of performing daily tasks (e.g. vacuuming or making beds). Clinical signs of cardiac failure should be quantified. Note, for example, the degree of peripheral oedema – does it affect the ankles only or extend to the knees or higher?

Chest x-ray

Chest x-ray will confirm the resolution of pulmonary oedema and can enable heart size to be monitored over a period of years (Figures 2a and b). The cardiothoracic ratio remains the most accurate measure available of heart size; it should always be recorded so that the ratio can be monitored even if the patient's old x-rays are unavailable.

Echocardiography

Chamber dimensions and ventricular mass can be monitored serially by echocardiography. Remodelling can be assessed accurately – for example, development of a globular heart, in which the length and width become similar, results in increased wall stress and a poorer prognosis. Ejection fraction, ventricular and atrial dimensions, and valvular function can be monitored accurately over time, helping to guide therapy and objectively assess progress and, in turn, to determine prognosis.

Exercise stress testing

Exercise stress testing is a useful procedure for objectively monitoring the patient's effort tolerance. The information that is provided is helpful even in the presence of ECG changes that will prevent the interpretation for ischaemia.

Blood tests

Serial monitoring of renal function and potassium is essential. Chronic use of diuretics can result in deficiencies of magnesium and zinc, and these levels should be checked from time to time. Overdiuresis may elevate levels of urea and creatinine.

Final comments

Now that we have effective treatment for heart conditions that were previously fatal, patients are surviving longer and developing cardiac failure later in life. In addition, degenerative conditions are becoming more frequent as the age of our population increases. Cardiac failure is thus becoming more prevalent, and it behoves us all to become more expert in its assessment and management. MT

Reference

1. Chandar S, Pawsey C, Kritharides L. Diastolic heart failure: a clinical update. Medicine Today 2001; 2(10): 22-30.

Further reading

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2. Maisel AS. B-type natriuretic peptide (BNP) levels: diagnostic and therapeutic potential. Rev Cardiovasc Med 2001; 2 suppl 2: S13-S18.
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