ABC of heart failure

Investigation

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Clinical assessment is mandatory before detailed investigations are conducted in patients with suspected heart failure, although specific clinical features are often absent and the condition can be diagnosed accurately only in conjunction with more objective investigation, particularly echocardiography. Although open access echocardiography is now increasingly available, appropriate pre-referral investigations include chest radiography, 12 lead electrocardiography, and renal chemistry.

Chest x ray examination

The chest x ray examination has an important role in the routine investigation of patients with suspected heart failure, and it may also be useful in monitoring the response to treatment. Cardiac enlargement (cardiothoracic ratio $> 50\%$) may be present, but there is a poor correlation between the cardiothoracic ratio and left ventricular function. The presence of cardiomegaly is dependent on both the severity of haemodynamic disturbance and its duration: cardiomegaly is frequently absent, for example, in acute left ventricular failure secondary to acute myocardial infarction, acute valvar regurgitation, or an acquired ventricular septal defect. An increased cardiothoracic ratio may be related to left or right ventricular dilatation, left ventricular hypertrophy, and occasionally a pericardial effusion, particularly if the cardiac silhouette has a globular appearance. Echocardiography is required to distinguish reliably between these different causes, although in decompensated heart failure other radiographic features may be present, such as pulmonary congestion or pulmonary oedema.

In left sided failure, pulmonary venous congestion occurs, initially in the upper zones (referred to as upper lobe diversion or congestion). When the pulmonary venous pressure increases further, usually above 20 mm Hg, fluid may be present in the horizontal fissure and Kerley B lines in the costophrenic angles. In the presence of pulmonary venous pressures above 25 mm Hg, frank pulmonary oedema occurs, with a "bats wing" appearance in the lungs, although this is also dependent on the rate at which the pulmonary oedema has developed. In addition, pleural effusions occur, normally bilaterally, but if they are unilateral the right side is more commonly affected. Nevertheless, it is not possible to distinguish, when viewed in isolation, whether pulmonary congestion is related to cardiac or non-cardiac causes (for example, renal disease, drugs, the respiratory distress syndrome).

Rarely, chest radiography may also show valvar calcification, a left ventricular aneurysm, and the typical pericardial calcification of constrictive pericarditis. Chest radiography may also provide valuable information about non-cardiac causes of dyspnoea.

12 lead electrocardiography

The 12 lead electrocardiographic tracing is abnormal in most patients with heart failure, although it can be normal in up to 10% of cases. Common abnormalities include Q waves, abnormalities in the T wave and ST segment, left ventricular hypertrophy, bundle branch block, and atrial fibrillation. It is a

Investigations if heart failure is suspected

Initial investigations

- Chest radiography
- Electrocardiography
- Echocardiography, including Doppler studies
- Haematology tests
- Serum biochemistry, including renal function and glucose concentrations, liver function tests, and thyroid function tests
- Cardiac enzymes (if recent infarction is suspected)

Other investigations

- Radionuclide imaging
- Cardiopulmonary exercise testing
- Cardiac catheterisation
- Myocardial biopsy—for example, in suspected myocarditis

Chest radiographs showing gross cardiomegaly in patient with dilated cardiomyopathy (top); cardiomegaly and pulmonary congestion with fluid in horizontal fissure (bottom)

useful screening test as a normal electrocardiographic tracing makes it unlikely that the patient has heart failure secondary to left ventricular systolic dysfunction, since this test has high sensitivity and a negative predictive value. The combination of a normal chest x ray finding and a normal electrocardiographic tracing makes a cardiac cause of dyspnoea very unlikely.

In patients with symptoms (palpitations or dizziness), 24 hour electrocardiographic (Holter) monitoring or a Cardiomemo device will detect paroxysmal arrhythmias or other abnormalities, such as ventricular extrasystoles, sustained or non-sustained ventricular tachycardia, and abnormal atrial rhythms (extrasystoles, supraventricular tachycardia, and paroxysmal atrial fibrillation). Many patients with heart failure, however, show complex ventricular extrasystoles on 24 hour monitoring.

Echocardiography

Echocardiography is the single most useful non-invasive test in the assessment of left ventricular function; ideally it should be conducted in all patients with suspected heart failure. Although clinical assessment, when combined with a chest x ray examination and electrocardiography, allows a preliminary diagnosis of heart failure, echocardiography provides an objective assessment of cardiac structure and function. Left ventricular dilatation and impairment of contraction is observed in patients with systolic dysfunction related to ischaemic heart disease (where a regional wall motion abnormality may be detected) or in dilated cardiomyopathy (with global impairment of systolic contraction).

A quantitative measurement can be obtained from calculation of the left ventricular ejection fraction. This is the stroke volume (the difference between the end diastolic and end systolic volumes) expressed as a percentage of the left ventricular end diastolic volume. Measurements, and the assessment of left ventricular function, are less reliable in the presence of atrial fibrillation. The left ventricular ejection fraction has been correlated with outcome and survival in patients with heart failure, although the assessment may be unreliable in patients with regional abnormalities in wall motion. Regional abnormalities can also be quantified into a wall motion index, although in practice the assessment of systolic function is often based on visual assessment and the observer's experience of normal and abnormal contractile function. These abnormalities are described as hypokinetic (reduced systolic contraction), akinetic (no systolic contraction) and dyskinetic (abnormalities of direction or timing of contraction, or both), and refer to universally recognised segments of the left ventricle. Echocardiography may also show other abnormalities, including valvar disease, left ventricular aneurysm, intracardiac thrombus, and pericardial disease.

Mitral incompetence is commonly identified on echocardiography in patients with heart failure, as a result of ventricular and annular dilatation ("functional" mitral incompetence), and this must be distinguished from mitral incompetence related to primary valve disease. Two dimensional echocardiography allows the assessment of valve structure and identifies thickening of cusps, leaflet prolapse, cusp fusion, and calcification. Doppler echocardiography allows the quantitative assessment of flow across valves and the identification of valve stenosis, in addition to the assessment of right ventricular systolic pressures and allowing the indirect diagnosis of pulmonary hypertension. Doppler studies have been used in the assessment of diastolic function, although there is no single reliable echocardiographic measure of diastolic dysfunction. Colour flow Doppler techniques are

Value of electrocardiography* in identifying heart failure resulting from left ventricular systolic dysfunction

Sensitivity	94%
Specificity	61%
Positive predictive value	35%
Negative predictive value	98%

*Electrocardiographic abnormalities are defined as atrial fibrillation, evidence of previous myocardial infarction, left ventricular hypertrophy, bundle branch block, and left axis deviation.

Electrocardiograms showing previous anterior myocardial infarction with Q waves in anteroseptal leads (top) and left bundle branch block (bottom)

Who should have an echocardiogram?

- Almost all patients with symptoms or signs of heart failure
- Symptoms of breathlessness in association with signs of a murmur
- Dyspnoea associated with atrial fibrillation
- Patients at "high risk" for left ventricular dysfunction—for example, those with anterior myocardial infarction, poorly controlled hypertension, or arrhythmias

Echocardiography as a guide to management

- Identification of impaired systolic function for decision on treatment with angiotensin converting enzyme inhibitors
- Identification of diastolic dysfunction or predominantly right ventricular dysfunction
- Identification and assessment of valvar disease
- Assessment of embolic risk (severe left ventricular impairment with mural thrombus)

particularly sensitive in detecting the direction of blood flow and the presence of valve incompetence.

Advances in echocardiography include the use of contrast agents for visualisation of the walls of the left ventricle in more detail, especially as in about 10% of patients satisfactory images cannot be obtained with standard transthoracic echocardiography. Transoesophageal echocardiography allows the detailed assessment of the atria, valves, pulmonary veins, and any cardiac masses, including thrombi.

The logistic and health economic aspects of large scale screening with echocardiography have been debated, but the development of open access echocardiography heart failure services for general practitioners and the availability of proved treatments for heart failure that improve prognosis, such as angiotensin converting enzyme inhibitors, highlight the importance of an agreed strategy for the echocardiographic assessment of these patients.

Haematology and biochemistry

Routine haematology and biochemistry investigations are recommended to exclude anaemia as a cause of breathlessness and high output heart failure and to exclude important pre-existing metabolic abnormalities. In mild and moderate heart failure, renal function and electrolytes are usually normal. In severe (New York Heart Association, class IV) heart failure, however, as a result of reduced renal perfusion, high dose diuretics, sodium restriction, and activation of the neurohormonal mechanisms (including vasopressin), there is an inability to excrete water, and dilutional hyponatraemia may be present. Hyponatraemia is, therefore, a marker of the severity of chronic heart failure.

A baseline assessment of renal function is important before starting treatment, as the renal blood flow and the glomerular filtration rate fall in severe congestive heart failure. Baseline serum creatinine concentrations are important: increasing creatinine concentrations may occur after the start of treatment, particularly in patients who are receiving angiotensin converting enzyme inhibitors and high doses of diuretics and in patients with renal artery stenosis. Proteinuria is a common finding in severe congestive heart failure.

Hypokalaemia occurs when high dose diuretics are used without potassium supplementation or potassium sparing agents. Hyperkalaemia can also occur in severe congestive heart failure with a low glomerular filtration rate, particularly with the concurrent use of angiotensin converting enzyme inhibitors and potassium sparing diuretics. Both hypokalaemia and hyperkalaemia increase the risk of cardiac arrhythmias; hypomagnesaemia, which is associated with long term diuretic treatment, increases the risk of ventricular arrhythmias. Liver function tests (serum bilirubin, aspartate aminotransferase, and lactate dehydrogenase) are often abnormal in advanced congestive heart failure, as a result of hepatic congestion. Thyroid function tests are also recommended in all patients, in view of the association between thyroid disease and the heart.

Radionuclide methods

Radionuclide imaging—or multigated ventriculography—allows the assessment of the global left and right ventricular function. Images may be obtained in patients where echocardiography is not possible. The most common method labels red cells with technetium-99m and acquires 16 or 32 frames per heart beat by synchronising (“gating”) imaging with electrocardiography. This allows the assessment of ejection fraction, systolic filling rate, diastolic emptying rate, and wall motion abnormalities. These

Transthoracic echocardiograms: two dimensional apical view (top) and Doppler studies (bottom) showing severe calcific stenosis, with an estimated aortic gradient of over 70 mm Hg (A=left ventricle, B=aortic valve, and C=left atrium)

Natriuretic peptides

- Biochemical markers are being sought for the diagnosis of congestive heart failure
- Brain natriuretic peptide concentrations correlate with the severity of heart failure and prognosis
- These could, in the future, be used to distinguish between patients in whom heart failure is extremely unlikely and those in whom the probability of heart failure is high
- At present, however, the evidence that blood natriuretic peptide concentrations are valuable in identifying important left ventricular systolic dysfunction is conflicting, and their use in routine practice is still limited
- Further studies are necessary to determine the most convenient and cost effective methods of identifying patients with heart failure and asymptomatic left ventricular dysfunction

Multigated ventriculography scan in patient with history of extensive myocardial infarction and coronary bypass grafting (left ventricular ejection fraction of 30%)

variables can be assessed, if necessary, during rest and exercise; this method is ideal for the serial reassessment of ejection fraction, but these methods do expose the patient to radiation.

Radionuclide studies are also valuable for assessing myocardial perfusion and the presence or extent of coronary ischaemia, including myocardial stunning and hibernating myocardium.

Angiography, cardiac catheterisation, and myocardial biopsy

Angiography should be considered in patients with recurrent ischaemic chest pain associated with heart failure and in those with evidence of severe reversible ischaemia or hibernating myocardium. Cardiac catheterisation with myocardial biopsy can be valuable in more difficult cases where there is diagnostic doubt—for example, in restrictive and infiltrating cardiomyopathies (amyloid heart disease, sarcoidosis), myocarditis, and pericardial disease. Left ventricular angiography can show global or segmental impairment of function and assess end diastolic pressures, and right heart catheterisation allows an assessment of the right sided pressures (right atrium, right ventricle, and pulmonary arteries) and pulmonary artery capillary wedge pressure, in addition to oxygen saturations.

Pulmonary function tests

Objective measurement of lung function is useful in excluding respiratory causes of breathlessness, although respiratory and cardiac disease commonly coexist. Peak expiratory flow rate and forced expiratory volume in one second are reduced in heart failure, although not as much as in severe chronic obstructive pulmonary disease. In patients with severe breathlessness and wheeze, a peak expiratory flow rate of <200 l/min suggests reversible airways disease, not acute left ventricular failure.

Stress studies use graded physical exercise or pharmacological stress with agents such as adenosine, dipyridamole, and dobutamine. Stress echocardiography is emerging as a useful technique for assessing myocardial reversibility in patients with coronary artery disease

Coronary angiography is essential for accurate assessment of the coronary arteries

Cardiopulmonary exercise testing

- Exercise tolerance is reduced in patients with heart failure, regardless of method of assessment
- Assessment methods include a treadmill test, cycle ergometry, a 6 minute walking test, or pedometer measurements
- Exercise testing is not routinely performed for all patients with congestive heart failure, but it may be valuable in identifying substantial residual ischaemia, thus leading to more detailed investigation
- Respiratory physiological measurements may be made during exercise, and most cardiac transplant centres use data obtained at cardiopulmonary exercise testing to aid the selection of patients for transplantation
- The maximum oxygen consumption is the value at which consumption remains stable despite increasing exercise, and it represents the upper limit of aerobic exercise tolerance
- The maximum oxygen consumption and the carbon dioxide production correlate well with the severity of heart failure
- The maximum oxygen consumption has also been independently related to long term prognosis, especially in patients with severe left ventricular dysfunction

Assessments for the investigation and diagnosis of heart failure

Assessments	Diagnosis of heart failure			Suggests alternative or additional disease
	Necessary	Supports	Opposes	
Symptoms of heart failure	++		++ (if absent)	
Signs of heart failure		++	++ (if absent)	
Response to treatment		++	++ (if absent)	
Electrocardiography			++ (if normal)	
Chest radiography (cardiomegaly or congestion)		++	++ (if normal)	Pulmonary
Echocardiography (cardiac dysfunction)	++		++ (if absent)	
Haematology				Anaemia
Biochemistry (renal, liver function, and thyroid function tests)				Renal, liver, thyroid
Urine analysis				Renal
Pulmonary function tests				Pulmonary

++ = Great importance; + = some importance.

Further reading

- Cheeseman MG, Leech G, Chambers J, Monaghan MJ, Nihoyannopoulos P. Central role of echocardiography in the diagnosis and assessment of heart failure. *Heart* 1998;80(suppl 1):S1-5.
- Dargie HJ, McMurray JJV. Diagnosis and management of heart failure. *BMJ* 1994;308:321-8.
- Schiller NB, Foster E. Analysis of left ventricular systolic function. *Heart* 1996;75(suppl 2):17-26.

The table showing the value of electrocardiography is adapted from Davie et al (*BMJ* 1996;312:222). The table of assessments for the investigation and diagnosis of heart failure is adapted with permission from the Task Force on Heart Failure of the European Society of Cardiology (*Eur Heart J* 1995;16:741-51).

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