Diagnostic investigations of adult cardiac disease

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Abstract

Preoperative investigations in cardiac surgery can be divided into two stages: diagnostic studies and assessment of fitness for surgery. Diagnostic investigations are used by cardiologists to detect and evaluate coronary, valvular, myocardial and thoracic aortic disease and, in conjunction with symptoms, are used to determine the appropriate management of cardiovascular disease. Patients presenting for cardiac surgery frequently have significant co-morbidities. Knowledge of these co-morbidities helps to plan the perioperative care of the patient with the aim of reducing postoperative morbidity and mortality thereby maximizing the chances of an uneventful recovery, and allows for more accurate informed consent. The preoperative assessment may also determine a patient to be very high risk for conventional treatment and may steer clinicians to offer patients alternative treatments such as transcatheter aortic valve implantation (TAVI) for severe aortic stenosis. This article highlights the tests for preoperative diagnosis and assessment of fitness for surgery in adult cardiac patients. In combination they guide clinicians in making appropriate management decisions, particularly with regard to elderly, frail or complex cardiac cases discussed in the setting of joint cardiology and cardiothoracic meetings.

Keywords Cardiac surgery; preoperative investigations

Coronary heart disease

The exercise tolerance test is a commonly used screening investigation for ischaemic heart disease in which patients undergo a standardized protocol of increasing exercise with continuous recording of 12-lead ECG and blood pressure monitoring (ST segment depression >1 mm, fall in blood pressure or angina considered positive), and the assessment of asymptomatic valve disease and exercise related arrhythmias. Exercise testing can also be used in conjunction with single-photon emission computed tomography (SPECT) and echocardiography. Its usefulness is limited in patients on β-blockers, those with limited exercise tolerance due to co-morbidities and those with resting ECG abnormalities. In patients unable to exercise, cardiovascular stress can be emulated pharmacologically with dobutamine, adenosine or dipyridamole in conjunction with SPECT, echocardiography, positron emission tomography (PET), or cardiovascular magnetic resonance (CMR).

SPECT with thallium or technetium can also be used as a screening investigation for significant coronary artery disease. For patients who are unable to exercise, vasodilators such as adenosine may be used to stress the heart. Images are obtained at peak stress and at rest. Reversible perfusion defects indicate viable ischaemic myocardium; irreversible defects indicate non-viable scar tissue.

Stress echocardiography provides information on ejection fraction, left ventricular size and regional wall motion abnormalities. Stress echocardiograms are performed using a dobutamine infusion to pharmacologically stress the heart by increasing cardiac work. It can identify hibernating myocardium and predicts the likely improvement of cardiac performance following revascularization. (Hibernating myocardium is defined as reversible left ventricular dysfunction caused by chronically insufficient myocardial perfusion.)

Positron emission tomography (PET) helps to differentiate stunned and hibernating myocardium from scarred myocardium in patients who do not complain of angina, but present primarily with symptoms of heart failure or poor left ventricular function. Fluorodeoxyglucose-PET (FDG-PET) visualizes metabolic activity in viable myocardial cells. It is commonly used to assess left ventricular function, myocardial perfusion and viability. Gadolinium contrast MRI can discriminate between partial thickness and full-thickness infarcts, and is therefore useful to evaluate patients with poor left ventricular function who are doubtful candidates for coronary revascularization. Cardiac MRI can also be used to visualize the coronary arteries (magnetic resonance angiography MRA) but requires further development to compete with the accuracy of standard coronary angiography or CT coronary angiography. The main indications for MRA are to visualize anomalies of the course and origin of coronary arteries and to visualize coronary artery grafts (Table 1).

Coronary CT angiography (CTA): advances in CT imaging technology, including the introduction of multi-detector (multi-slice) row systems with electrocardiographic gating, have made imaging of the heart and the coronary arteries feasible. CTA can provide information about coronary anatomy and left ventricular (LV) function that can be used in the evaluation of patients with suspected or known CAD. It is also useful to visualize previous coronary grafts in patients planned for redo cardiac surgery.

In most circumstances, a negative coronary CT angiogram rules out significant obstructive coronary disease with a very high degree of confidence, based on a negative predictive value of 93% obtained in cohorts. Therefore it is useful for managing patients scheduled for non-coronary artery cardiac surgery particularly in the surgery of aortic root aneurysms where it may be difficult to engage the coronary ostia in angiography.

On the contrary, the positive predictive values probabilities following a positive coronary CT angiogram are more variable, due in part to the tendency to overestimate disease severity, particularly in smaller and more distal coronary segments or in segments with artefacts caused by calcification in the arterial walls. It can therefore be used concomitantly with myocardial perfusion imaging (MPI).

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Sensitivity and specificity of various non-invasive tests to diagnose the presence of coronary heart disease (CHD)

	Sensitivity (%)	Specificity (%)
Exercise ectrocardiogram	45–61	70–90
Exercise stress echocardiogram	70–85	77–89
Exercise stress single photon emission computed tomography (SPECT)	73–92	63–88
Pharmacological stress echocardiogram	72–90	79–95
Pharmacological stress single photon emission computed tomography (SPECT)	88–91	75–90
Coronary computed tomography angiogram	93–99	64–90

Table 1

The differences in the parameters measured by MPI ('function' or 'physiology') and CTA ('anatomy') must be considered when making patient management decisions with these studies. Of note, a normal MPI does not exclude the presence of coronary atherosclerosis although it does signify a very low risk of future major adverse events over the short to intermediate term. Conversely, coronary CTA allows detection of some coronary atherosclerotic plaques that are not haemodynamically significant. Neither test can presently identify with any reasonable clinical probability non-obstructive coronary plaques that might rupture in the future and cause acute myocardial infarction.

Cardiac catheterization*:** Despite the advances in imaging of the coronary arteries using CT, coronary angiography remains the gold standard in the diagnosis of coronary disease. A recent (within the previous 12 months) ***coronary angiogram is required for patients undergoing coronary artery bypass surgery. It is used to demonstrate coronary artery anatomy and to identify the location and severity of disease; a stenosis greater than 50% in the left main stem and 70% in all other vessels is considered significant. This guides selection of the target vessels to graft. A more quantitative assessment of the degree of stenosis can be provided by intravascular ultrasound studies (IVUS) or by measuring the Functional flow reserve (FFR) also termed, more descriptively, pressure wire studies. FFR can be measured using a flow probe during coronary angiography and is used to assess equivocal lesions to determine the haemodynamic significance of these lesions. A measured FFR of 0.8 or less is considered a significant stenosis. The instantaneous wave-free ratio (IFR) is a recently developed physiological index which has been shown to be equivalent to FFR in the assessment of the degree of coronary stenosis but does not require the administration of adenosine and is therefore more comfortable for the patient. An IFR of less than 0.9 is considered significant. It has been shown that angiography with FFR or IFR is superior to angiography alone in the assessment of coronary disease and is likely to become the standard of care for coronary artery disease. A ***left ventriculogram*** shows left ventricular function and may detect mitral regurgitation.

Valvular heart disease

Echocardiography

Transthoracic echocardiogram (TTE) is the primary investigation for valvular heart disease. It detects most valvular conditions and is widely available in UK hospitals, but the quality of images obtained is operator and machine dependent.

Transoesophageal echocardiography (TOE) provides excellent images of the heart, allowing more detailed examination of the mitral valve and aortic root. It is vital in patients with mitral regurgitation who may be suitable for mitral valve repair. Limitations include the need for sedation or anaesthesia and the availability of a skilled operator to conduct the procedure and interpret the images.

Three-dimensional transthoracic echocardiography can be performed via a transthoracic or a transoesophageal approach. It can provide a surgeon's view of the mitral valve allowing morphologic evaluation of the valve leaflets especially of the prolapsing segment and measurement of the mitral annulus which can help plan surgical intervention. It also allows a dynamic assessment of the mitral valve following surgical repair, with the ability to look at the closure line in a loaded ventricle in systole.

Four-dimensional echocardiography is used to provide real-time rendering of the heart based on 3-D reconstructed images.

Cardiac catheterization

Coronary angiography is performed in patients aged over 40 years and in younger patients with significant risk factors for coronary artery disease.

Aortography is useful to demonstrate the severity of aortic regurgitation or the presence of any aortic root or ascending aortic dilatation.

Right-heart catheterization is useful in patients with mitral or tricuspid valve disease, congenital heart disease, pulmonary hypertension and severe left ventricular dysfunction.

CT angiography

CT angiography can be useful in younger patients with a low risk of coronary artery disease to delineate the coronary arteries. It is also useful in patients with anomalous coronary arteries and patients with previous bypass grafts where it may be difficult to find the coronary ostia. In some cases angiography may be considered risky i.e. in patients with dilated aortic roots or aortic dissection and CT angiography can be a very helpful tool to rule out coronary disease.

CMR

MRI studies of the heart can be used to assess the degree of valvular disease and can measure left and right heart function. MRA can also be used to assess coronary arteries prior to surgery.

Structural disease of the heart

Non-valvular heart disease such as atrial or ventricular septal defects, more complex adult congenital heart disease, pericardial fluid or thickening can be identified and evaluated using techniques already described, particularly ***echocardiography, cardiac MRI*** and ***cardiac catheterization***.

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