# Cardiac catheterization

Deepak Goyal
Karim Ratib
Rajay Narain
Jim Nolan

## Abstract

Cardiac catheterization involves insertion of fine-bore tubes (catheters) into the heart through cannulae inserted into a peripheral artery or vein. Procedures are commonly performed via the femoral vessels. However, the radial artery approach has the best safety record and is becoming increasingly popular. Brachial access is now rarely used because of its complexity and potentially higher complication rates.[1] Left heart catheterization is used to diagnose or evaluate coronary artery disease and valvular heart disease. Left ventriculography, selective coronary angiography and measurement of pressure in the left ventricle (LV) are routinely performed. Aortography is performed in patients with aortic regurgitation or aortic root dilatation. Left ventriculography allows visual assessment of LV size/function as well as measurement of LV pressure and systolic pressure gradients across diseased aortic valves. Coronary angiography provides information on coronary anatomy. Right heart catheterization allows measurement of haemodynamic data and oxygen saturations from the right heart chambers and pulmonary circulation. It provides information on right ventricular function, pulmonary artery pressure, right-sided and left-sided filling pressures, cardiac output and left-to-right shunts. Combined right and left catheterization is used in the comprehensive evaluation of patients with complex cardiac conditions, particularly those with valvular heart disease, intra-cardiac shunts or heart failure.[2]

**Keywords** aortography; cardiac catheterization; coronary angiography; right heart catheterization; ventriculography

## What's new?

- With improvement in technology and miniaturization of equipment, radial access is increasingly being used for routine cardiac catheterization.
- Catheters have been designed that enable engagement of both left and right coronary ostia with the same catheter, limiting the need for catheter exchanges.
- Vascular closure devices have been developed to aid in managing femoral arterial punctures.
- The requirement for cardiac catheterization has been reduced by comprehensive non-invasive imaging, but it remains the gold standard for quantifying disease severity and planning therapy for many patients with severe cardiac disease.

## Introduction

Cardiac catheterization involves insertion of fine-bore tubes (catheters) into the heart through a cannula in a peripheral artery or vein under fluoroscopic guidance. The first human heart catheterization was performed in 1929, when Werner Forssman inserted a catheter into his own heart via a cut-down of his left antecubital vein. Modern invasive and interventional cardiology began when Mason Sones obtained the first selective coronary angiogram in 1958, using a brachial artery cut-down technique.[3] The introduction of the Seldinger technique and development of pre-shaped catheters in the late 1960s established the femoral approach as the preferred method. The radial artery approach, which has better procedure-related vascular complication rates, was introduced in 1989 by Campeau and has been rapidly adopted by many cardiologists as their access site of choice.[4]

Left heart catheterization involves injection of contrast into the left ventricle (ventriculography) and selective coronary angiography. Pressures in the left ventricle and aorta are also measured. Right heart catheterization involves passing a catheter through the right heart chambers into the pulmonary circulation, and provides additional haemodynamic data. Some of the haemodynamic data obtained rely on several assumptions, and so must be interpreted together with information from other sources and assessment of the patient's clinical condition.

## Indications

Patients with known or suspected coronary artery disease or aortic valve disease usually undergo left heart catheterization to clarify the diagnosis and to help in planning an optimal treatment strategy. Left ventricular catheterization allows visual assessment of left ventricular (LV) function and size, measurement of LV end-diastolic pressure (LVEDP) and the systolic pressure gradient across the aortic valve. Coronary angiography provides information on coronary anatomy. Aortography is also performed in those with aortic regurgitation, aortic root dilatation or during assessment for aortic valve interventions.

Patients with mitral, tricuspid or pulmonary valve disease, heart failure, pericardial constriction or suspected intra-cardiac shunts, and those being assessed for cardiac transplantation usually undergo both right and left cardiac catheterization. Right heart catheterization provides haemodynamic information on pulmonary and tricuspid valve gradients, right ventricular function, pulmonary artery pressure, right-sided and left-sided filling

***Deepak Goyal*** *MD MRCP is Specialist Registrar in Cardiology in the West Midlands Deanery, UK. Competing interests: none.*

***Karim Ratib*** *MRCP is Cardiology Research Fellow at the University Hospital of North Staffordshire, Stoke-on-Trent, UK. Competing interests: none.*

***Rajay Narain*** *MRCP is Specialist Registrar in Cardiology in the West Midlands Deanery, UK. Competing interests: none.*

***Jim Nolan*** *MD FRCP is Consultant Cardiologist in the Cardiothoracic Centre at the University Hospital of North Staffordshire, Stoke-on-Trent, UK. Competing interests: none.*

pressures, cardiac output and left-to-right shunts. Simultaneous left heart catheterization allows assessment of LV and mitral valve function and associated coronary disease.

## Pre-catheterization evaluation

This should include a full medical history, with particular emphasis on co-morbidities such as diabetes, kidney disease and anticoagulation status. Any previous allergies to contrast medium or latex should be recorded. Full procedural details relating to previous cardiac or peripheral arterial interventions or cardiac surgery should also be obtained along with a physical examination and ECG. Routine laboratory tests should include a full blood count including platelet count, serum electrolytes and creatinine, plasma glucose and an international normalized ratio. Patients with diabetes taking metformin should omit this drug on the morning of the procedure and for 2 days after it. Patients with a history of contrast medium allergy should be given prophylaxis with corticosteroids and antihistamines. Patients with chronic renal impairment are susceptible to contrast nephropathy, and require pre-treatment with fluid loading and acetylcysteine, and use of low-nephrotoxicity contrast agents.[5]

## Procedures

### Left heart catheterization

Left heart catheterization is commonly performed via a sheath positioned in the right femoral artery. The sheath is inserted using a Seldinger technique, and a side-hole catheter (usually a pigtail catheter) is passed over a J-tipped guide-wire to the aortic root and across the aortic valve into the left ventricle. A straight guide-wire is used to cross the valve in patients with aortic stenosis. If good echocardiographic data are available, it is often unnecessary to cross a severely stenosed aortic valve, as the non-invasive test will provide sufficient information on stenosis severity and left ventricular function.[6]

With the catheter in the left ventricle, pressure is recorded and the end-diastolic pressure measured. Ventriculography is performed using a mechanical power injector. Pressure is then recorded as the catheter is withdrawn across the aortic valve; a decrease in pressure indicates the presence of aortic stenosis. The catheter may also be placed above the aortic valve and a further power injection performed to image the ascending aorta and assess aortic regurgitation (aortography).

Selective coronary angiography is then performed. In about 90% of transfemoral diagnostic studies, Judkin's catheters are used. These are pre-shaped end-hole catheters that are designed to engage the coronary ostia with minimal manipulation. In the other 10% of cases, catheters of various shapes are used, depending on the size and orientation of the aortic root and the relative positions of the coronary ostia. The left and right coronary arteries (Figure 1) are imaged in several different projections, using 5–10 mL of contrast for each view. Typically, six to eight views of the left coronary artery and three of the right coronary artery are obtained. These angiographic images are used to detect and quantify the presence of stenotic coronary lesions. When the procedure is completed, the catheters and sheath are removed and manual pressure applied to the femoral puncture sites to obtain haemostasis. As an alternative, vascular closure devices can be used to close the vascular puncture rapidly and reduce the need for bed rest.

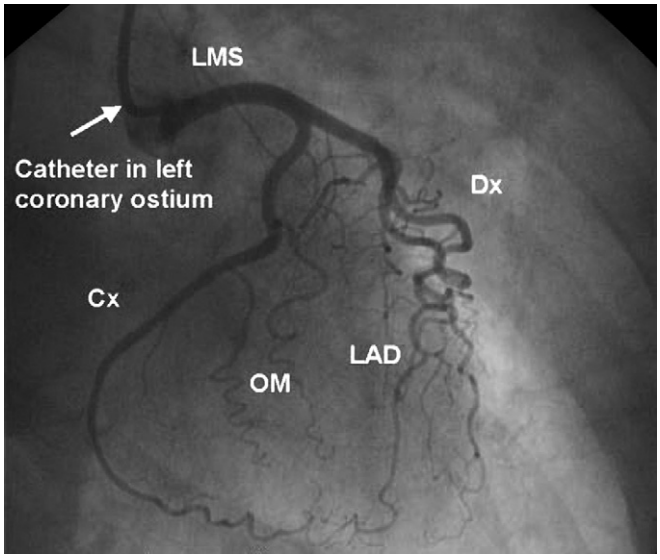


**Figure 1** Angiogram demonstrating the left coronary artery anatomy in the left anterior oblique view. The left coronary artery arises from the proximal ascending aorta as the left main stem (LMS). This bifurcates into the circumflex artery (Cx) and the left anterior descending artery (LAD). Branches of the LAD are the septal arteries which supply the septum and the diagonal arteries (Dx). Branches of the circumflex artery (Cx) are called obtuse marginals (OM). The circumflex artery (Cx) is dominant. This artery is free from disease.

### Right heart catheterization

The femoral vein is the most commonly used access site for right heart catheterization. A sheath is placed in the vein using a percutaneous Seldinger technique and a pre-shaped end-hole catheter is passed into the right atrium, the right ventricle and the pulmonary artery using standard manipulations under fluoroscopic control. Pulmonary artery pressure is recorded, and the catheter is advanced until it plugs a branch of one of the pulmonary arteries and the waveform changes to a pulmonary capillary wedge (PCW) tracing closely matched to the left atrial pressure.

When mitral valve disease is suspected, simultaneous left heart catheterization is performed and the LV and PCW pressures are recorded simultaneously. Any difference between these measures in end-diastole indicates mitral stenosis.

The pulmonary artery catheter is then withdrawn and pressures in the pulmonary arteries, the right ventricle and the right atrium are measured sequentially (Figure 2). Left-to-right intracardiac shunts are assessed using a 'saturation run', in which blood samples withdrawn from the pulmonary artery, the right ventricle, the right atrium and the caval veins are analyzed and their oxygen saturations compared. In patients who have a significant left-to-right shunt, oxygenated blood enters the right heart via a defect (such as an ASD, PDA or VSD) and produces an abnormal increase in oxygen saturation (the magnitude of this increase is proportional to the size of the shunt and this allows quantification of the lesion).[7]

Flexible, balloon-tipped catheters may also be used to measure right heart pressures and cardiac output in ICUs and coronary care units (e.g. the Swan–Ganz catheter). They are commonly inserted via the subclavian, femoral or jugular vein, and are floated across the tricuspid and pulmonary valves; in many cases fluoroscopic guidance is not needed. With the

 