Cardiac catheterization

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Abstract

Cardiac catheterization involves the insertion of fine-bore tubes (catheters) into the heart through cannulae inserted into a peripheral artery or vein. Previously, transfemoral access was predominantly used, but the safer radial artery approach has now become the preferred access route for most UK operators. Left heart catheterization is used to evaluate coronary arteries, left-sided valvular function, left ventricular function and aortic root anatomy. Haemodynamic and oxygen saturation data obtained from right and left heart catheterization provide information on cardiac chamber function, valvular function, pericardial constraint and pulmonary and systemic circulation haemodynamics. The comprehensive evaluation is especially invaluable in the diagnostic work-up and/or monitoring of patients with complex cardiac conditions; this particularly includes those with ischaemic heart disease, valvular disease, pulmonary arterial hypertension, intracardiac shunts, pericardial disease or heart failure.

Keywords Aortography; cardiac catheterization; coronary angiography; MRCP; right heart catheterization; ventriculography

Key points

- Despite the increasing diagnostic role of non-invasive techniques for ischaemic heart disease, cardiac catheterization remains the gold standard for evaluation of coronary artery disease
- With improvements in technology and reduction of vascular complications, radial access has become the preferred access route for left cardiac catheterization
- Direct functional assessment of a coronary artery stenosis with a pressure wire can guide treatment and improve outcome in patients with chronic stable angina
- Haemodynamic assessment by left and right heart catheterization is invaluable for diagnosis and treatment-planning in valvular and structural heart disease, and plays an important role in the treatment and monitoring of pulmonary arterial hypertension

Introduction

Although non-invasive imaging of cardiac anatomy using echocardiography, cardiac computed tomography and magnetic resonance imaging is increasingly used, cardiac catheterization remains the gold standard method for evaluating coronary artery disease and cardiac haemodynamics; it is mandatory in many patients before percutaneous or surgical treatment. Advances in equipment design and catheterization techniques, particularly use of the radial access site, have improved the tolerability and safety of this technique.

Cardiac catheterization involves the insertion of fine-bore tubes (catheters) into the heart through a peripheral artery or vein under fluoroscopic guidance. The first human heart catheterization was performed in 1929, when Werner Forssmann inserted a catheter into the right side of 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. 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 superior procedure-related vascular complication rates, was introduced in 1989 by Campeau, and has rapidly been adopted by most cardiologists as their access route of choice.[1]

Left heart catheterization involves injection of contrast into the coronary arteries (selective coronary angiography) and/or left ventricle (ventriculography) and/or aorta (aortography). Pressures in the left ventricle and aorta are also measured. Right heart catheterization involves the measurement of pressures (haemodynamic data) in the pulmonary circulation and right heart chambers. Some of the haemodynamic data obtained rely on several assumptions, 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 that is unstable or not controlled by optimal antianginal medication usually undergo left heart catheterization to clarify the diagnosis and help plan an optimal treatment strategy. Left ventricular catheterization allows visual assessment of left ventricular function and size, and measurement of left ventricular 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 patients with aortic regurgitation or aortic root dilatation, and during assessment for aortic valve interventions.

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Please cite this article in press as: Schwarz K, et al., Cardiac catheterization, Medicine (2018), https://doi.org/10.1016/j.mpmed.2018.05.014

Patients with mitral, tricuspid or pulmonary valve disease, heart failure, pericardial constriction or suspected intracardiac 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 pressures, cardiac output (CO) and left-to-right shunts. Simultaneous left heart catheterization allows assessment of left ventricular and mitral valve function, as well as associated coronary disease.

Pre-catheterization evaluation

This should include a full medical history, with particular emphasis on co-morbidities such as diabetes mellitus, kidney disease and anticoagulation status. 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 be obtained, along with a physical examination and electrocardiogram. Routine laboratory tests should include a full blood count including platelet count, serum electrolytes and creatinine, plasma glucose and international normalized ratio. Patients with diabetes mellitus who are taking metformin should omit this drug on the morning of the procedure and for 2 days afterwards. Patients with a history of allergy to contrast media should be given prophylaxis with corticosteroids and antihistamines. Patients with chronic renal impairment are susceptible to contrast nephropathy, and require pre-treatment with intravenous fluids.

Left heart catheterization

Left heart catheterization is performed via arterial access using the radial or femoral artery.

Transfemoral catheterization

For most procedures, a sheath is inserted using a Seldinger technique. Selective coronary angiography is then performed using dedicated pre-shaped catheters; these are passed over a J-tipped guidewire into the aortic root, and fluoroscopically guided into the coronary artery ostia. In about 90% of transfemoral diagnostic studies, a Judkins' catheter is used. This is a pre-shaped end-hole catheter designed to engage the coronary ostia with minimal manipulation. In the other 10% of studies, catheters of various shapes are used, depending on the size and orientation of the aortic root, and 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 at different angles. These angiographic images are used to detect and quantify the presence of stenotic coronary lesions, usually described by the percentage diameter stenosis compared with adjacent reference vessels. Once the procedure has been completed, the catheters and sheath are removed, and manual pressure is applied to the femoral puncture site(s) 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.

For left ventriculography, a side-hole pigtail catheter is passed over a guidewire into the aortic root and across the aortic valve into the left ventricle. With the catheter in the left ventricle, the pressure is recorded and the end-diastolic pressure measured. Contrast ventriculography is performed using a mechanical power injector. Left ventricular size and global or regional wall motion abnormalities are visually assessed. Pressure is then recorded as the catheter is withdrawn across the aortic valve; a drop in systolic pressure indicates the presence of aortic stenosis. In patients with severe aortic stenosis, a straight guidewire can facilitate crossing of the valve but this carries potential complication risks (stroke, valve damage) and is no longer necessary as non-invasive tests, such as echocardiography, provide sufficient information on stenosis severity and left ventricular function. The pigtail catheter can also be placed above the aortic valve, and further contrast injected to image the ascending aorta and aortic arch, and assess aortic regurgitation (aortography).

Transradial catheterization

Although the femoral artery is large and accessible, vascular complications have always been an inherent part of cardiac catheterization using the femoral approach. They occur in up to 5% of cases, and are associated with increased mortality and other adverse outcomes. An access site haematoma requiring transfusion is independently associated with in-hospital and 1-year mortality.[2] Brachial access is rarely used because of its complexity and potentially higher complication rates.

The Radial Vs femorAL access for coronary intervention (RIVAL) trial was decisive in accelerating the uptake of the transradial approach for coronary catheterization.[3] This was a prospective, multicentre, randomized trial comparing femoral and radial access in patients with acute coronary syndrome. There was no difference in procedural success rates between groups, but there were significantly fewer major vascular complications in the radial group (1.4%) than the femoral group (3.7%), and there were no local vascular complications at radial puncture sites.[3]

A recent meta-analysis of 24 randomized control trials (n = 22,843) confirmed that, compared with femoral access, radial access reduces mortality and major adverse cardiac events, while reducing major bleeding and vascular complications across the whole spectrum of patients presenting with coronary artery disease.[4] As a consequence, diagnostic and interventional coronary procedures are increasingly being performed via the radial route (80% of cases).[1] The radial artery is superficial and easily compressible, and any bleeding can therefore be easily controlled. In addition, no major veins or nerves lie close to the artery, thereby limiting the risks of neurological damage or arteriovenous fistula formation. Other benefits include immediate ambulation and greater post-procedure comfort for the patient, early discharge and lower costs.

Dedicated radial sheaths with a hydrophilic coating are inserted into the radial artery close above the wrist via a Seldinger approach. Specific catheters have been developed to allow cannulation of both coronary ostia with a single specific transradial catheter, although it is also possible to use conventional transfemoral catheters. After completion of the procedure, simple devices are used to apply compression to the radial puncture site to achieve haemostasis.

Please cite this article in press as: Schwarz K, et al., Cardiac catheterization, Medicine (2018), https://doi.org/10.1016/j.mpmed.2018.05.014