# Surgery for coronary artery disease

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## Abstract

Coronary artery disease (CAD) is one of the most common diseases in the Western world, with >100,000 deaths a year in the UK. It occurs as a result of mismatch between supply and demand of oxygen, usually due to atherosclerotic narrowing of one of more of the major coronary arteries. CAD can remain asymptomatic initially as the stenosis caused by the plaques may not be flow limiting. As it progresses with time, patients present with angina, acute coronary syndromes or even sudden death. Treatment can be medical or surgical, including percutaneous coronary intervention (PCI) and/or coronary artery bypass grafting (CABG). CABG provides a safe and effective treatment for a large number of people with coronary artery disease for whom PCI and medications are unsatisfactory. With overall improvement in technique and perioperative care, patients undergoing these procedures have prognostic and symptomatic benefit.

**Keywords** Acute coronary syndromes; angina; atherosclerosis; conduit; coronary artery; coronary artery bypass graft; preoperative assessment; revascularization

## Introduction

The estimated prevalence of coronary artery disease (CAD) below the age of 75 years in the UK is 7.4% for men and 4.5% for women. CAD is the most common cause of death in the UK, with mortality rates of 1 in 5 for men and 1 in 6 for women.

Coronary artery bypass surgery (CABG) offers symptomatic and prognostic benefit for patients with CAD.[1] This chapter gives a concise description of relevant anatomy, pathology and preoperative investigations relevant to CAD and explains surgical details and postoperative complications of CABG.

## Normal coronary anatomy

Left and right coronary arteries are the first two branches of the aorta. Arising from the left and right aortic root sinuses respectively, they run in the epicardial surface of the heart.

## Pathology of coronary atherosclerosis

Atherosclerosis is triggered by vascular endothelial dysfunction induced by factors including free radicals, elevated low-density lipoproteins, hypertension, infectious micro-organisms, smoking and shear stress.

Under resting conditions, the vascular endothelium regulates the passage of intravascular substrates to the extravascular space and ensures the unhindered flow of cellular and serum components through the capillary network. Endothelial cells are sensitive to stimuli and can change their normal homoeostatic properties, causing alteration to the selective permeability, induction of procoagulant factors and up regulation of different adhesion molecules, leading to the adherence of inflammatory cells to the endothelial cells and their subsequent transmigration.

The earliest phase in atherosclerosis presents as fatty streaks (sub-endothelial accumulation of lipid-laden macrophages called foam cells). These lesions expand as they become complex, with a necrotic core of inflammatory foam cells and apoptotic cells separated from the lumen by fibrous tissue called the 'fibrous cap'. As the lesion gets larger, the plaque may rupture, exposing the thrombogenic tissue to blood leading to thrombus formation.

## Risk factors

Coronary artery disease is multifactorial in origin. These include hypercholesterolaemia, hypertension, smoking, stress, positive family history, obesity and sedentary lifestyle.

## Pathophysiology

Angina represents myocardial ischaemia. It occurs when blood supply does not match the metabolic demands of muscle. Approximately 70% of the luminal area of a blood vessel is obstructed before patients experience angina. Hence, intervention (percutaneous coronary intervention [PCI] and/or coronary artery bypass grafting [CABG]) is contemplated when the vessel lumen is stenosed more than 70%. The exception is in left main stem (LMS) stenosis, where a 50% stenosis is considered haemodynamically significant as a large amount of myocardium is in jeopardy.

## Clinical presentation

Angina is the most common presenting symptom. The Canadian Cardiovascular Society Angina Classification (CCS) grades angina, as shown in Box 1.

Clinical examination yields few signs. Pedal oedema, raised jugular veins and jugular venous pressure and ascites are cardinal signs of right heart failure. Features of pulmonary oedema are usually associated with left ventricular failure. It is common for CAD patients to have features of peripheral vasculopathy.

## General investigations

### Electrocardiogram (ECG)

Preoperative ECG identifies myocardial ischaemia or infarction and its anatomical location. It helps in differentiating between ongoing ischaemia (ST segment depression) and myocardial infarction (ST segment elevation).

### Chest X-ray (CXR)

A properly performed CXR is a source of enormous information including cardiomegaly, pulmonary congestion, lung parenchymal changes, pleural effusion, mediastinal widening and mass lesions.

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### Canadian Cardiovascular Society Grading System score for describing and categorizing effort-related angina

Class I

Angina with strenuous, rapid, or prolonged exertion (ordinary physical activity such as climbing stairs does not provoke angina)

Class II

Slight limitation of ordinary activity (angina occurs with postprandial, uphill, or rapid walking; when walking more than 2 blocks of level ground or climbing more than one flight of stairs; during emotional stress; or in the early hours after awakening)

Class III

Symptoms with everyday living activities, i.e. moderate limitation. Marked limitation of ordinary activity (angina occurs with walking 1-2 blocks or climbing a flight of stairs at a normal pace)

Class IV

Inability to perform any activity without angina or angina at rest, i.e. severe limitation.

**Box 1**

#### Echocardiogram

Preoperative echocardiography is useful in assessing left and right ventricular function at rest and after pharmacological stress or exercise. It assesses the valve function prior to surgery. It also allows better assessment of surgical risk and helps discussion on treatment options with the patient before informed consent.

### Imaging useful in the diagnosis of coronary artery disease and assessment of prognosis including stress testing

#### Coronary angiography

Coronary angiogram remains the gold standard investigation to delineate coronary anatomy and identify stenosis. It is not reliable to assess the quality of coronary vessels. Figure 1a and b shows normal coronary arteries while Figure 2a and b demonstrate angiographic evidence of left coronary artery (LCA) and right coronary artery (RCA) stenosis.

Fractional flow reserve (FFR) is defined as the ratio of the pressure distal to a coronary lesion relative to the proximal pressure. FFR could be measured during coronary angiography to determine the functional effect of the coronary stenosis as it takes collateral circulation into account. Normal coronary artery gives FFR = 1, any FFR < 0.8 means that stenosis causes 20% drop in blood flow making it haemodynamically significant warranting revascularization.

#### Intravascular ultrasound (IVUS)

IVUS is useful in imaging cross sections of coronary artery, particularly when the lesion size is difficult to estimate by routine angiogram. IVUS also helps in studying the quality of the coronary arterial wall and plaque stability as it helps differentiate intima, media and adventitia (Figure 3).

#### Multidetector computed tomography coronary angiography (MDCT)

MDCT is reliable for ruling out significant CAD in patients with stable and unstable anginal syndromes and in patients with low to moderate likelihood of CAD (Figure 4). In CAD, MDCT together with calcium scoring (Agatston score) is used to estimate severity of CAD. Calcium score of zero rules out obstructive CAD with a high sensitivity of (>95%) and a negative predictive value of (99%). A calcium score >400 gives a high probability of a haemodynamically significant stenosis but MDCT angiography overestimates the severity of atherosclerotic obstructions and decisions for patient management may require further functional testing.

#### Optical coherence tomography (OCT)

Optical coherence tomography is a technique that uses near-infrared light for the cross-sectional visualization of the vessel wall at the microscopic level. It enables excellent resolution of coronary architecture and precise characterization of plaque architecture (Figure 5).

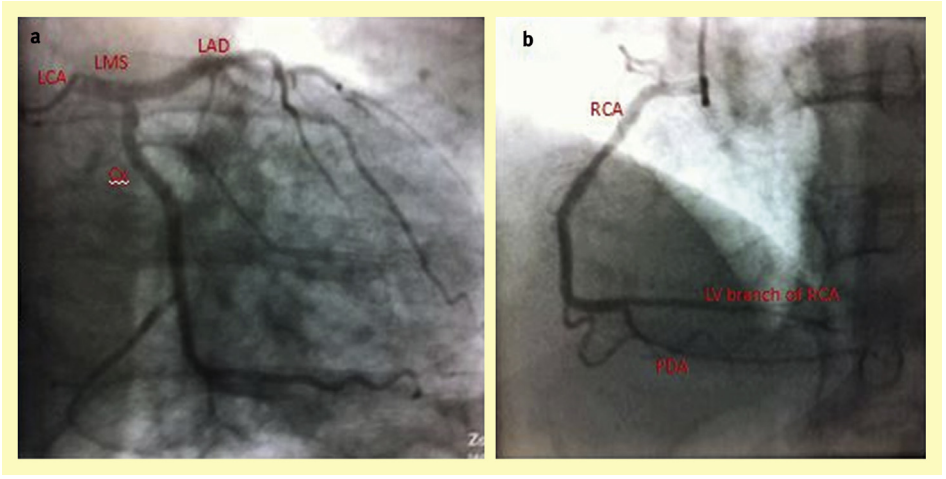


**Figure 1** Normal anatomy of the **(a)** left coronary artery (LCA) with its respective tributaries as shown. LMS—left main stem, LAD—Left anterior descending artery, Cx—Circumflex artery **(b)** right coronary artery (RCA) with its respective tributaries as shown. PDA—posterior descending artery, LV Branch—left ventricular branch.