

All you want to know about

coronary arteries and angiography

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Introduction

The twists and turns of the coronary arteries have been forgotten by most clinicians well before (and for many during) their third medical year at university, and coronary anatomy quickly fades to a set of vaguely remembered three letter acronyms. The appearance of the coronary tree if accurately rendered is somewhat confusing (figure 1) but its anatomy is in principle quite simple. This article outlines coronary anatomy, the make-up of coronary arteries in health and disease, and briefly describes the methods of performing coronary angiography the way in which we study the coronary arteries on a day to day basis. Before we move to discussing coronary anatomy in more detail, coronary histology will be briefly addressed.

Coronary histology

All arteries, the coronaries included, are made up of three layers: intima, media and adventitia (figure 2). The intima consists of a superficial layer, the endothelium, and subendothelial tissue consisting of connective tissue and smooth muscle cells. Intimal thickness increases with age, from a single cell layer at birth, to approximately a quarter of a millimetre in middle age. The internal elastic lamina, a thin sheet of elastic tissue, separates the media from the intima. The external elastic lamina, separating the media from the adventitia is structurally similar, but thinner than the internal elastic lamina. The muscular media of coronary arteries is predominantly composed of smooth muscle cells with smaller amounts of collagen, elastic tissue and proteoglycans. Medial thickness also averages about a quarter of a millimetre. The adventitia is composed of loose collagen and elastic tissue that merges with the surrounding peri-adventitial tissue and measures up to a half a millimetre in thickness.

The calibre of normal arteries varies according to gender and the size of the individual (small women

have small coronaries). It is important to emphasise that they are all relatively small and often remarkably difficult to visualise (with an untrained eye) when viewed on the surface of the heart (they may be covered in epicardial fat, or on occasion a bridge of myocardium). Figure 3 shows a surgeon's view of the surface of the heart during bypass surgery. The left main coronary artery measures 2.5-5mm (mean 4.0mm); the left anterior descending artery 2.0-5.0mm (mean 3.6mm); the left circumflex artery 1.5-5.5mm (mean 3.0mm) and right coronary artery 1.5-5.55mm (mean 3.2mm). The left anterior descending and left circumflex arteries taper along their length, but the calibre of the right coronary artery remains more or less constant as far as the origin of a distal branch, the posterior descending artery.

Coronary disease

Coronary atherosclerosis is predominantly a disease of the intima (figure 2). Whereas healthy intima measures a fraction of a millimetre in thickness, atherosclerosis results in intimal thickening of up to two or three millimetres. This follows progressive infiltration by smooth muscle cells, macrophages, foam cells, and fibroblasts lying in an extracellular matrix made up of collagen, proteoglycans and extracellular lipid. The media undergoes fibrous degenerative change, particularly of the inner third, and thins and indeed may rupture in the presence of atherosclerosis. In the earlier stages of atheroma development the calibre of the arterial lumen does not change appreciably as a consequence of compensatory enlargement of the outer border of the vessel. Thus a so-called normal or near normal coronary angiogram (which outlines the coronary lumen) may fail to define the presence of significant early atheroma formation.

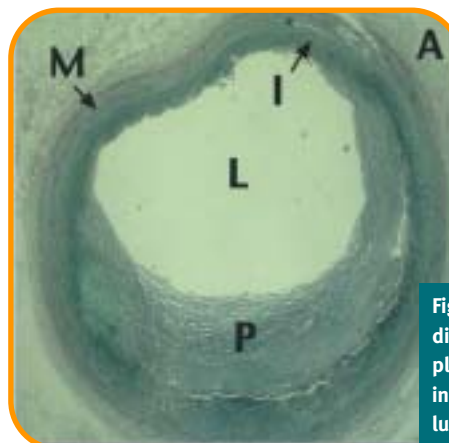
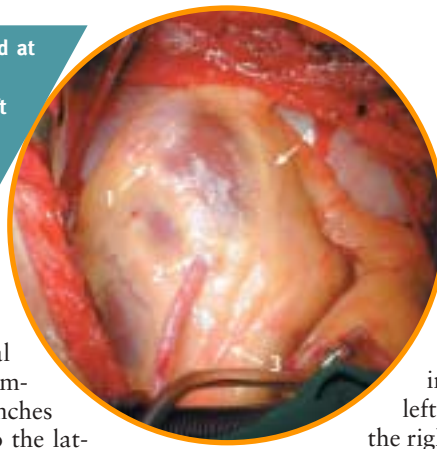


Fig. 2: Histological section of a moderately diseased coronary artery. There is a fibrofatty plaque, consisting of diseased thickened intima, extending from 1 to 9 o'clock, L - lumen, M - media, A - adventitia, P - plaque.

Figure 3: The surgeon's view. The coronary arteries are small and at times difficult to discern as they run over the surface of the heart. 1 indicates the distal marginal branch to which the distended vein graft has been grafted more proximally. 2 delineates the anastomosis. The proximal left anterior descending branch (3) runs under the epicardial fat within 1cm of its origin. In the mid third of the vessel a linear arteriotomy is shown (4), to which the left internal mammary artery is about to be grafted.



We have also come to realise that certain plaques are more vulnerable to rupture than others. These classically have large, lipid containing cores that are separated from the lumen by a thin fibrous cap. Rupture of the plaque results in exposure of the highly thrombogenic plaque constituents to flowing blood, clot formation and development of an acute coronary syndrome.

Since coronary atherosclerosis frequently involves compensatory enlargement of the vessel, it can readily be appreciated that many of these vulnerable plaques are not necessarily those which cause significant stenosis, and thus are not specifically identifiable on coronary angiograms.

left ventricle, known as diagonal branches. The circumflex produces branches that run forward to the lateral wall of the ventricle, obtuse marginals, and frequently terminates on the posterolateral surface of the ventricle as a posterior left ventricular branch. In 10-15% of the population, the circumflex supplies the inferior interventricular septum, giving rise to the posterior descending artery as its terminal branch. The right coronary artery arises separately and runs in the right atrioventricular groove over the right and anterior aspect of the heart. It may produce a number of right ventric-

branches. Dominance refers to that artery (right or left) which produces the posterior descending artery and supplies the inferolateral wall of the left ventricle. When both the right coronary artery and the left circumflex contribute to the supply of the inferior interventricular septum, the coronary circulation is said to be balanced, and the arteries co-dominant.

Coronary angiography

Selective injection of a coronary artery with iodine containing, radiodense contrast medium during radiographic imaging produces a coronary angiogram. The coronaries were first visualised non-invasively during aortic

Anatomy

The coronary arteries conduct blood from their origin at the base of the aorta, over the epicardial surface of the heart, and into the myocardium. Where the three leaflets of the aortic valve join the aorta are three shallow outpouchings known as the sinuses of Valsalva. The left and right coronary arteries arise from those sinuses orientated to the left and right anterior aspect of the valve respectively. The left coronary starts as the left main stem, and bifurcates usually within 1-2cms into the left anterior descending artery, running over the anterior surface of the heart in the anterior interventricular groove, and the left circumflex artery, which bears left and runs down the posterior surface of the heart in the atrioventricular groove (figure 4,5). The left anterior descending artery produces a number of branches on its left side to supply the anterolateral aspects of the

ular branches, extends within the atrioventricular groove to the crux cordis where the atrioventricular and interventricular grooves meet, and in the majority of cases (85-90%) supplies the inferior interventricular septum, producing the posterior descending artery (figure 6,7). In many cases, the artery continues in the atrioventricular groove to supply the posterior and inferior aspects of the left ventricle with a number of terminal posterior left ventricular

root injection (figure 8), and in 1959 Sones produced the first selective angiogram (figure 9). He approached the coronaries using a cut-down over the brachial artery and advanced his catheter retrogradely to the base of the aorta. In the early 1960s Judkins designed a set of catheters to access the heart from the femoral artery. This technique and the catheters he designed for cannulating the right and left coronary arteries, remain the standard today, although technology has been constantly refined. We now use arterial sheaths which allow access to the artery without blood loss; softer, smaller catheters (typically less than or equal to 2mm outer diameter), less toxic non-ionic contrast media, and much lower doses of radiation. The marked mobility of the heart requires the recording of sequential images to produce a cineangiogram. A sufficient frame rate (the number of



Figure 4: Schematic diagram of the left coronary artery viewed from a right anterior oblique orientation.



Figure 5: Schematic diagram of the left coronary artery viewed from a left anterior oblique orientation.



Figure 6: Schematic diagram of the right coronary artery viewed from a right anterior oblique orientation.

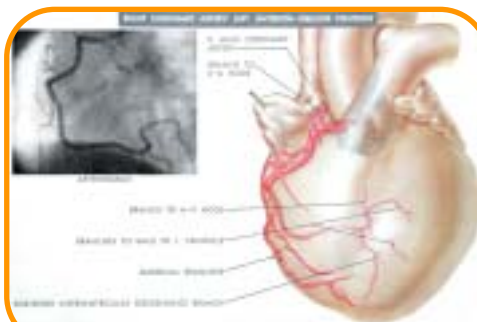
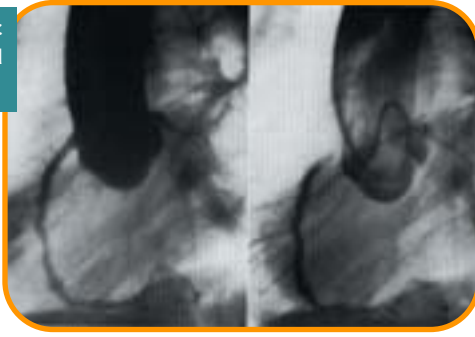


Figure 7: Schematic diagram of the right coronary artery viewed from a left anterior oblique orientation.

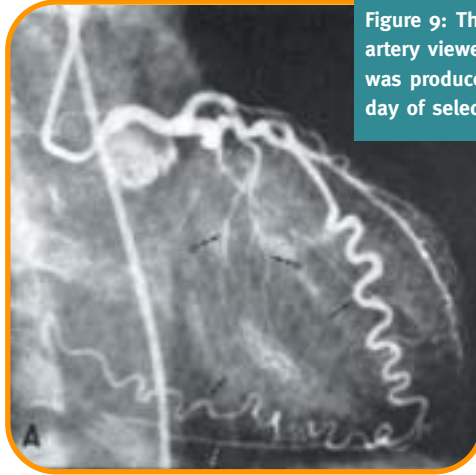
Figure 8: The first non-selective angiographic views of the coronary arteries were produced during root aortograms.



including haematoma, pseudoaneurysm or fistula, and reactions (allergic and otherwise) to contrast medium (now rare given the almost ubiquitous use of non-ionic contrast medium). As on might expect, complications are more likely to occur in sicker patients. As an example the relative risk of a patient with left main coronary artery disease is increased twenty-fold.

images recorded per second) is used to avoid motion artefact during playback of the angiogram. Multiple projections are used to cater for the marked tortuosity of the coronary arteries, their multiple branch points and the frequently eccentric nature of coronary stenoses. An eccentric stenosis may be invisible in one projection, but evident as a severe narrowing in that at right angles to it. Typically the left coronary will be comprehensively studied using five to seven different projections, the right using two to three projections. These are achieved by moving the image intensifier and camera (we now produce a digital record on a compact disc as opposed to 35mm film), positioned at the end of a 'C' arm gantry, around the patient's chest, as he/she lies on a radiolucent table, which is also mobile in all planes. The left coronary is typically opacified using 6-8mls of contrast medium, the right somewhat

Figure 9: This high quality angiogram of the left coronary artery viewed using a right anterior oblique projection was produced by Judkins and colleagues in the earliest day of selective coronary angiography.



New methods

Newer methods of visualising the coronary arteries have been developed. Intracoronary ultrasound, whereby a miniaturised ultrasound probe is advanced into the coronary arteries to provide a high resolution tomographic realtime image of the artery, provides previously unavailable information concerning the vessel wall, and clarifies the nature of unusual or unquantifiable angiographic appearances (figure 10). Angioscopy is a method of direct visualisation of the coronary lumen using optical fibres while the coronary is transiently occluded and injected with saline. Both angioscopy and intravascular ultrasound have remained largely research tools, although both have provided invaluable insights into coronary disease and its treatment, and intravascular ultrasound has a recognised clinical role in cases of uncertain diagnosis and as an adjunct during selected cases of percutaneous coronary intervention.

Efforts continue to develop a non-invasive method for studying the coronary circulation. Magnetic resonance imaging is showing particular promise in this regard, providing anatomical and functional information concerning the coronary arteries, myocardium and cardiac chambers. Further work is required to improve temporal and spatial resolution and to provide complete three-dimensional reconstruction of the arteries which wander in and out of plane in current systems (figure 11). The technological challenge is significant, but not likely to be insuperable, and the technique offers the real prospect of non-invasive diagnostic coronary angiograms.

Baroldi G. Disease of the coronary arteries. In Cardiovascular Pathology. Vol. 1. (Ed. Silver MD) Churchill Livingstone, New York (1983) 317-391

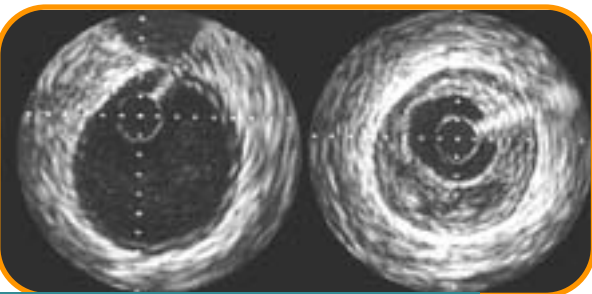


Figure 10: Intravascular ultrasound provides a tomographic view of the artery, similar to what is seen on histological study. On the left side, a normal artery is shown, with a large lumen and disease free wall, consisting of a thin layer corresponding with the intima, a thin dark layer representing the media, and surrounding adventitia. The diseased artery shown on the right side is characterised by circumferentially thickened and diseased intima.

less. Most patients undergoing coronary angiography, will also undergo left ventriculography, during which 30-45 mls of contrast is injected using a power injector directly into the left ventricle. The remainder of the cardiac catheterisation involves recording of intraventricular and aortic pressures during the cardiac cycle.

A set of coronary angiograms, including administration of local anaesthetic, sheath insertion, coronary injections, sheath removal and

haemostasis, takes approximately 30-45 minutes to perform, although complex and unusual anatomy, or the study of bypass grafts, including the left and occasionally the right internal mammary artery may take more time. A mild sedative is often given before the study. Most coronary angiograms can be performed as day case procedures, the principal constraint being the distance travelled by the patient from their home. Certain conditions, including cases of particularly severe disease, clinical instability, or following intraoperative complications necessitate a longer admission. The procedure is generally very safe, but as with all invasive procedures carries some risks. These include myocardial infarction (c.0.1%), cerebrovascular accidents (c.0.1% - 0.2% transient, 0.1% permanent), arrhythmia (ventricular fibrillation in c.0.4% of cases), or conduction disturbance (complete heart block in c.0.3% of cases), vasovagal reactions, peripheral complications

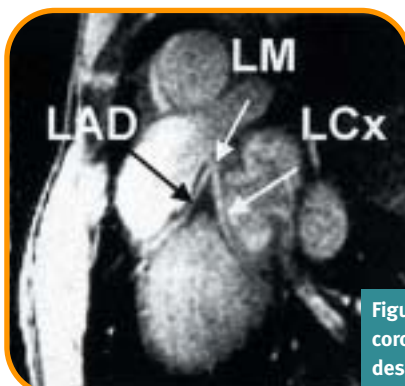


Figure 11: MRI offers the possibility of non-invasive characterisation of coronary anatomy. The left main artery (LM) divides into left anterior descending (LAD) and left circumflex arteries (LCx) arteries.