Normal and Abnormal Coronary Artery Anatomy: Is it significant?

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Learning objectives

1. Describe and illustrate the normal anatomy of the coronary arteries
2. Illustrate anomalous origins of the coronary arteries, myocardial bridging and coronary artery fistulas
Background

The advent of ECG gated multi-detector CT has led to Cardiac CT being increasingly used for risk stratifying patients with chest pain as well as a host of other indications. Knowledge of coronary artery anatomy is an important part of reporting cardiac CTs.

In this presentation, we present a range of coronary artery anomalies compared to normal coronary artery anatomy while highlighting the abnormalities which are of clinical importance. The coronary artery anomalies are divided into 3 groups:

1. Anomalies of the origin
2. Anomalies of the course
3. Anomalies of termination
Imaging findings OR Procedure details

Normal Coronary Artery Anatomy:

There are two ostia at the sinuses of valsalva. The right coronary artery ostium originates from the right coronary sinus which on CT can be recognised as the coronary sinus facing the sternum. The left coronary artery originates from the left coronary cusp which is posterior and pointing to the left. While the non-coronary sinus is also posterior and faces the interatrial septum.

**Right Coronary Artery (RCA)**

The RCA travels along the anterior atrioventricular groove. In about 50% of cases the RCA gives off a conus branch\(^1\) (Fig 1). The second branch is the sinoatrial branch which is present in 55% of patients\(^1\). The right coronary artery then travels inferiorly. Close to the margin just before the RCA bends round the right ventricle it gives off the acute marginal branch (Fig 1 & 2) which supplies the anterior wall of the right ventricle. The RCA bends sharply at the margin to travel along the posterior surface of the heart. In 80-85% of patients the RCA gives off the posterior descending artery (PDA) (Fig 2) and the posterolateral branch (PLB). This is called right coronary dominance.

**Left Coronary Artery (LCA)**

The LCA is short (5-10mm) (Fig 3) and divides into the left anterior descending artery and the left circumflex artery. A common variant is a ramus intermedius (Fig 3) which is a branch which emerges at the bifurcation of the left coronary artery and travels along the antero-lateral wall of the left ventricle.

**Left Anterior Descending Artery (LAD)**

The LAD (Fig 3 & 4) travels along the anterior interventricular groove and gives off diagonal branches which emerge on the left side of the LAD and supply the anterior wall of the left ventricle. The diagonal branches are numbered sequentially starting (Eg. 1st Diagonal is the first proximal diagonal branch from the LAD, see Fig 4). The LAD also gives off septal branches which emerge on the right side of the LAD.

**Left Circumflex Artery (LCx)**

The LCx (Fig 3 & 4) travels along the posterior atrioventricular groove and gives off branches called the obtuse marginals (OM) (Fig 4).
Dominance

Dominance is determined by the coronary artery which gives off the PDA and PLB. Right coronary artery dominance is the most prevalent. If the LAD or circumflex artery gives off the PDA this is left coronary artery dominance. Co-dominance is present in 10% of the population where the right and left coronary artery supply the inferior aspect of the heart.

Anomalies of the Origin:

There are several different types of anomalous origins which are:

1. Origin from opposite sinus or non-coronary sinus
2. Origin from the pulmonary artery
3. Single coronary artery
4. Multiple ostia

Usually, these anomalies are not significant but in some cases this has potentially fatal implications from increased risk of myocardial ischaemia to sudden death.

They are:

- Anomalous right or left coronary artery from the opposite coronary sinus travelling in between the pulmonary trunk and aortic root. Sometimes called a malignant course or interarterial course.
- Anomalous origin of the left or right coronary artery from the pulmonary trunk.

1. Origin from opposite sinus or non-coronary sinus

The normal coronary artery arrangement has the right coronary artery coming off the right coronary sinus and the left coronary artery coming off the left coronary sinus. The non-coronary sinus normally does not have any coronary arteries originating from it. However, as the name suggests the origins of the right and left coronary arteries can occasionally originate from the opposite coronary sinus or from the non-coronary sinus. However, the significance of the origin is not as clinically important as the course by which the anomalous artery takes.

The route by which these anomalous coronary arteries travel can be divided into 4 main types which are:

- Retroaortic (Fig 5, 23 & 24)
• Prepulmonic (Fig 6)
• Interarterial (Malignant Course) (Fig 7 & 8)
• Subpulmonic (Fig 9-11)

Of these four courses, the interarterial/ malignant course is the most clinically significant as the coronary artery can potentially be occluded resulting in myocardial ischaemia by the expansion of the aorta and pulmonary artery causing compression (Fig 7).

2. Origin from the Pulmonary Artery

A rare but serious type of coronary artery anomaly which is normally detected in childhood. The frequency of this condition is estimated to be 1 in 300,000 live births. Unfortunately, 90% of patients not treated in the first year of life die from this congenital anomaly and only a few patients survive to adulthood (Fig 12-14).

Left coronary artery originating from the pulmonary artery/ trunk (Fig12-14) is more common than right coronary artery.

The treatment for anomalous left coronary artery originating from the pulmonary trunk (ALCAPA) is surgical. In infants, the LCA is directly reimplanted into the aorta or an intrapulmonary conduit is created from the LCA ostia to the aorta. In adults, the LCA is ligated and coronary artery bypass grafting is performed using either an internal mammary graft (Fig 15) or saphenous vein graft.

3. Single Coronary Artery

A rare anomaly with an incidence of 0.0024%- 0.044%. As the name suggests a solitary ostium originating from the aortic root is present (Fig 16-22). 20 different variations have been described by which the anomalous branches go on to supply the whole heart. Patients with this anomaly are expected to have normal life expectancy but they are at increased risk of sudden death as an occlusion at the ostium would result in catastrophic infarction of the entire heart.

4. Multiple Ostia

A benign anomaly in which more than the normal two ostia of the RCA and LCA are present in the aortic root. Common examples include the circumflex artery and LCA having separate ostia (Fig 5) and the conus branch and RCA having a separate ostia. This usually has no significant clinical implication except at coronary angiography which can be more technically challenging.
**Anomalies of the Course:**

Two types of anomalous courses:

1. Myocardial bridging
2. Duplication

### 1. Myocardial Bridging

This anomaly involves part of or the whole segment of a coronary artery travelling through the myocardium. The LAD is most commonly involved\(^6\) (Fig 25 & 26). Myocardial bridging has the potential for fatal complications as the myocardium encircling the coronary artery can cause complete occlusion of the vessel during systole leading to myocardial ischaemia.

In patients, where the clinician suspects a clinically significant myocardial bridge, images during diastolic and systolic phases should be obtained as the degree of luminal narrowing in the myocardial bridge can be assessed.

### 2. Duplication

A rare anomaly in which there is commonly duplication of the left anterior descending artery (Fig 27 & 28). There is usually a long LAD and a short LAD. A few case reports of right coronary artery duplication has been reported in the literature\(^7\) but this is a much rarer anomaly.

Duplication has no significant clinical implications except in the context of potential coronary bypass graft surgery.

**Anomalies of Termination:**

1. Coronary artery fistula

### 1. Coronary Artery Fistula

This is defined as an abnormal connection between a coronary artery and a cardiac chamber, major vessel or other vascular structure. The majority of these are asymptomatic and found incidentally. Commonly fistulas drain into the right side of the heart. Usually the right ventricle followed by the right atrium and pulmonary artery (Fig 29-33).
Fig. 1: Normal coronary artery anatomy. Volume rendered image showing the right coronary artery giving off a conus branch and an acute marginal branch.

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Fig. 2: Normal coronary artery anatomy. The inferior surface of the heart is shown on this volume rendered image with the right coronary artery giving off acute marginal artery and the posterior descending artery (PDA). This patient has right coronary artery dominance.

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Fig. 3: Normal coronary artery anatomy. Left coronary artery is shown dividing into the left anterior descending artery (LAD) and the left circumflex artery (Cx). Note, the patient also has a common variant which is a ramus intermedius artery emerging in between the bifurcation of the left coronary artery.

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**Fig. 4:** Normal coronary artery anatomy. Volume rendered image showing the left coronary artery giving off the left anterior descending artery (LAD) and left circumflex artery (Cx). A first diagonal branch (D1) is seen coming off the LAD on its left side to supply the left ventricular anterior wall. An obtuse marginal (OM) is also seen branching off the circumflex artery.

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**Fig. 5:** Anomalous circumflex artery (arrow) originating from the right coronary sinus with a retroaortic course on an oblique axial MIP image. This is also an example of multiple ostia as the circumflex artery has a separate origin from the LAD.

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**Fig. 6:** Anomalous RCA originating from LCA with a prepulmonic course.

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**Fig. 7:** Anomalous origin of the RCA from the left coronary sinus with a short interarterial/malignant course.

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**Fig. 8:** Sagittal oblique MIP image showing the anomalous RCA (arrow) with interarterial/malignant course lying inbetween the pulmonary trunk and aorta.

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**Fig. 9:** Anomalous origin of left coronary artery (LCA) coming off the right coronary sinus. The ventricles and pulmonary trunk have been phased out to show the left coronary artery origin and its subpulmonic course. (RCA = Right coronary artery)

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**Fig. 10:** Anomalous origin of left coronary artery (LCA) with subpulmonic course. Same patient as Figure 9. This coronal maximum intensity projection (MIP) image shows a long segment of myocardial bridging of the left coronary artery through the left ventricle wall.

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**Fig. 11:** Sagital MIP image of the figure 9 patient showing the left coronary artery (LCA) bridging the left ventricle wall and in a subpulmonic position.

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**Fig. 12:** Axial oblique MIP images showing the anomalous left coronary artery originating from the pulmonary trunk (ALCAPA). This patient was only diagnosed in his early 20s after presenting with symptoms of heart failure.

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**Fig. 13:** Same patient as figure 12 with the axial oblique MIP image taken slightly more inferiorly and showing the left coronary artery becoming the left anterior descending artery.

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**Fig. 14:** Curved planar reformat image of the ALCAPA in a sagittal oblique plane.

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Fig. 15: Post operative image of the ALCAPA in which the LCA ostium in the pulmonary trunk was closed up and a left internal mammary artery (LIMA) graft was used to supply the LCA.

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Fig. 16: An example of a single coronary artery on axial MIP images. This shows a single right coronary artery (RCA) which originates from the right coronary cusp. It has a normal course but this continues on in the form of the LAD and circumflex arteries. As demonstrated on these images, there is no left main stem coronary artery originating from the aortic root.

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**Fig. 17:** This axial MIP image from the same patient as figure 16 but taken slightly superiorly shows the left main stem is absent.

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Fig. 18: Single coronary artery. Volume rendered images of the patient in figure 16 and 17 shows the continuation of the right coronary artery as the posterior descending artery (PDA) which in turn continues on as the LAD and later the circumflex artery.

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Fig. 19: Volume rendered image showing the absent left main stem and the LAD continuing as the circumflex artery. This is not to be confused with the great cardiac vein which lies close by.

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Fig. 20: Angiogram LAO view images to correlate with the CT images of the single coronary artery. The right coronary artery is shown to continue towards the left heart and the subsequent images show the right coronary artery supplies the LAD which then leads on into the circumflex artery.

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Fig. 21: Angiogram LAO view images of the same patient as figure 20 with single coronary artery taken slightly further along the right coronary artery. The right coronary artery is now seen supplying the LAD.

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Fig. 22: Angiogram LAO view images of the single coronary artery showing the LAD supplying the circumflex artery and diagonal branch which correlates with the CT findings.

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Fig. 23: There is an anomalous origin of the left coronary artery from the non-coronary sinus with a retroaortic course.

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Fig. 24: Same as patient as figure 23. Image taken slightly inferior to figure 23 showing the branches of the anomalous left coronary artery.

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Fig. 25: Myocardial bridging of the LAD (arrow) on 2 chamber view.

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Fig. 26: Myocardial Bridging of the LAD (LAD) on short axis images.

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Fig. 27: LAD duplication

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**Fig. 28:** LAD duplication Volume rendered image shows the LAD duplication has an anomalous origin from the right coronary artery

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Fig. 29: Volume rendered image showing the right coronary artery fistula

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Fig. 30: Axial MIP image showing coronary artery fistulas (arrows) originating from the right and left coronary arteries and formed a connection with the main pulmonary trunk.

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Fig. 31: The coronary artery fistulas (arrows) from the same patient are shown draining into the main pulmonary trunk.

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Fig. 32: Coronary Angiogram LAO view of the same patient as figure 29 showing a coronary fistula coming off the right coronary artery (arrow).

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Fig. 33: Coronary angiogram of the left coronary artery of the same patient as figure 29 showing the second fistula coming off the left anterior descending artery.

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Conclusion

A variety of coronary artery anomalies (ie. anomalous origins, course and termination) have been demonstrated and particular clinically significant anomalies have been highlighted (eg. Interarterial course, ALCAPA, myocardial bridging).

Cardiac CT is an excellent imaging modality as it can highlight potentially significant coronary anomalies and guide surgical therapy.
References


