Detection and characterization of origin and course anomalies of the coronary arteries: review of 410 cases

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Purpose

We have reviewed 410 patients who have undergone a 64-MDCT coronary study for the detection and characterisation of origin and course anomalies of the coronary arteries (CA).

Coronary angiography is often performed to assess atherosclerotic arterial stenosis. But it is important to consider other possible causes of chest pain, including congenital anomalies and no atherosclerotic disease. The dramatic end result of a coronary artery anomaly can manifest at any age. The detection of these anomalies is essential to prevent its outcome, and its diagnosis is fundamental for treatment planning. Although the no stenosing pathology of the CA is rare, is important and often treatable.

In recent years, it is spectacular how the non-invasive study of the heart and coronary vessels by CT and MRI has developed. One of the most important advances is the temporal and spatial resolution improvement on CT imaging, allowing the visualisation of arteries as thin as the CA (origin, course and end). Therefore, it is essential to know the coronary anatomy, their most frequent variants and pathologies, for an appropriate approach for each patient.
Methods and Materials

The major arteries that are evaluated in MDCT are the right coronary artery (RCA), the left coronary artery (LCA) and its divisions: left anterior descending artery (LAD artery) and circumflex (Cx). The dominance is given by the CA that is origin of the posterior descending branches. Classically 85% from the right, 8% from the left and 7% of codominance. The coronary sinus originate from the aortic valves, usually three. The two anterior valves are the coronary sinus; from there, the RCA and LCA begin their course. The posterior valve is the noncoronary sinus.

We cannot forget that the quality of the study depends heavily on the heart rate (HR). The HR can be reduced to 60 bpm, this brings a quality imaging and a significant dose reduction. The drugs of choice are the beta-adrenergic blockers (beta 1 receptors, cardioselective), whose safety and short-term efficacy are proven in reducing the HR. There are several protocols for the administration of beta-blockers, either orally or intravenously (these ones produce a higher effect in reducing the HR).

Retrospectively we have reviewed 410 MDCT studies that were performed in our hospital (Cruces University Hospital, Vizcaya, Spain) during 2010 and 2011.

Previously, a beta-blocker is administered to the patient (Atenolol) or, if contraindication because of asthma or allergy, ivabradine (Procoralan), until a HR under 65 bpm.

All patients have undergone a prospective coronary study, ECG-gated Multi-Detector Row CT, (64 MDCT Lightspeed VCT, GE)

The injection protocols depends on the pump injector:

- Ulrich: 90 mL of iodinated contrast material (ICM) and 40 ml of NaCl at 5 mL/s for coronary study. 120 mL of ICM and 40 mL of saline at 5 mL/s for a triple rule out study.

- Stellant: triphasic injection of ICM (90 mL), a mixture of 60 mL (50% of ICM and 50% of ClNa) and 40 mL more of ClNa.
Results

In our review, 11 patients had different types of anomalies in the origin of the CA (2.68%) and 23 patients presented myocardial bridging (5.6%).

14 of the 34 patients with coronary anomalies, presented with symptoms: 6 of the 11 patients with an origin anomaly and 8 of 23 patients (34.78%) of those with myocardial bridging.

From the anomalous origins collected in our series, 7 had an RCA arising from the left coronary sinus (Fig 1), all with an interarterial course (Fig 2) between the ascending aorta and the pulmonary artery. This is the most common variant and is potentially malignant because its high risk for sudden cardiac death.

In our series, there is a patient with situs inversus (one of less common variants) whose LCA arises anomalously from the noncoronary sinus (Fig 4) and presents a retroarterial course (Fig 5). From it, arise the LAD artery and the Cx. In this case, the artery which feeds the RCA territory, arises from an anterior coronary sinus and gives branches that seem the posterior descendent artery (PDA).

Another patient, 44 year-old woman, presented with a single coronary sinus which originates the three main arteries (Fig 6). Their courses were different: the Cx had a retroartic course (Fig 7), and the LAD artery took a subpulmonic-septal course. This woman came to the Emergency Department (ED) complaining of chest pain, sweating and nausea, with the diagnosis of STEMI. Her ECG reflected an infero-posterior subepicardial injury. A stent was placed in the LAD artery because a 90% stenosis was evident in conventional angiography, affecting a 20 mm length segment. She also presented an intramyocardial bridge.

Other less important variants were a LAD artery arising from the left coronary sinus and taking a subpulmonic course (Fig 8); and the Cx arising from the RCA and taking a retroauricular course (Figs 9 and 10).

Of these 11 patients presenting CA anomalies, 4 were diagnosed by MDCT because their low-risk conditions and low pretest probability of coronary artery disease (CAD). The other 7 were diagnosed by conventional angiography, requiring 2 patients a MDCT confirmation for the different courses of the CA anomalies (one of them was the patient with a single coronary sinus but three ostium).
There have been performed 4 surgical interventions for reimplantation the anomalous CA in their corresponding sinus, with a good outcome for all of them. There were another 3 patients who had a CA arising from the contralateral sinus: one of them refused the surgery and was ruled out for the other 2, because of their age.

These anomalies may be incidentally diagnosed in less than 1% of healthy people. There are several conditions: a high takeoff, multiple ostia, single CA, ALCAPA syndrome (Anomalous Origin of the CA from the Pulmonary Artery), origin from the opposite or noncoronary sinus. In this last case, the CA arising from the opposite or noncoronary sinus can take any of four common courses (interarterial, retroaortic, prepulmonic or septal-subpulmonic).

On the other hand, of the 23 patients with myocardial bridging, 15 were located in middle segment of the LAD artery. The length of the segments varies from 10 to 60 mm. 8 of them presented a deep path (a deep path is considered >3 mm). 8 of 23 complained of atypical chest pain, of which only 3 underwent conventional coronary angiography. The angiography was normal for 2 of them and positive for the remaining patient presenting "milking". This one had the longer path (55 mm) and the greater depth (4 mm) (Fig 13).

Myocardial bridge is a variant defined as an intramural segment of a CA that normally courses epicardially. When the tunneled segment of CA takes a deep course through the myocardial thickness (Figs 14 and 15), a "milking" is induced by systolic compression; this effect is more severe in case of ventricular hypertrophy (Fig 16). The bridging is most commonly localized in the middle segment of the LAD artery and its strictures varying between 0.7 and 5.5%. The bridging often occurs without overt symptoms so it seems that symptoms are arguably caused by this condition (8 of 23 patients in our series). It can be explained because coronary flow occurs mainly in diastole, when there is no myocardial contraction and the blood requires a lower perfusion pressure.

Identified as less frequent finding, there was a patient with a RCA through the right atrial wall, along approximately 34 mm (Figs. 17 and 18).

It seems that conventional angiography underestimates this finding: only 1 of our patients (with the longest and deepest bridging), has been diagnosed by conventional angiography. It has traditionally been the gold standard for this pathology showing the typical "milking effect". However, MDCT clearly shows the intramyocardial location of the involved coronary arterial segment.
Images for this section:

**Fig. 1:** Axial and volume-rendered image (VR) showing the right coronary artery (RCA) arising from the left coronary sinus.

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**Fig. 2:** VR image shows an interarterial course of the RCA. Ao: Aorta. PA: pulmonary artery.

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Fig. 3: Curved MPR of the circumflex artery (Cx): this patient also had a permeable stent.

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**Fig. 4:** Situs inversus. Axial image. Theoretical left ventricle (LV) on the right side.

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**Fig. 5:** Theoretical LCA that arises from the posterior sinus, and its retroarterial course.

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**Fig. 6:** A common origin of the three coronary arteries from a single sinus. Oblique images showing the three ostium (red arrows): LCA, Cx and RCA from a single coronary sinus.

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Fig. 7: VR image showing the retroaortic course of the Cx artery (arrow).

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**Fig. 8:** Patient with dual anterior descendent artery: the abnormally artery arising from the right coronary sinus (ADA*) with the same origin as the RCA (it takes a subpulmonic course). And the LAD artery which arises from the LCA (normally from the left coronary sinus).

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**Fig. 9:** Cx artery from RCA and retroatrial course. VR image: A. Anterior view. B. Postero-superior view.
Fig. 10: VR image showing different projections of the anomalous origin and course of the Cx artery.

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**Fig. 11:** Curved MPR. 32 year-old patient with a reimplanted RCA in the corresponding sinus. Previously, she had a RCA arising from the left coronary sinus. Surgical material. Arteries filled of contrast material.

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**Fig. 12:** VR image: A. View of the reimplanted RCA and surgical sutures (arrow). B. View of a normal LCA, and its branches (LAD artery and Cx).

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**Fig. 13:** Curved MPR and transverse LAD artery axis image showing the artery included in the thickness of the myocardium along 5 cm.

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Fig. 14: Transverse axis images of two coronary arteries, showing the difference between an intramyocardial bridging (left image) and a CA that normally courses epicardially (right image).

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Fig. 15: MPR on the transverse axis and curved reconstruction of a LAD artery presenting a deep course (>3 mm).

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Fig. 16: MPR on the transverse axis and curved reconstruction of the Cx through the left ventricular wall thickness.

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Fig. 17: Axial, coronal and curved MPR. A RCA with an atypical course in the thickness of the right atrial wall.

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Fig. 18: Curved MPR of the RCA. We can see the middle segment of the RCA surrounded by the right atrial wall (RA).

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Conclusion

1. The anatomic variations of the CA are uncommon, both in its origin, course and perfusion territories. This allows radiologists performing standard reports on such studies.

2. The vascular abnormalities in the heart may be clinically very relevant. Thus, radiologist should be aware of the most frequent alterations.

3. In our study, 20 of 34 patients with some coronary anomalies had no symptoms, so we are detecting more alterations in the CA than expected. This is probably due to the great development of the cardiac imaging in recent years.

4. Furthermore, it has been reported that angioCT (MDCT) may be superior to conventional angiography in defining the origin and proximal course of anomalous coronary branches. The 64-MDCT equipment are being sufficient for an adequate study of the coronary tree.

5. The MDCT has high sensibility and high NPV to rule out coronary disease. It is important to recognize the potential diagnostic failures caused by artifacts (motion, venous staining…). The middle segment of the RCA is the mostly affected by motion artifacts.
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