Rediscovering the third coronary artery

A second right coronary artery is not at all unusual, as described here from Oxford, England

Introduction

Anatomy and functionality of the coronary circulation have been of interest to physicians ever since it emerged that mammalian hearts have their own blood supply. If asked how many coronary root vessels the normal human heart has, most medical students (and many practitioners) would answer ‘two’. Some might refer to a possible abnormal supernumerary left coronary artery, present in about 5% of patients. However, the frequent presence of two right coronary artery (RCA) roots is not generally well appreciated, even though it has been evident to anatomists and cardiac surgeons for centuries.

Reference to this can be traced back in the European medical literature to Giovanni Battista Morgagni’s 1761 De Sedibus et causis morborum per anatomem indagatis (see Supplementary material online, References). Justus Halbertsma (1863), author of an early extensive case study in human coronary artery lay-outs, commented: ‘two coronaries are all but rare and multiplication of coronaries is so common that one is almost embarrassed and has to question whether what we established as normal above (two coronaries) really is the norm’. At about the same time, Richard Quain’s seminal atlas of human vascular anatomy illustrated the presence of three coronary root vessels, one left and two right (Figure 1), as ‘the most frequent or standard conformation of the vessels’.

That very configuration continues to be illustrated in modern anatomy textbooks, such as Gray’s, although now in a graphically less vivid fashion.

The second RCA-root arises from the right aortic sinus of Valsalva, most commonly ventral to the main RCA. In cases where there is no distinct additional RCA, it is usually replaced...
by the first branch of the main RCA. In either configuration, this vessel generally supplies the Conus venosus, and part of the upper septum. Occasionally, a supernumerary artery arises dorsally to the RCA, then usually feeding the sino-atrial node.

This anatomical insight is in contrast to how the coronary circulation is portrayed in modern ‘functional’ textbooks, which describe the presence of two coronary roots (left and right) as the physiological standard. This view filters through even to specialist communications on cardiovascular system function, diagnostics, or therapeutic interventions.

Three questions arise in this context:

(i) What is the relative propensity of a second RCA?
(ii) If cardiac surgeons and anatomists know that a second RCA is common—why do the rest of us not?
(iii) Does this knowledge matter?

**Second RCA propensity**

In order to address the first question, it is helpful to recapitulate past observations and relate them to technologies used to study coronary artery configuration.

For the assessment of propensity, one should note that different names have been applied to the second RCA. Arturo Banchi (1904) called it the ‘adipose artery’, Georges Piquand (1910) referred to it as ‘l’artère graisseuse de Vieussens’, and Al Crainicianu (1922) used the term ‘arteria preinfundibularis’. Since the seminal work of Monroe Schlesinger et al. (1949), ‘conus artery’ has been preferred. However, the term has been used to refer to different vessel—origin configurations: a ‘true’ second RCA (with separate or shared aortic ostium, relative to the main RCA), or the first branch of the main RCA. Even if one allowed the term conus ‘artery’ for the latter configuration, rather than conal branch of the RCA, it should be applied only in the confirmed absence of a true second RCA. Such exclusion criterion is not generally applied.

Further confusion may arise from variations in second RCA ostium location, which may form an independent entity, or share access to the aortic blood pool with the main RCA, both originating from a small ‘bulge-like’ extension of the aortic wall. A clear distinction between two RCAs (both vessels connected in parallel to an equally accessible aortic blood pool) and one RCA with a conal branch (where conal access to the aortic blood pool involves an in-series connection) may not always be possible, even if attempted. This may account for some of the variation in reported second RCA incidence. It may also contribute to an apparent age-related increase in propensity, reported by Brooks Edwards et al. (1981) and Motonobu Miyazaki and Morio Kato (1986), as aortic growth could integrate lateral bulges more smoothly into the aortic wall, making distinction of separate ostia easier.

With these limitations in mind, we conducted a meta-analysis of 35 case series (see Supplementary material online, bibliography) involving 12,161 human hearts, revealing a mean prevalence of the second RCA of 23.8%.

Reported incidence appears related to the method used for vessel identification. Based on in-situ imaging, mean prevalence of a second RCA was 14.5% (six studies; 4,787 hearts; prevalence 2.4–40.9%). In contrast, ex-situ inspection revealed a second RCA in 29.8% (29 studies; 7,374 hearts; prevalence 7.6–93.8%). This method dependence may be explained by the second RCA-size:proximal vessel diameter is ≏1 mm in adult human, which is at the limit of spatial resolution for non-invasive imaging (one needs three voxels indicating wall/lumen/wall to discern a vessel, yet few routine in-vivo imaging techniques have voxel sizes <0.5 mm). In addition, techniques requiring contrast agent injection may fail to discover a second RCA (see below). This suggests that the lower apparent incidence observed in vivo may result from false-negative detection errors, so that true prevalence of a second RCA in humans is likely to be closer to ex-vivo observations.

Thus, while we are not able to offer a firm value in response to question (i), a second RCA in humans clearly is far from unusual, with prevalence apparently exceeding one-third.

**A knowledge gap**

If RCA propensity is indeed that high, why is this fact not much more widely appreciated? One possible explanation is that the predomiance of non-invasive imaging, in particular in functional cardiovascular investigations, has helped us to be accustomed with the picture of coronary root—vessel configuration that these methods offer. In addition, classical anatomical training has been de-emphasized in modern medical curricula (e.g. see Stanley Monkhouse, 1992); so that a ‘functional imaging-compatible’ view of anatomy may appear both opportune and convenient, perhaps answering the second question.

If second RCA occurrence is indeed more common than generally assumed by non-anatomists/non-cardiac surgeons, the final question regarding relevance of the second RCA is even more important.

**Second RCA relevance**

In 1981, David Levin et al. analysed the frequency of failure to visualize any conus artery during coronary angiography of 508 patients. They reported that in patients with a separate conus artery ostium, it was visualized only if there was reflux of contrast medium from the main RCA injection site into the right aortic sinus. Such inadvertent filling of the second RCA was described in ~30% of cases. They speculated that another ~20% of patients, in whom no conus artery was visualized at all, also had a second RCA. Similar occurrences of ‘missing vessel’ in myocardial tissue with normal contractility prompted Javier Escaned et al. (1992) to suggest searching for a second RCA, using narrow-gauge catheters to facilitate engagement with small ostia, to resolve apparent discrepancies between coronary anatomy, clinical history, and ventricular function. However, indiscriminate injection of contrast medium into the right aortic sinus has been associated with arrhythmogenesis, including ventricular fibrillation. Therefore, without an awareness-driven approach to RCA angiography, the presence of (and abnormalities in) the flow-bed of a second RCA may go undetected.

The functional relevance of second RCA blood supply has been illustrated in several case reports, but has not been investigated systematically. Ray Matthews and Stephen Oesterle (1989) found that occlusion of the conus artery during angiography can result in ST-segment elevation. Jonas Eichhofer and Nicholas Curzen (2005) reported similar results during angioplasty, as well as chest pain and evidence of myocardial infarction. Matthews and...
Oesterle also highlighted the importance of a second RCA as a source of collateral supply during chronic occlusion of the main coronary arteries, potentially with the ability of maintaining adequate myocardial perfusion even in severe coronary artery disease. This was also demonstrated by Abdul Rathore et al. (1970), Gregory Mishkel et al. (1991), Escaned et al. (1992), Tuvia Ben-Gal et al. (1997), and José de Agustín et al. (2010).

In addition, undiagnosed disease of conus arteries with separate ostia could represent a cause for unexplained cardiac pathologies, including ‘idiopathic’ RVOT arrhythmias. Therefore, in answer to question (iii): it would seem that knowledge of the second RCA may indeed matter.

**Summary**

It would appear that there is a chasm between anatomical insight and its functional application regarding coronary artery root configuration. Ongoing improvements in non-invasive imaging may help to swing the pendulum back to a more anatomically grounded view, and promote re-evaluation of the true prevalence of different coronary artery root layouts in different patient cohorts in vivo. Awareness of the fact that the right aortic sinus can contain multiple coronary ostia, and that these give rise to a second RCA that feeds the RVOT in a third of patients (possibly more), would seem to be relevant to heart research, diagnostics, and treatment.

**Supplementary material**

Supplementary material is available at *European Heart Journal* online.

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**References**

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