Indian Heart Journal 69 (2017) 81–86

Contents lists available at ScienceDirect

Indian Heart Journal

journal homepage: www.elsevier.com/locate/ihj

Original Article

A study of coronary artery variants and anomalies observed at a tertiary care armed forces hospital using 64-slice MDCT

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ARTICLE INFO

Article history:
Received 1 April 2016
Accepted 31 May 2016
Available online 10 June 2016

Keywords:
Coronary artery variants
Coronary CT angiography
Coronary artery anomalies

ABSTRACT

Background: Isolated coronary artery anomalies are usually clinically silent and mostly detected incidentally during angiography or autopsy. However, few of them may be implicated in cases of sudden cardiac death even in the absence of additional heart abnormalities. Prior knowledge of such variants and anomalies is necessary for planning various interventional procedures. Multiple detector computed tomography coronary angiography has proved a very useful non-invasive modality in this field given its superiority over conventional coronary angiography in providing detailed coronary artery anatomy.

Methods: A retrospective review of the coronary CT angiography studies was carried out at our center between August 2014 and December 2015 with the purpose of describing the coronary artery variants and anomalies that we came across in our cohort.

Results: In our cohort, about 77% (n = 391) of the patients had a right dominant system while left dominant and co-dominant systems were seen in 12% (n = 61) and 11% (n = 56) respectively. Coronary CT angiography was successful in visualizing smaller branches, such as the conus artery (96.25%, n = 489), the sinus node artery (83.07%, n = 422), and the septal branches (95.27%, n = 484). Coronary anomalies were observed in the 10.04% of our population (n = 51). Eleven anomalies of origin and course were found.

Conclusion: Coronary CT angiography gives us a good understanding of the variations and anomalies of the anatomy of the coronary arteries. This can be of immense help to the clinician planning interventional procedures.

1. Introduction

It has been a constant endeavor in coronary artery imaging to find a variety of non-invasive techniques that may successfully replace invasive conventional coronary angiography. Some of these techniques like electron-beam computed tomography (CT) and magnetic resonance have shown promising results; however, they are limited by their inadequacy for large-scale clinical implementation and limited availability.[1–3] The introduction of multiple detector computed tomography coronary angiography has been a significant step forward in this direction. For improved isotropic spatial resolution and faster temporal resolution of the latest 64-slice and above, computed tomography equipment is a viable alternative to conventional coronary angiography in select patient populations.[4,5]

While there is still no consensus regarding the differentiation between coronary artery variants and anomalies, Angelini et al.[6] have proposed that any variation from the normal anatomy that is found in more than >1% of the general population be considered a variant, while those occurring in <1% of the population may be designated as anomalies.

The most cited study describing the various coronary variants and anomalies based on catheter angiography by Angelini et al.[6] described and classified various anomalies based on origin, course, branching pattern, and termination of coronary arteries. They reported an incidence of anomalies in about 1% of the general population.

Following the establishment of coronary CT angiography as an alternative to catheter angiography, a few articles have also been published on the variations and anomalies detected using coronary CT angiography. The incidence of coronary anomalies is purportedly higher using coronary CT angiography compared to conventional angiography. According to Cademartiri et al.,[7] catheter angiography

Abbreviations: RCA, right coronary artery; LCX, left circumflex artery; LAD, left anterior descending artery; CAD, coronary artery disease; CT, computed tomography.

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http://dx.doi.org/10.1016/j.ihj.2016.05.018
0019-4832/

cannot detect ectopic openings of coronary arteries being a two-dimensional study. They have reported 100 (18%) anomalies from 543 consecutive coronary CT angiography done using a 64-slice CT scanner. On coronary CT angiography, 14 (16.5%) coronary anomalies were detected among the 85 patients without any associated coronary artery disease in their study, while 86 coronary anomalies (18.8%) were detected among the 458 patients with significant coronary artery disease.

Not only do variations in coronary anatomy have a known association with structural forms of congenital heart,[8] but an anomalous coronary artery with an oblique origin, intramural course (within the wall of the aorta), or positioning between the great arteries puts the coronary arteries at risk for compression and may significantly limit the reservoir capacity of the epicardial coronary system. Myocardial ischemia is thus the commonest manifestation of these anomalies. Coronary artery anomalies are clinically significant as a cause of sudden death in asymptomatic individual. Taylor et al. found a significantly higher risk of exercise related sudden death in a retrospective review of clinicopathologic records of 242 patients with isolated coronary artery anomalies.[9] Prior knowledge of such variants and anomalies is necessary for planning various interventional procedures.

In this study, we propose to describe the various coronary artery variants and anomalies discovered in an Indian subset with symptomatology suggestive of coronary artery disease (CAD).

The aim of this study is to increase awareness about the various coronary artery variants and anomalies in a symptomatic subset of Indian population.

2. Materials and methods

This is a retrospective review of the coronary CT angiography study carried out at our center. The study period was from August 2014 to December 2015.

The aim of this study is to describe the coronary artery variants and anomalies that we have come across in our cohort.

2.1. Inclusion criteria

All patients undergoing coronary CT angiography for suspected/diagnosed coronary artery disease.

2.2. Exclusion criteria

Nil.

2.3. Imaging

All examinations were performed using a GE Discovery PET/CT 610 64-Slice PET/CT scanner with the following parameters: tube voltage 120 kV, tube current 250 mAs effective, collimation 64 mm $\times$ 0.6 mm, effective slice thickness 0.6 mm, reconstruction increment 0.3 mm, and rotation time 330 ms. Images were acquired from the level of carina to the base of the heart.

Patients with heart rate >70 beats per minute received 50 mg of metoprolol twice daily for three days prior to the examination. A bolus of 1.5 mL/kg of iso-osmolar non-ionic iodinated contrast medium (290 mg/mL of iodine) was injected into the antecubital vein at the rate of 5 mL/s using a pressure injector. Image acquisition was triggered manually using bolus tracking keeping the ROI cursor in left ventricle.

Data were reconstructed by retrospective gating in end-diastolic phase (from −300 to −450 ms before the peak of the subsequent R wave). Retrospective gating was used in our study since our cohort comprised symptomatic patients, in whom it was desirable to provide functional analysis which is not available in prospective gating in spite of its benefit of lower exposure to ionizing radiation.

2.4. Definitions

Normal coronary artery anatomy was defined as falling under the criteria laid down by Angelini et al. for normal features of the coronary anatomy in humans.[6] According to these criteria, the coronary arteries may arise only from the upper midsection of right and left coronary sinuses respectively with an orientation of 45–90° off the aortic wall. A common trunk is seen exclusively on the left side. The course of the coronary arteries should be subepicardial with termination into the capillary bed. The right coronary artery (RCA) supplies the free wall of the right ventricle and the left anterior descending artery (LAD) supplies the anteroseptal wall while the left circumflex artery (LCX) supplies the left ventricular free wall.

2.5. Image and data analysis

All coronary CT angiography examinations were loaded into a dedicated workstation (Brilliance, Phillips, USA). All data were analyzed with post-processing tools such as multiplanar reconstructions, curved multiplanar reconstructions, maximum intensity projections, and volume rendering to three-dimensionally image the complex anatomy of the coronary artery tree. Segments were classified according to the American Heart Association scheme.[10]

Variants considered were:

1. Coronary dominance (right, left, balanced)
2. Variable origin of the conus branch and sinus node artery
3. Presence of the ramus intermedius branch

Anomalies considered were:

1. Anomalies of origin and course
2. Intrinsic coronary anomalies
   i) Myocardial bridging
   ii) Aneurysms >1.5 mm
3. Anomalies of termination (fistulas)

Prevalence data of coronary artery variants and anomalies were collated in a tabulated form.

2.6. Ethical issues

This study conforms to widely accepted ethical principles guiding human based research.

As this is a retrospective observational study not involving any additional risk to the patients, we received approval for the study from the institutional ethics committee with a waiver of consent.

3. Results

A total of 508 patients underwent CT coronary angiography at our center between August 2014 and December 2015.

The mean age of the patients in our cohort was 54.2 $\pm$ 13.7 years and the majority of these were in the age group of 51–60 years. Male patients formed the majority 78% of the cohort while female patients formed the rest 22%.

3.1. Coronary artery variants

We have enumerated the coronary variants as well as the number of smaller branches observed in our study, to reiterate the superiority of coronary CT angiography in depicting even the

Table 1
Prevalence of coronary artery variants.

Variants	Patients % (n)
Conus branch	
From proximal RCA	65.15 (331)
From ostial RCA	17.91 (91)
From aorta	13.18 (67)
	3.74 (19)
Sinus node artery	
From RCA	62.59 (318)
From LCX	12.20 (62)
From RCA and LCX	8.07 (41)
From LCX and PA	0.19 (1)
Not detected	16.92 (86)
Ramus intermedius	21.85 (111)
Diagonal branches from LAD	
Not detected	1.37 (7)
1	35.23 (179)
2	56.10 (285)
>2	7.28 (37)
Septal branches from LAD	95.27 (484)
Marginal branches from LCX	
Not detected	0.19 (1)
1	46.25 (235)
2	35.82 (182)
>2	17.71 (90)

RCA, right coronary artery; LAD, left anterior descending artery; LCX, left circumflex; LM, left main.

minutest details of coronary anatomy. Also, since the primary role of coronary CT angiography is in screening patients for conventional catheter angiography, it thus provides a reliable roadmap for interventional procedures.

In our cohort, about 77% ($n = 391$) of the patients had a right dominant system while left dominant and co-dominant systems were seen in 12% ($n = 61$) and 11% ($n = 56$) respectively.

Coronary anatomy variants discovered in our study are tabulated in Table 1.

Ramus intermedius branch was seen in approximately 21.92% ($n = 111$) of the patients and we observed fewer diagonal branches in its presence. This was slightly less than reported in the literature.[11] A direct correlation between presence of ramus intermedius branch and decreased number of diagonal branches is observed.

Furthermore, coronary CT angiography was successful in visualizing smaller branches, such as the conus artery (96.25%, $n = 489$), the sinus node artery (83.07%, $n = 422$), and the septal branches (95.27%, $n = 484$).

Septal branches of the LAD were detected in the 95.3% of the patients. The opportunity of reporting septal branches of LAD must be taken into account because of the hemodynamic relevance of these vessels.

3.2. Coronary artery anomalies

Coronary anomalies were observed in the 10.04% of our population ($n = 51$) and anomalies of course and origin comprised about 2.1% ($n = 11$). Eight patients without significant CAD presented with coronary anomalies. Three patients with significant CAD (with >50% stenosis, during stent or by-pass follow-up) were found to have associated coronary anomalies.

Patients presenting with single or associated coronary anomalies were classified as follows (represented in given in Table 2):

- Anomalies of origination and course
- Anomalies of intrinsic coronary arterial anatomy
- Anomalies of coronary termination

Table 2
Incidence of hemodynamically significant and non-hemodynamically significant coronary artery anomalies.

Coronary anomalies	Patients % (n)
Hemodynamically significant anomalies	1.37 (7)
RCA arising from left coronary sinus	0.59 (3)
LCX arising from right coronary sinus	0.39 (2)
LAD arising from right coronary sinus	0.19 (1)
Deep myocardial bridging	0.19 (1)
Non-hemodynamically significant anomalies	8.66 (44)

In our study, we found four cases of ectopic RCA (three from left coronary sinus and one from non-coronary sinus) and four cases of ectopic LCA arising from right coronary sinus. The LCX was seen arising from right coronary sinus in two patients. Two cases of dual LAD arising from LCA (Fig. 1) and two cases of accessory LCX arising from left coronary sinus were observed respectively. One case revealed absence of LCX with a super-dominant RCA coursing in left atrio-ventricular groove and supplying the territory of LCX. One case uniquely revealed a common origin of RCA, LCX, and LAD from the right coronary sinus (Fig. 2). In twenty patients, the left main artery was absent and LAD and LCX were seen arising from separate ostia in left coronary sinus.

Only one patient was found to have deep myocardial bridging while superficial myocardial bridging was seen in 98 patients.

These coronary artery anomalies can be further classified into "malignant" and "benign". An interarterial course (between the aorta and pulmonary artery) is called "malignant" as it is associated with increased risk of myocardial ischemia or sudden cardiac death. Various hypotheses for this increased risk include compression between the pulsating vessels during heavy exercise, presence of a slit-like opening, or an acute angulation at the origins of such arteries.[12] We found six cases of such "malignant" anomalies in our study. Out of this, three were cases of anomalous origin of RCA from left coronary sinus. The RCA was seen traversing between the pulmonary trunk and aorta to reach its final position in right atrio-ventricular groove. Two cases of anomalous origin of LCX from right coronary sinus were observed. In one case with common origin of RCA, LCX, and LAD from the right coronary sinus, the LAD was seen taking an interarterial course to reach the anterior ventricular groove.

4. Discussion

Correct interpretation of a coronary variant or anomaly leads to lesser complications during interventional procedures, for purposes of revascularization. Coronary anomalies are usually discovered accidentally and are often asymptomatic. Their detection is gaining clinical importance, given the increase in interventional procedures being carried out in today's day and age. The coronary anomalies cannot be considered just rare aspects because they may often lead to relevant clinical consequences.[13]

Conventional catheter angiography was traditionally considered the "gold standard" for diagnosis of coronary anomalies. However, conventional catheter angiography is limited by the fact that it is a two-dimensional modality providing information about complex three-dimensional anatomy. Also, in conventional catheter angiography, the diagnosis of a coronary anomaly is often established upon the impossibility of finding the coronary artery in its normal anatomical position.[14,15]

In recent years, many techniques have been developed for coronary anatomy imaging; however, out of these, multiple detector computed tomography shows the most promise.

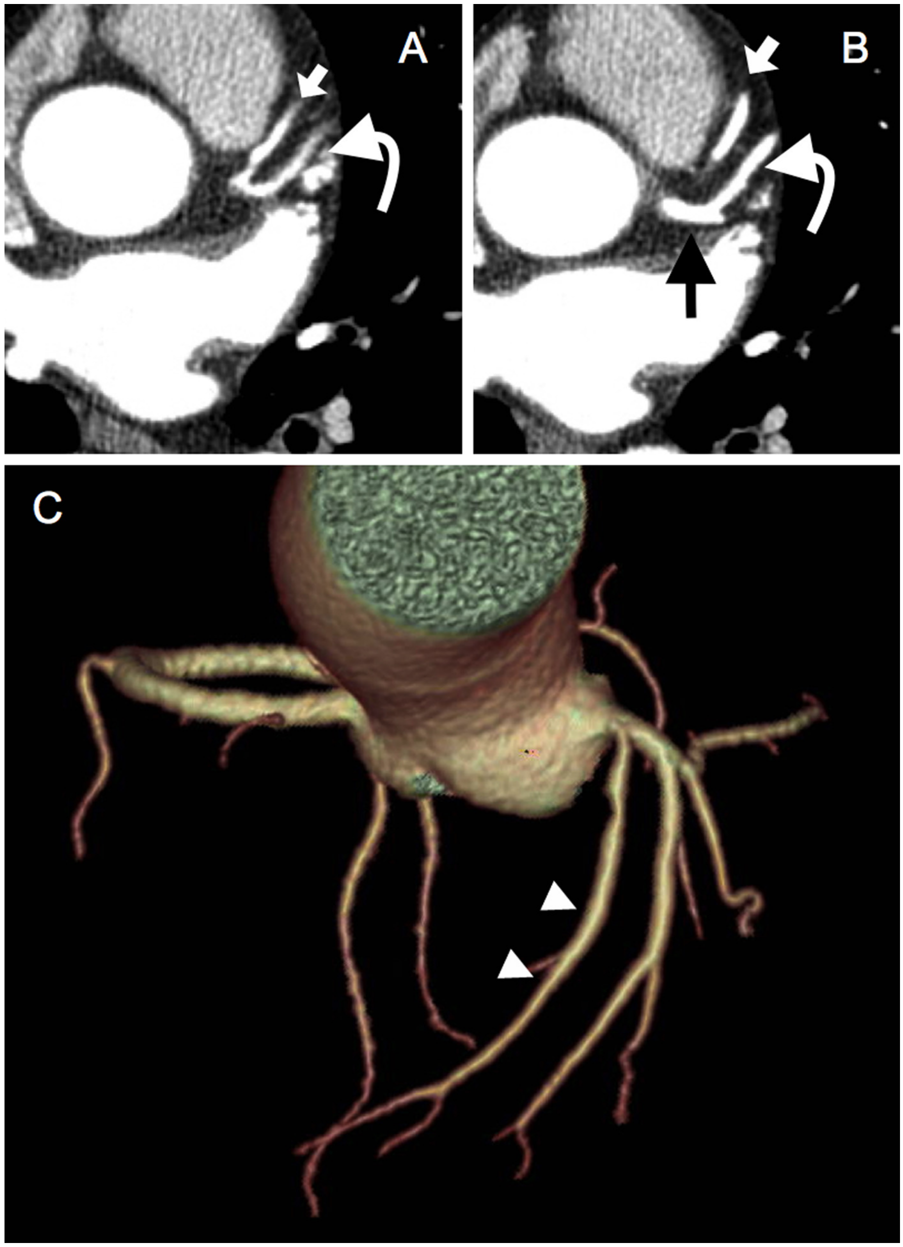

Fig. 1. (A, B) Axial images showing the accessory LAD (white arrow) coursing through the interventricular groove. The LM (black arrow) is seen dividing into the conventional LAD and LCx. The conventional LAD (curved white arrow) is seen coursing alongside the accessory LAD branch toward left along the interventricular groove. (C) VRT (volume rendered technique) image in the same patient reveals accessory LAD (white arrowheads) arising from the left main artery just proximal to its bifurcation.

The advantages of multiple detector computed tomography lie primarily in its high level of diagnostic and anatomical accuracy. The technique offers excellent spatial resolution with the possibility of performing a flexible post-processing (i.e. multi-planar reconstructions, maximum intensity projections, and volume rendering).

Ropers et al.[2] first studied the ability of contrast-enhanced electron beam computed tomography to accurately identify anomalous coronary arteries and their course. Recent advances in multiple detector computed tomography equipment have continuously improved the quality of non-invasive coronary artery imaging. Various studies have demonstrated a high negative predictive value of 64-slice computed tomography for excluding significant coronary artery stenoses.[4,5,16] By selecting only those patients with significant coronary lesions to undergo conventional catheter angiography, multiple detector computed tomography-coronary angiography could avoid cardiac catheterization in a large number of patients without CAD. The latest advance of computed tomography technology is represented by the dual-source computed tomography coronary angiography with improved temporal resolution overcoming the previous limitations in patients with extensive coronary calcifications and poor heart rate control.

In our study, unfortunately we could not compare the efficacy of coronary CT angiography and conventional catheter angiography since all patients with coronary anomalies did not suffer from atherosclerotic coronary artery disease that was severe enough to warrant conventional catheter angiography.

The study with the largest number of cases, performed in North America at the Cleveland Clinic on 126,595 patients who underwent coronary angiography, reported an incidence of 1.3% for coronary artery anomalies.[17]

Table 3
Comparison of our findings with two other published studies using conventional catheter angiography and 64-slice MDCT coronary angiography respectively.

Variable	Our study (%)	Conventional catheter angiography, Angelini et al.[6] (%)	64-Slice MDCT coronary angiography, Cademartiri et al.[7] (%)
Coronary anomalies (total)	10.2	5.64	18.4
Ectopic RCA	0.78	2.05	0.36
Fistulas	–	0.87	0.5
Absent left main coronary artery	3.93	0.67	3.3
Circumflex arising from right sinus	0.59	0.67	0.55
LCA arising from right sinus	0.78	0.15	0.36
Other anomalies	1.77	0.27	13.07
Coronary dominance patterns			
Dominant RCA	77	89.1	86.6
Dominant LCX	12	8.4	9.2
Codominant arteries (RCA, LCX)	11	2.5	4.2

We have studied the incidence of coronary variants and anomalies in a symptomatic subset of the Indian population. A table comparing our findings with two other published studies using conventional catheter angiography and 64-slice multiple detector CT coronary angiography respectively is given in Table 3.

The incidence of right dominance (77%) was much lower in our study compared to similar studies in the western population[6,7] while incidence of left dominance (11%) and co-dominance (12%) was relatively higher.

In our study, the incidence of coronary anomalies (10.04%) was almost double the incidence of anomalies in a study by Angelini et al.,[6] (5.64%) using conventional catheter angiography. This could be due better depiction of coronary artery anatomy using coronary CT angiography vis-à-vis conventional catheter angiography resulting in higher detection rate for these anomalies. Compared to another study by Cademartiri et al.,[7] that was done using 64-slice multiple detector computed tomography (18.4%); however, our incidence was much lower which could be explained by the small size of our cohort compared to that study as well as by the inclusion of only symptomatic patients in our study.

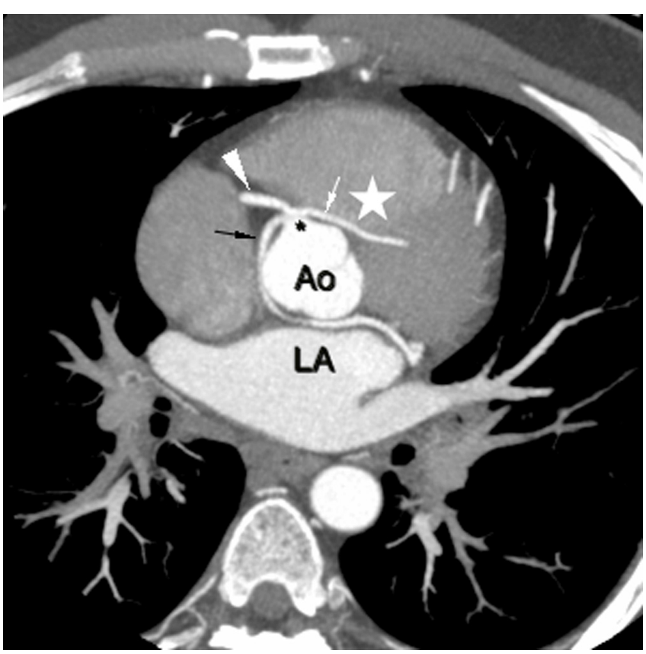

Fig. 2. Axial image showing common origin (*) of right coronary artery (arrowhead), left anterior descending (white arrow), and left circumflex (black arrow) arteries from right coronary sinus at the root of aorta (Ao). Also, note interarterial "malignant" course of left anterior descending artery between aorta and origin of pulmonary trunk (★).

The incidence rate of absent left main artery was found to be much higher in coronary CT angiography studies compared to conventional catheter angiography and this was the commonest anomaly of origin in our cohort as well, as opposed to the finding of split RCA in conventional angiography. Meanwhile, the incidence of other specific anomalies was more or less in consonance with other studies.

Also surprisingly, we found myocardial bridging in only about 19.3% of our cohort, out of which there was only one case of deep myocardial bridging with significant vessel attenuation. This is much lower than the usual reported rate of about 30% in other published studies.

We saw only 5 cases of coronary aneurysms while not a single case of anomalies of termination was observed. This lower incidence may reflect lower incidence of these anomalies in the Indian populace.

Even though, isolated coronary artery anomalies are usually clinically silent and mostly detected incidentally during angiography or autopsy, the hemodynamically significant anomalies may be implicated in cases of sudden cardiac death. In a study by Taylor et al.,[9] the incidence of sudden cardiac death in cases of isolated coronary artery anomalies was approximately 32% and out of these, 45% sudden deaths occurred during exercise. Also, the risk of sudden death was significantly higher in younger patients (<30 years). Detection of these anomalies, in our study, was promptly reported to the clinician who was then able to better advise and guide the patient as regards prevention of morbidity/fatality. This significantly benefited patient, the discussion of which is beyond the purview of our study.

4.1. Study limitations

Our study is limited by the small size of our cohort and the fact that the patients were symptomatic with coronary artery disease and hence not representative of the general population.

5. Conclusion

Coronary CT angiography is extremely useful in demonstrating the variations and anomalies in the coronary artery anatomy. This knowledge gains clinical importance in planning interventional procedures such as stenting, balloon dilatation, or graft surgery, particularly when there are secondary changes of atherosclerosis and stenosis. The greatest advantage of coronary CT angiography is the high spatial and temporal resolution it provides, thus enabling us to visualize and confirmed the ectopic origins of anomalous arteries and their paths with greater ease and confidence.

By this study, we hope to sensitize the environment to the incidence and distribution of coronary artery variants and anomalies in the Indian context. Although the relatively small cohort presently limits our study, nonetheless, we will continue to collate data on the ongoing coronary CT angiography studies carried out at our department and are planning to expand into a multi-centric study involving other service hospitals to further our knowledge in this field.

What is already known?

- That 64-slice MDCT is superior to other available modalities in depiction of coronary artery anatomy and there have been a number of publications on incidence of coronary artery variants and anomalies using 64-slice MDCT western literature.

What this study adds?

- This study adds to the existing knowledge on the demographic trends of these variants and anomalies in the Indian context, as very few similar studies on the subcontinent's population exist.

Conflicts of interest

The authors have none to declare.

References

1. McConnell MV, Ganz P, Selwyn AP, Li W, Edelman RR, Manning WJ. Identification of anomalous coronary arteries and their anatomic course by magnetic resonance coronary angiography. *Circulation.* 1995;92:3158–3162.
2. Ropers D, Moshage W, Daniel WG, Jessl J, Gottwik M, Achenbach S. Visualization of coronary artery anomalies and their anatomic course by contrast-enhanced electron beam tomography and three-dimensional re-construction. *Am J Cardiol.* 2001;87:193–197.
3. Gaither NS, Rogan KM, Stajduhar K, et al. Anomalous origin and course of coronary arteries in adults: identification and improved imaging utilizing transesophageal echocardiography. *Am Heart J.* 1991;122:69–75.
4. Leschka S, Alkadhi H, Plass A, et al. Accuracy of MSCT coronary angiography with 64-slice technology: first experience. *Eur Heart J.* 2005;26:1482–1487.
5. Mühlenbruch G, Seyfarth T, Soo CS, Pregalathan N, Mahnken AH. Diagnostic value of 64-slice multi-detector row cardiac CTA in symptomatic patients. *Eur Radiol.* 2007;17:603–609.
6. Angelini P, Velasco JA, Flam S. Coronary anomalies: incidence, pathophysiology and clinical relevance. *Circulation.* 2002;105:2449–2454.
7. Cademartiri F, La Grutta L, Malagò R, et al. Prevalence of anatomical variants and coronary anomalies in 543 consecutive patients studied with 64-slice CT coronary angiography. *Eur Radiol.* 2008;18:781–791.
8. Shirani J. *Isolated Coronary Artery Anomalies*. Available from: http://www.emedicine.com.
9. Taylor AJ, Rogan KM, Virmani R. Sudden cardiac death associated with isolated congenital coronary artery anomalies. *J Am Coll Cardiol.* 1992;20(3):640–647.
10. Austen WG, Edwards JE, Frye RL, et al. A reporting system on patients evaluated for coronary artery disease. Report of the Ad Hoc Committee for Grading of Coronary Artery Disease, Council on Cardiovascular Surgery, American Heart Association. *Circulation.* 1975;51:5–40.
11. Levin DC, Fallon JT. Significance of the angiographic morphology of localized coronary stenoses: histopathologic correlations. *Circulation.* 1982;66:316–320.
12. Rahalkar AM, Rahalkar MD. Pictorial essay: coronary artery variants and anomalies. *Indian J Radiol Imaging.* 2009;19(1):49–53.
13. Becker AE. Congenital coronary arterial anomalies of clinical relevance. *Coron Artery Dis.* 1995;6:187–193.
14. Maron BJ, Thompson PD, Puffer JC, et al. Cardiovascular preparticipation screening of competitive athletes: a statement for health professionals from the Sudden Death Committee (Clinical Cardiology) and Congenital Cardiac Defects Committee (Cardiovascular Disease in the Young), American Heart Association. *Circulation.* 1996;94:850–856.
15. Baltaxe HA, Wixson D. The incidence of congenital anomalies of the coronary arteries in the adult population. *Radiology.* 1977;122:47–52.
16. Mollet NR, Cademartiri F, van Mieghem CA, et al. High-resolution spiral computed tomography coronary angiography in patients referred for diagnostic conventional coronary angiography. *Circulation.* 2005;112:2318–2323.
17. Yamanaka O, Hobbs RE. Coronary artery anomalies in 126,595 patients undergoing coronary arteriography. *Cathet Cardiovasc Diagn.* 1990;21:28–40.