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ORIGINAL ARTICLE

Coronary arteries variants & congenital anomalies; using MDCT to assess their prevalence in 1000 of the Egyptian population

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KEYWORDS

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MDCT;
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Abstract *Objectives:* To display the prevalence rate of the coronary artery anatomical variations & congenital anomalies in 1000 patients of the Egyptian population using multidetector computed tomography (MDCT) exhibiting its diagnostic capability.
Patients & methods: MDCT angiography was used to examine 1000 patients (clinically suspected patients with CAD & others with suspected congenital cardiac anomalies). Coming fasting, non-contrast cardiac CT was carried after intravenous injection of contrast material & ultra-thin cardiac scanning. Images were analyzed with MPR, cMPR, MIP & VR. The data of coronary artery variations and anomalies were gathered.
Results: Among 1000 patients, most of patients (88.7%) had right coronary dominance. Type III LAD was the most prevalent (77.4%). Most of patients (47.3%) had two diagonal branches arising from the LAD. The incidence of congenital anomalies was 18.9%. Myocardial bridging was the most frequent reaching 16.8% (88.9% among all anomalies).
Conclusion: Wide range of variation was noted among the examined population. Satisfying imaging capability of MDCT was encountered making it an essential tool for assessing coronary artery variants and anomalies before coronary revascularization being accurate & less invasive than conventional angiography.

1. Introduction

Coronary artery anomalies can be fatal during or subsequent to heavy physical activity, usually in young population. The information of coronary anomalies is also crucial for cardiologist before performing any invasive procedure in coronary artery disease patients. The coronary anomalies cause 11.8%

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deaths in young athletes in USA. Another study showed that a considerable percentage (12%) of sudden cardiac deaths with sports activity originated from coronary abnormalities (1).

Screening of coronary anomalies in population is becoming viable with Contrast-enhanced CT angiography. In comparison with Conventional angiography, coronary CTA has developed into an imperative non-invasive modality in diagnosing coronary artery diseases. Being of high temporal and spatial resolution, multislice computed tomography (MSCT) enables detailed visualization of coronary artery anatomy without artifacts, especially motion artifact. The origin, course, anomalies and variations of the coronary artery with the anatomy of the heart can now be meticulously studied with coronary CTA. Furthermore, radiologists became more skilled in interpreting the cross-sectional images of the coronary arteries, declaring their normal anatomy & anomalies, that finally improved diagnostic precision (1).

2. Patients and methods

2.1. Study population

One thousand patients were scheduled for elective MSCT coronary angiography between January and August 2014. CT was clinically requested for coronary assessment & exclusion of coronary heart disease. They were referred to the CT unit in Al Kasr Al Ainy hospitals and to one of the radiological centers.

Patients included 653 male patients with 347 female patients, with the age range between 16 days and 86 years and mean age was 55 years old.

Exclusion Criteria include Pregnant women, heart rate irregularity, contrast media allergy, renal insufficiency (creatinine $\geqslant$1.5 mg/dL), inability to hold breath for 8 s, morbid obesity & patient with bad general condition needing life support.

3. Methods

3.1. Image acquisition

All patients were instructed to fast 4–6 h prior to the examination with no discontinuity of their medications. They were taught to hold breath. Those with heart rate above 75 bpm were given beta blockers (50 mg Atenolol) 45 min prior to the examination (unless contraindicated), to prolong the diastole phase time of the cardiac cycle, which facilitates acquisition process. Non-contrast ECG gated thin sections were carried through the coronary arteries to detect and calculate the coronary calcium score. Injection of 80 ml of non-ionic contrast material through an arm vein at a high flow rate (5.5 ml/s) is to be followed by injecting 40 ml of saline with the same flow rate simultaneous with rapid acquisition of ultra-thin sections through the heart to evaluate the coronary arteries. In children, the examination was performed under general anesthesia, high heart rates were accepted, no calcium scoring performed, the contrast volume was justified according to the patient's body weight and the rate of injection was reduced.

Coronary CTAs were performed by 320-row CT scanners (Aquilion ONE, Toshiba Medical Systems, Tochigi-ken, Japan), using examination parameters as follows: 120 kv, 165 ms, 900 mAs, slices/collimation 320/0.5, speed of tube rotation 350 ms, temporal resolution (180° algorithm), table feed/s 11.63 mm, effective slice thickness 0.6 mm, images reconstruction increment 0.3 mm, field of view (FOV) was 140–180 mm.

3.2. Image analysis

Finished CT examinations were analyzed on the workstation by two experienced radiologists in cardiac CT. All coronary arteries were studied at 75% and 40% of the cardiac cycle with selective reconstruction of the improperly visualized coronary segments at different cardiac cycle phases. All the collected images were assessed using different tools of image post-processing such as maximum intensity projections (MIP), multiplanar reconstruction (MPR), curved MPR (cMPR) & volume rendering (VR) to fully visualize the coronary artery anatomy. Variations in the coronary artery anatomy such as coronary dominance, conus branch and sinus node artery variable origins, left main (LM) length, the existence of the intermediate branch, the number of marginal & diagonal branches were assessed. Coronary anomalies in their origin and course, myocardial bridging and fistulas were also checked. Finally the prevalence data of coronary artery variation & anomalies were registered.

4. Results

A total number of 1000 patients were referred for coronary CT angiography, 347 females and 653 males, ranging in age between sixteen days and 86 years with mean age of about 55 years (Table 1).

4.1. Anatomical variants of coronary arteries (Table 2)

4.1.1. Coronary dominance

The right dominance was 88.7% (887 patients), left dominance was 9.9% (99 patients) and the co-dominance was 1.4% (14 patients), where we considered the dominance by the PDA artery, i.e. co-dominance means that both the RCA and the LCX give PDA branches.

4.1.2. Left anterior descending branch

In the studied group the LAD was type I in 2% of cases (20 patients), type II in 4.2% of cases (42 patients), type III in 77.4% (774 patients) and type IV in 16.4% of the studied group (164 patients), where type I means LAD not supplying the apex, type II means LAD partially supplying apex, type III means LAD totally supplying apex and type IV means LAD wrapping around the apex.

Table 1 Gender and mean age distribution of our examined study group.

	Males	Females
Gender (%)	65.3	34.7
Mean age	53	57

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Table 2 Prevalence of the anatomical variations among our study group.

Dominance	
RCA	88.7%
LCA	9.9%
Co-dominant	1.4%
LAD type	
I	2%
II	4.2%
III	77.4%
IV	16.4%
Number of diagonals	
One	31%
Two	47.3%
More than two	21.7%
Number of OM branches	
One	59.9%
Two	31.7%
More than two	5.3%
Not identified	3.1%
Ramus intermedius branch	31.2%
High lateral branch	34%
Conus branch	
RCA	47%
Right sinus	14%
Common origin	34.8%
Two branches	1.2%
SA nodal branch	
RCA	54%
LCX	21.8%
LMT	0.2%
Two branches	1%

4.1.3. Diagonal branches

31% had one diagonal arising from the LAD, 47.3% had two diagonals, 17.3% had three diagonal branches, 4.3% had four diagonals and 0.1% had five diagonal branches arising from the LAD.

4.1.4. Obtuse marginal (OM) branch

3.1% of the cases had no OM branch, 59.9% had one OM branch, 31.7% had two OM branches, 5.1% had three OMs, and 0.2% had four OM branches arising from the LCX.

4.1.5. Ramus intermedius branch

31.2% of the cases the LMT tri or quadrifurcated to give ramus branches, 30.3% had one ramus branch while 0.9% had two rami arising from the LMT.

4.1.6. High lateral branch

34% of the cases have high lateral branches arising from the LCX, 31.6% one HL branch and two high lateral branches in 2.4% of the cases.

4.1.7. Conus branch

It couldn't be identified in 3% of the cases, while in 14% of the cases it is seen arising directly from right coronary sinus away from the RCA origin, 34.8% arising with the RCA in common origin from the right coronary sinus, 47% arising from RCA and 1.2% have two conus branches one from the RCA and the other from the right coronary sinus in a common origin with the RCA.

4.1.8. SAN branch

In 23% of the cases it couldn't be identified, while in 21.8% of the cases it is seen originating from the LCX, 54% from the RCA (52.8% from RCA and 1.2% in common origin with RCA from right sinus), 0.2% from LMT and 1% have two SA nodal branches, one from LCX and the other from the RCA.

4.2. Coronary arteries congenital anomalies (Table 3)

Total incidence of congenital anomalies was 18.9% (189 patients), 54 females (28.6%) and 135 males (71.4%). Myocardial bridging was the most frequent anomaly reaching 16.8% of the entire study group, and separate ostia for the LCX and LAD from the left coronary sinus (Fig. 1) was found in 0.9% of cases, ectopic origin from another sinus in 0.4%, single coronary artery in 0.4% of cases, high takeoff in 0.2%, fistula in 0.1% and finally ALCAPA in 0.1% of the cases.

Single coronary artery (Fig. 2) was seen in 0.4% (4 patients) of our patients, one with absent RCA, with the LCX after giving PDA continues in the right AV groove supplying RCA territory, and RV branch arising from LAD and runs anterior to the RVOT to each RV free wall. Another case with single coronary artery arises from tubular aorta 3 mm above the sino-tubular junction, then divides into two branches, one directed toward the right AV groove, taking the RCA course and the other running in a prepulmonic course and then divides into two branches, one directed toward the anterior IV groove to reach it near its lower portion (presumed LAD) and the other directed toward the left AV groove (presumed LCX). The third case showed LMT arising from the RCA and having an interarterial course. The last case showed RCA arising from LAD at mid IV groove and running in a prepulmonic course.

Anomalous coronary artery origin from an improper sinus was seen in 4 patients (0.4%), two with anomalous RCA from the left coronary sinus anterior to the origin of the LMT and having interarterial course in its way (Fig. 3) to reach the right AV groove. Another patient showed anomalous origin of the LMT from non-coronary sinus. The last patient showed anomalous origin of LMT from right coronary sinus, running in the prepulmonic region to reach the mid part of the anterior interventricular groove.

High takeoff was seen in two cases with the two involving the RCA. In the first it was arising from the tubular aorta above the right sinotubular junction. The second one was arising from the left anterolateral aspect of the tubular aorta.

Coronary fistula was seen in one patient (0.1%), 16 day old female child with suspected fistulous communication by echo, and she had posteriorly directed fistulous communication between the proximal RCA, that reached 3.3 mm in diameter, and the right atrium with 2 mm fistulous opening after which the RCA was of normal caliber and course.

ALCAPA (Fig. 4) was seen in one patient (0.1%), 14 year old male child who had previous conventional coronary angiogram that suspected ALCAPA, and CCTA was done

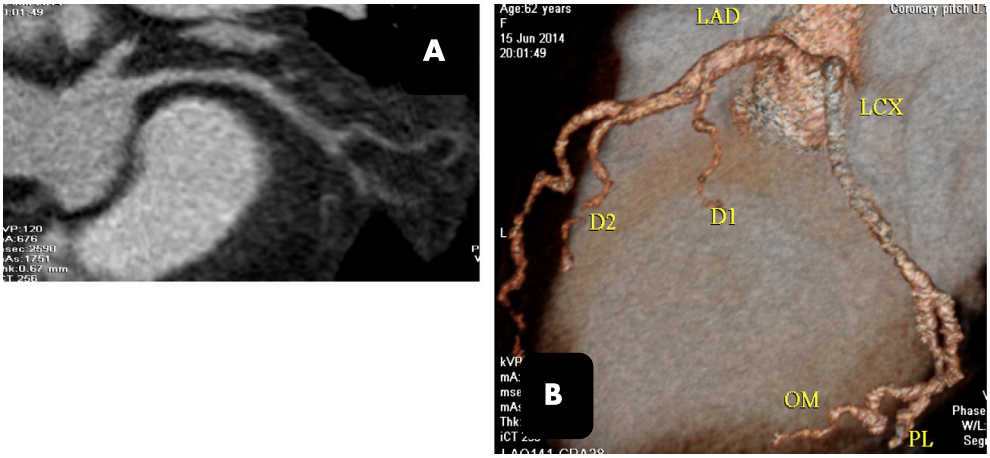

Fig. 1 LAD and LCX separate ostia. (A) CPR image showing separate ostia for LAD and LCX from LS. (B) VR image showing LAD and LCX with separate origins from LS.

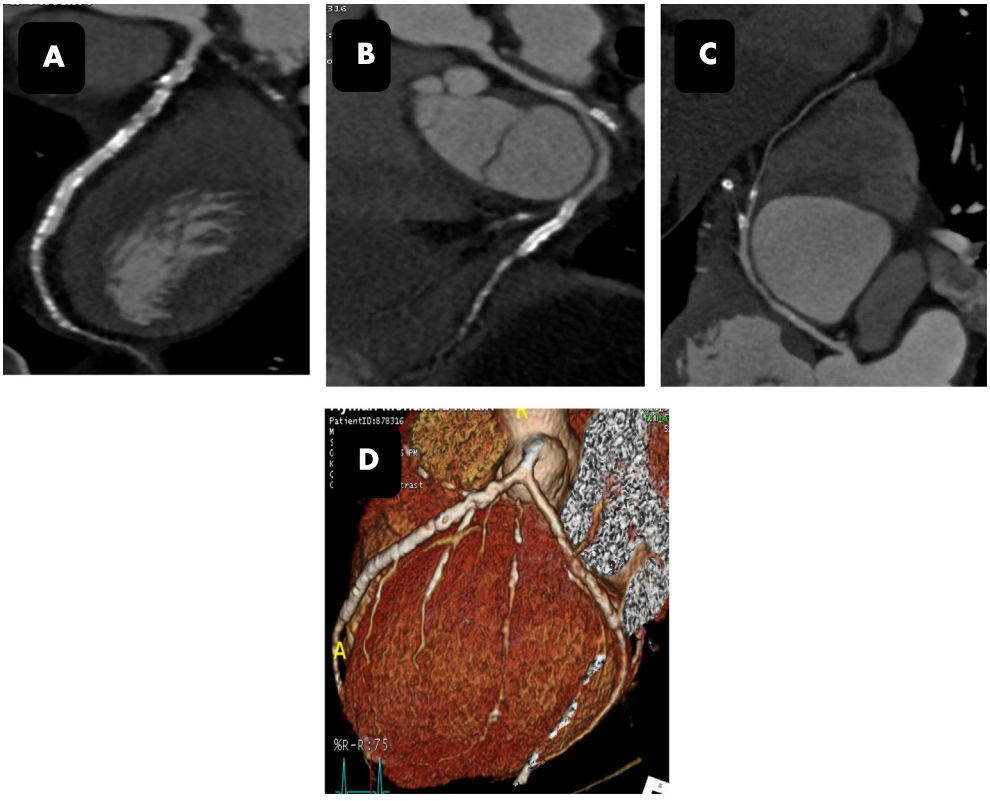

Fig. 2 Single coronary artery: congenitally absent RCA with left coronary dominance. The distal LCX, after it supplies the PDA, continues running in the right AV groove and supplies the RCA territory. (A) CPR image showing the LMT giving LAD. (B) CPR image showing LMT giving LCX then OM1. (C) CPR image showing continuation of the LCX in the Rt AV groove. (D) VR image showing LMT trifurcates into LAD, ramus intermedius and LCX arteries.

and revealed that the LMT was seen arising from the main pulmonary artery, and is mildly dilated (5.6 mm in diameter).

5. Discussion

Before coronary revascularization procedures, precise evaluation & description of the coronary artery tree is greatly needed, to report possible coronary variations or anomalies which may possibly cause technical difficulties during coronary interventional procedures & end in catastrophic complications for the patient (2).

We proposed that: *normal finding*, that can be any morphological feature observed in >1% of an unselected population: *normal variant*, which is relatively unusual finding, with a morphological feature seen in >1% of the population;

Table 3 Prevalence of the different congenital anomalies among our study group.

	Number of cases	% Among anomalies (%)	% Among study group (%)
Myocardial bridging	168	88.9	16.8
Separate ostia	9	4.8	0.9
Single coronary	4	2.1	0.4
Ectopic origin	4	2.1	0.4
High takeoff	2	1.1	0.2
Fistula	1	0.5	0.1
ALCAPA	1	0.5	0.1

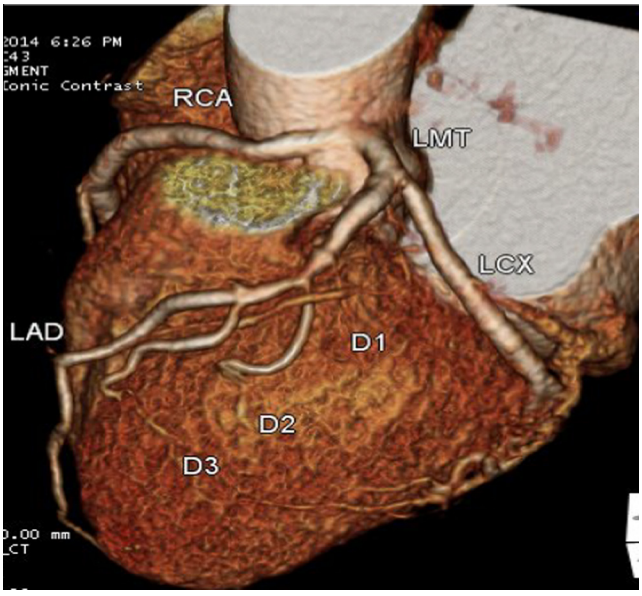

Fig. 3 Ectopic origin of RCA from LCS. (A) RCA appears from the left coronary sinus anterior aspect. The proximal segment runs between the ascending aorta and the RVOT (inter-arterial course) with caliber attenuation.

& *an anomaly*, that is a rarely encountered morphological feature (< 1%) in the general population (3). These coronary anomalies are claimed to be responsible for 19% of sudden deaths in young people, that is why their diagnosis should be a medical issue (4).

For a long time, conventional Coronary angiography (CCA) has been the "gold standard" for assessing the coronary arteries. Unawareness about the atypical location of the vessel orifice by the operator, can make selective coronary catheterization & its assessment so difficult in CCA. It also does not provide three dimensional images that can be very helpful for detailing the coronary anatomy (5).

In cardiologic diagnostic imaging, transthoracic echocardiography (TTE), trans-esophageal echocardiography (TEE), magnetic resonance angiography (MRA) and MSCT are used (6).

TransThoracic Echocardiography (TTE), is almost limited to pediatric patients as it is difficult to be applied in adults because of the chest wall barrier compared to a child chest wall, in addition to pulmonary parenchyma and subcutaneous tissues. In spite of being an invasive technique, trans-esophageal echocardiography (TEE) is more sensitive than TTE in the detection of coronary anomalies but it is operator dependent & consequently cannot be used for screening of coronary arteries (7).

Magnetic resonance angiography MRA is advantageous in inducing no ionizing radiation & it can give additional information about the associated cardiac anomalies (chambers, myocardium & valves anomalies), to be superior to CCA. However, it cannot visualize the whole length of the coronary arteries, making it quiet difficult to diagnose coronary fistulas (8).

Using 64-slice CT coronary angiography, a high negative predictive value was achieved (i.e. reliable exclusion of a significant coronary artery stenosis can be made) (9). So, it can represent a possible alternative to CCA for coronary arteries assessment being also non-invasive. Now, with the dual-source CT coronary angiography, temporal resolution is further improved providing high diagnostic accuracy for coronary assessment, even with extensive coronary calcifications & without adjusting the heart rate (10).

MSCT coronary angiography gives excellent spatial resolution. In addition to its ability to produce informative

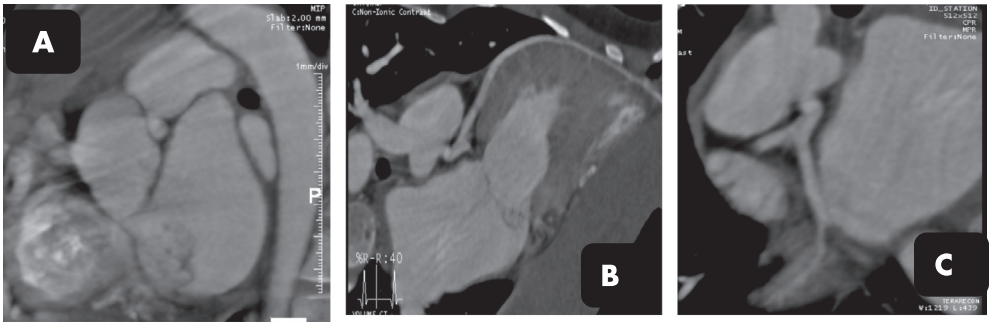

Fig. 4 ALCAPA in 14 years old male patient, with a murmur heard on his chest. Echo was recommended that suspected fistula with the pulmonary artery. CCA was done and suspected ALCAPA so CCTA assessment was required. (A) Sagittal oblique images showing the left coronary artery originating from the pulmonary artery, ALCAPA. (B) CPR image showing LAD continuation of the LMT which is originating anomalously from the pulmonary artery. (C) CPR MIP image of LMT giving LCX.

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post-processing images, it provides high diagnostic accuracy level (11).

Over a period of 10 months, we performed one thousand diagnostic CTCA studies using 320 slices MSCT. Coronary artery dominance was found to be right sided in 88.7%, left sided in 9.9% and co-dominant in 1.4%, close to Bazzocchi et al. (12) that found right dominance in 88.1%, left sided in 8.5% and co-dominant in 3.4% (conducted study over 3236 patients), while Mehta and Agarwal (1) (conducted study over 106 patients) found right dominance in 85%, left dominance in 12% and co-dominance in 2.8% and Erol and Seker (13) (conducted study over 2096 patients) found right dominance in 86.6%, left dominance in 9.6% and co-dominance in 3.8% of the cases. This difference is mostly due to the difference in defining co-dominant or balanced circulation, where mainly, the co-dominance is a condition where branches from both the distal RCA and the distal LCX supply the posterior interventricular septum. However, co-dominance was defined by other authors as a condition where the PDA is seen originating from the RCA, and the PLB is originating from the LCX.

The intermediate branch was identified in 31.2% matching with Erol and Seker (13) who found it in 31.3% of the cases, however not matching with Mehta and Agarwal (1) who found it in 16.98%. In our study, out of this 31.2%, 30.3% had single ramus branch and 0.9% had two ramus intermedius branches, close to Bazzocchi et al. (12) who found two intermediate branches in 0.8% of cases that appeared after left main stem quadrifurcation.

Regarding the number of the diagonal branches of the LAD, our results were not totally going with those reported by Bazzocchi et al. (12) as the presence of one or two diagonal branches was seen in 78.3% of our patients while >90% in theirs. However, regarding the number of marginal branches from LCX the reverse happened as we agreed with Bazzocchi et al. (12) who found one or two OMs in >90% and we found it in 91.6% of the patients.

In our study the variation in LAD was found as type I in 20 cases (2%), type II in 42 cases (4.2%), type III in 774 cases (77.4%) and type IV in 164 cases (16.4%) in controversy with Mehta and Agarwal (1) results who found type I in 24.5%, type II in 34.9%, type III in 23.5% and type IV in 16.9%. This could be attributed to the use of the high end MSCT scanner that allowed better evaluation of the distal LAD segment.

Talking about the congenital anomalies, the incidence is 18.9% (when myocardial bridge is included as an anomaly) among our study population matching with 18.4% as found by Cademartiri et al. (14) (conducted study over 543 patients), while 1.55% as found by Tariq et al. (15) (conducted study over 900 patients).

Myocardial bridging was found in 16.8% of our study group (88.9% of the congenital anomalies), making it a variant rather than a congenital anomaly, agreeing with Mehta and Agarwal (1) who found myocardial bridging in 11.3% of their population. When excluding myocardial bridging as an anomaly, the incidence of congenital anomalies was 2.1% in our study.

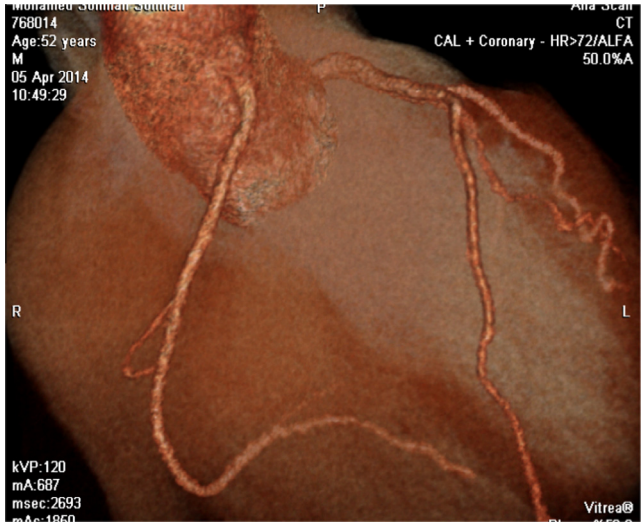

Fig. 6 High takeoff of LMT: VR image showing the LMT arising above the sino-tubular region from the tubular ascending aorta.

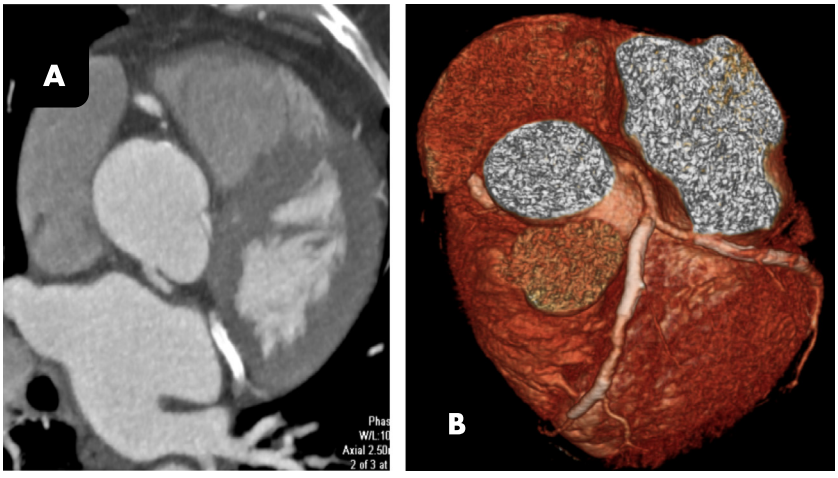

Fig. 5 LMT arising from non-coronary sinus with right dominance. (A) Axial MIP image showing the LMT originating from the non-coronary sinus. (B) VR image showing the LMT originating from the posterior non-coronary sinus and branching into LAD and LCX branches.

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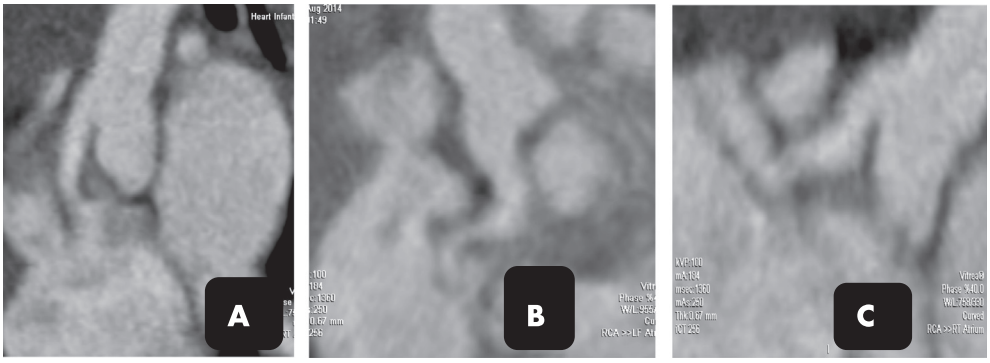

Fig. 7 Coronary fistula in a sixteen day old female child with suspected fistulous communication by echo. The proximal segment of the RCA is dilated, measuring about 3.3 mm in average diameter. The dilated segment of the proximal RCA supplies an anomalous fistulous communication that passes posteriorly to open in the right atrium (could be a dilated atrial branch or SA nodal branch of the RCA). The diameter of the fistula opening into the right atrium is about 2.0 mm. (A), (B) and (C) CPR images showing fistulous communication between the RCA and the Rt atrium.

100% of the myocardial bridges in our study were found in LAD with 81.5% involving the mid segment only, 12.5% involving the distal segment only, 4.8% involving mid to distal segment and 1.2% involving the proximal and mid segments. Erol and Seker (13) found that 76% were located in the mid LAD, 18% in the distal LAD, 2.4% in the mid to distal LAD, 0.9% in the RCA, 0.9% in the intermediate artery, and 0.9% in the PDA. Ghadri et al. (16) found that MB was involving the LAD in 88% with stating that the most affected portion is the mid segment.

Another frequently encountered anomaly is separate ostia for LAD and LCX from the left coronary sinus, and it was 0.41% in the study by Tariq et al. (15). A single coronary artery was seen in 0.4% (4 patients) of our study group, agreeing with Tariq et al. (15) who found it in 0.33% of their study group.

Ectopic origin of the coronary artery (Fig. 5) was found in 0.4% of our cases (one with ectopic LCA from non-coronary sinus, two with ectopic RCA from the left coronary sinus and one with ectopic LMC from the right coronary sinus), close to Tariq et al. (15) who found it in 0.22% of their cases and Erol and Seker (13) who stated that the RCA originates from the LCS in 0.03–0.5% and it is rare for the coronary artery to originate from a non-coronary sinus.

High take-off of the coronary arteries (Fig. 6) from the tubular aorta was found in 0.2% of our cases matching with Erol and Seker (13) mentioning that the CCTA incidence of high take-off is under 1% (0.43–0.8%).

For the coronary fistula (Fig. 7), there was only one case among our patients (0.1%) with fistulous communication between the RCA and the right atrium, matching with Temperikidis et al. (17) finding it in 0.16% of their patients.

Finally, the ALCAPA was found in 0.1% of our cases, agreeing with Tariq et al. (15) who found it in 0.11% of their study group. It was in one patient, 14 year old male child who had previous conventional coronary angiogram that suspected ALCAPA. Coronary CTA was done and revealed the origin of the LMT from the main pulmonary artery near its site of bifurcation, and is mildly dilated 5.6 mm in diameter.

Among our cases, three had a malignant course, running interarterially between the ascending aorta and RVOT and they complained of ischemic symptoms. Being discovered early by CCTA before leading to significant ischemic outcomes offers a chance for management to avoid the occurrence of myocardial infarcts or sudden death.

To conclude, wide range of variation was noted among the examined population. Satisfying imaging capability of MDCT was encountered making it an essential tool for assessing coronary artery variations and anomalies before coronary revascularization being accurate & less invasive than conventional angiography. Also it can assess almost the whole length of the coronary arteries to be superior over MRA. The exposure to high radiation should be a matter of concern in young patients. So, the use of MRI would be advisable in these patients with suspected complex congenital heart disease, to avoid radiation exposure & to assess those suspected cardiac anomalies (18).

Finally, that study statistically showed the spectrum & the prevalence of coronary variations & anomalies among a sample of the Egyptian population, in the same time displaying the capabilities of MDCT in assessing the coronary arteries, its advantages & disadvantages.

Conflict of interest

We have no conflict of interest to declare.

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