World Journal of Cardiovascular Diseases, 2023, 13, 261-274
https://www.scirp.org/journal/wjcd
ISSN Online: 2164-5337
ISSN Print: 2164-5329

Coronary Artery Anomalies Detected by Multi-Detector Computed Tomography: A Single Centre Experience

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How to cite this paper: Hammad, B., El-sharkawy, E., Morsi, Y., Shabaan, N., Eltahan, S., Elshafi, M., Abohashem, S., Mir, T. and Elwany, M. (2023) Coronary Artery Anomalies Detected by Multi-Detector Computed Tomography: A Single Centre Experience. *World Journal of Cardiovascular Diseases*, **13**, 261-274.
https://doi.org/10.4236/wjcd.2023.136023

Received: April 7, 2023
Accepted: June 6, 2023
Published: June 9, 2023

Abstract

Background: Coronary artery anomalies (CAA) prevalence represents less than 1% of congenital heart diseases. It includes anomalies in origin, course, and termination. Its detection has been easier with advances in imaging techniques using multi-detector computed tomography (MDCT). MDCT helps not only detection of the anomalous origin, but it allows delineation of the course and termination of the arteries, differentiation between benign and malignant courses, and guiding therapeutic interventions. **Results:** There were consecutive patients with a low-to-intermediate probability of coronary artery disease scanned with 128 MDCT. Each patient underwent a non-contrast prospective gating acquisition for coronary calcium scoring followed by contrast-enhanced helical retrospective gated scans for the detection of coronary artery origin, course, termination, and detection of concomitant atherosclerosis. We scanned 1000 patients with a mean age of 57.5 ± 8.3, and 68% were males. Thirty-two anomalies were noted (3.2%) including; nineteen (1.9%) anomalous origin from the opposite sinus, three (0.3%) anomalous left coronary arteries from the pulmonary artery (ALCAPA), one (0.1%) super dominant left anterior descending artery (LAD) giving origin to the posterior descending artery (PDA), three single coronary arteries (0.3%)in which the left main (LM) and right coronary arteries were originating with a common stem from the right coronary sinus (RCS)and the LM took a pre-pulmonic course. Along with six (0.6%) dual LAD including five (0.5%) patients with type I (short LAD and long diagonal), there was one (0.1%) type 4 with an extra LAD originating from the RCS

with a pre-pulmonic course. **Conclusions:** MDCT allows easy detection of coronary anomalies with high spatial resolution and overcomes limitations in conventional invasive coronary angiography. Based on our study we recommend the use of MDCT as an efficient and feasible modality for the diagnosis of coronary anomalies once this pathology is clinically suspected.

Keywords

Coronary Artery Anomalies, Spatial Resolution, Multi-Detector Computed Tomography

1. Background

Invasive coronary angiography has been the first adopted method for diagnosing coronary artery anomalies (CAA); however, it allows 2 D data acquisition and carries some limitations in the detection of coronary artery course and termination. [1] Moreover, Detection of CAA is of paramount importance, especially in young athletes as it represents the second most common cause of sudden cardiac death (SCD). [2] [3] Currently, Multi-detector computed tomography (MDCT) allows 3D data acquisition with a high spatial resolution that helps in detection of coronary artery origin, course, and termination. [4] [5] [6] MDCT helps in decision-making in patient management and guiding subsequent therapeutic interventions. Indeed, the prevalence of CAA has increased with the introduction of MDCT into the clinical arena [3].

2. Methods

Data were obtained retrospectively from a pool of 1000 consecutive patients referred to our facility with a low-to-intermediate probability of coronary artery disease for MDCT gated coronary scan. The main complaint was angina and palpitation; however, one patient was referred following resuscitation from SCD. Patients were screened for risk factors for coronary artery disease.

The human material was performed in accordance with the Declaration of Helsinki (Alexandria University ethics committee, reference number: 0306082).

3. Exclusion Criteria

1) Renal impairment (CrCl < 40 ml/min);
2) Claustrophobia;
3) History of severe or anaphylactic reaction to iodinated contrast;
4) Inability to cooperate with scan protocols;
5) Hemodynamic instability, decompensated heart failure;
6) Acute myocardial infarction.

Multi-detector computed tomography data acquisition.

Patients were fasting for 4 - 6 hours before the scan. B-blockers were administered half an hour before the scan for those with a heart rate above 65 beats/minute.

Images were acquired using 128 slices -MDCT (Aquilion 128 Toshiba Medical system): slice collimation of 128 × 0.5 mm, tube voltage of 120 kV, and a tube current of 450 mAs, gantry rotation time of 400 msec, and slice thickness of 0.5 mm with a helical retrospective gating. A bolus of 80 ml intravenous non-ionic contrast (Iopamidol 370) (0.5 - 2.0 mL/kg, 80 mL maximum volume) was injected followed by a 10 - 30 mL saline flush at rates ranging from 1.5 to 2.5 mL/s, bolus tracking technique was used for optimal scan timing.

Multi-detector computed tomography data analysis.

Reconstruction was obtained at 75% of the R-R interval for most of the cases. However, reconstruction in more phases was left for the reader's preference. The image analysis was done using Vitrea 3D workstation by 3D multi-planar reconstruction, axial images, curved multi-planar reconstruction (MPR), volume rendering, and maximal intensity projection (MIP). Two reviewers assessed the presence of coronary origin, course, termination, and concomitant significant luminal narrowing (>50% lumen reduction).

4. Results

Thirty-two CAA were detected from 1000 consecutive scans, with a mean age of 57.5 ± 8.3, 68% were males. The main complaints were angina and palpitation, 76%. One patient was resuscitated from sudden SCD, patient's baseline demographics were illustrated in Table 1.

Thirty-two CAA were noted (3.2%) including; nineteen (1.9%) anomalous origin from the opposite sinus, three (0.3%) anomalous left coronary artery from the pulmonary artery (ALCAPA), one (0.1%) super dominant left anterior descending artery (LAD) giving origin to the posterior descending artery (PDA),

Table 1. Baseline characteristics of individuals with coronary artery anomalies.

Baseline characteristics	N = 32 (%)
Age	57.5 ± 8.3
Gender	22 (68)
Diabetes Miletus	10 (31)
Hypertension	23 (72)
Dyslipidaemia	3 (10)
Smoking	7 (22)
Family history	1 (3)
Symptoms at presentation	
Chest pain	17 (54)
Palpation	7 (22)
Dyspnea	5 (16)
Sudden cardiac death	1 (3)

three single coronary artery (0.3%) in which left main (LM) and right coronary arteries (RCA) were originating with a common stem from the right coronary sinus and LM took a pre-pulmonic course subsequently. Along with six (0.6%) dual LAD including five (0.5%) patients with type I (short LAD and long diagonal), there was one (0.1%) type 4 with an extra LAD originating from the right coronary sinus with a pre-pulmonic course (Table 2).

Anomalous origin from the opposite sinus of Valsalva:

The most common anomaly noted was the abnormal origin of the RCA from the left coronary sinus with an inter-arterial course (malignant), eight cases (0.8%) were noted; five males and three females were referred with a low to intermediate probability of coronary artery disease. A slit-like opening of the RCA ostium was noted in two patients. In the eight cases with an inter-arterial course, no intramural course inside the aortic wall was noted; hence, no further downstream testing was requested. The second most common was the abnormal origin of the left circumflex artery (LCX) from the right coronary sinus with a retro-aortic course (benign course); six cases (0.6%) were reported, followed by abnormal origin of the left LAD from the right coronary sinus; five cases (0.5%)

Table 2. Types of coronary artery anomalies detected.

Type of coronary artery anomaly	N = 32
Anomalous origin from the opposite sinus	19 (1.9%)
Anomalous origin of LCX from RCS	6 (0.5)
Retro-aortic course	0
Intra-arterial course	6
Anomalous origin of LAD from RCS	5 (0.4)
Retro-aortic course	3 (0.3)
Intra-arterial course	2 (0.2)
Anomalous origin of RCA from LCS	8 (0.6)
Retro-aortic course	0
Intra-arterial course	8 (0.6)
Anomalous origin of LMCA from pulmonary artery	3 (0.3)
Superdominant LAD	1 (0.1)
Single coronary artery	3 (0.3)
Dual LAD	6 (0.6)
Type 1	5 (0.5)
Type 4	1 (0.1)

Abbreviation: LCX: left circumflex artery; RCA: right coronary artery; LAD: left anterior descending artery; RCS: right coronary sinus; LCS: left coronary sinus; LMCA: left main coronary artery.

were reported three with a retro-aortic course (benign course with no further interventions); among them one patient was referred for stent patency evaluation (stent in the LAD), and two had inter-arterial course (malignant) between the main pulmonary artery and the aorta, one patient underwent coronary artery bypass surgery (CABG), due to documented ischemia noted in prior stress electrocardiogram (ECG) (**Figure 1**).

Anomalous left coronary artery from the pulmonary artery:

ALCAPA was noted in three patients; the first was a young athlete referred following resuscitation from a SCD at the field, and he had a history of frequent attacks of anginal pain in the past that were neglected. The second patient was middle age female presented with frequent attacks of palpitation that found to be atrial fibrillation, subsequent testing showed documented ischemia in LAD territory. MDCT showed the LM was originating from the main pulmonary artery along with gigantic RCA reaching the apex. These two patients underwent surgical correction with re-implantation of the LAD into the aorta (**Figure 2**). The third patient was middle-aged female with infrequent attacks of palpitation and refused further downstream testing.

Super dominant LAD:

Super dominant LAD was noted in one patient in which LAD did not terminate at the cardiac apex but continued along the posterior inter-ventricular groove as a PDA. [7] The patient was a middle-aged male who was referred to for atypical chest pain with normal resting ECG (**Figure 3**).

Single coronary artery:

A single coronary artery was noted in three patients, with both LM and RCA originating with a common stem. The single coronary artery originated from the right coronary sinus then bifurcates into RCA that ran in the right atrioventricular groove and LM that took prepulmonic course and bifurcated afterwards into LAD that ran in the anterior interventricular groove and LCX that ran in the left atrioventricular groove. There was no rudimentary LM seen originating from the left coronary sinus (**Figure 4**).

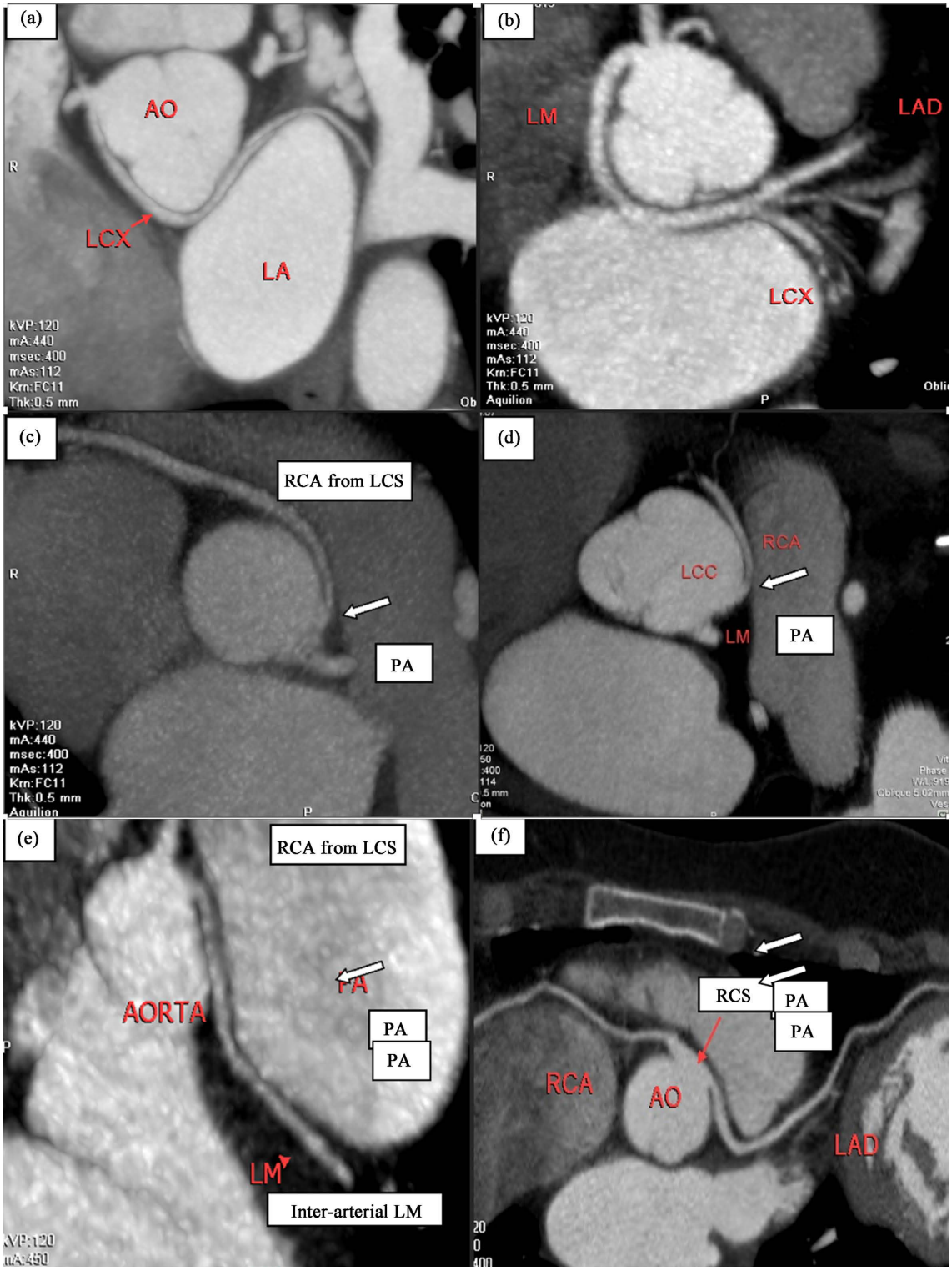
Dual LAD:

Dual LAD is a rare congenital CAA and there have been different types of classification of dual LAD [8].

Dual LAD was noted among six patients (0.6%); one of them was referred for LAD stent evaluation. In five patients the LAD originated from the left coronary sinus and terminated in the proximal part of the anterior interventricular septum (AIVS) while the diagonal branch took a longer course along the left side of the AIVS and terminated in the distal part of the septum (Type 1). One patient showed dual LAD with an extra LAD originated from the right coronary sinus and took a prepulmonic course (Type 4) (**Figure 5**).

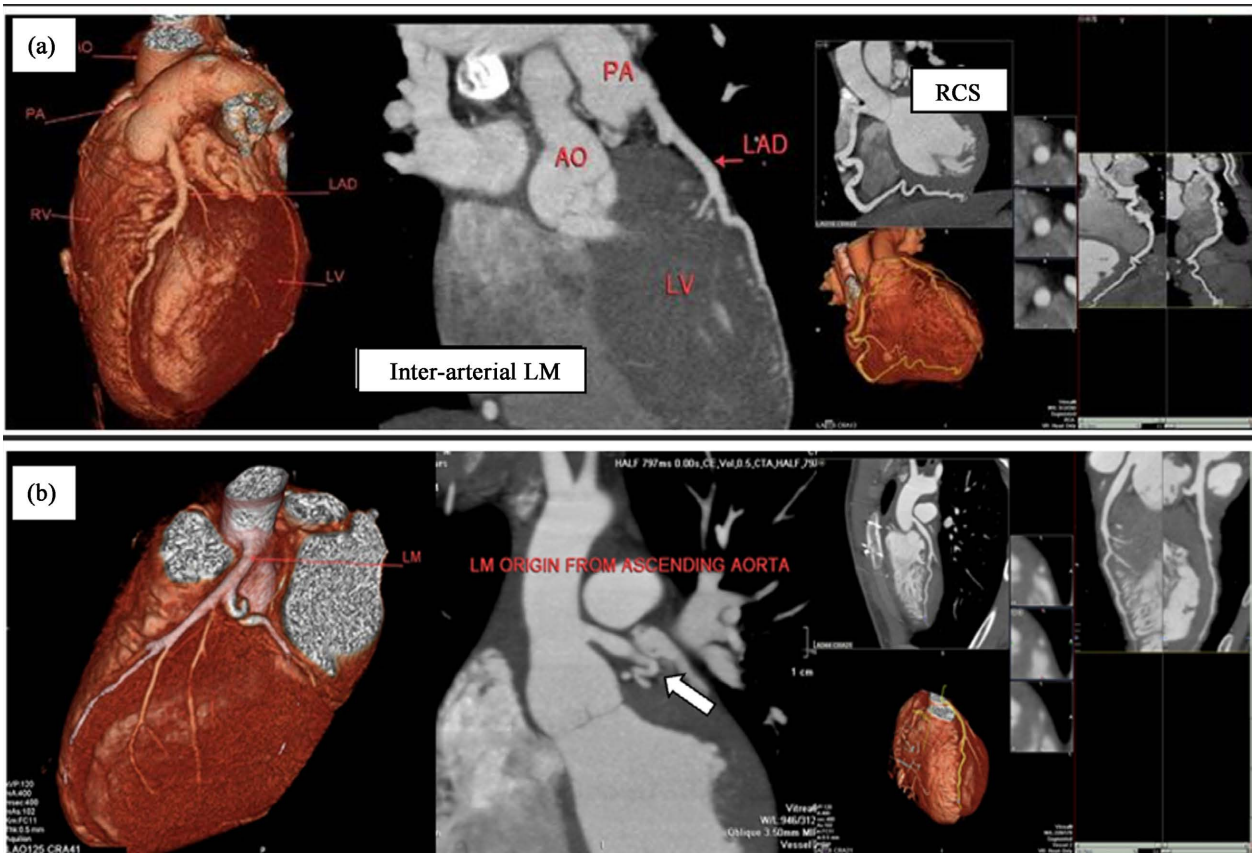
5. Discussion

Coronary artery anomalies are rare congenital heart disease that carries its



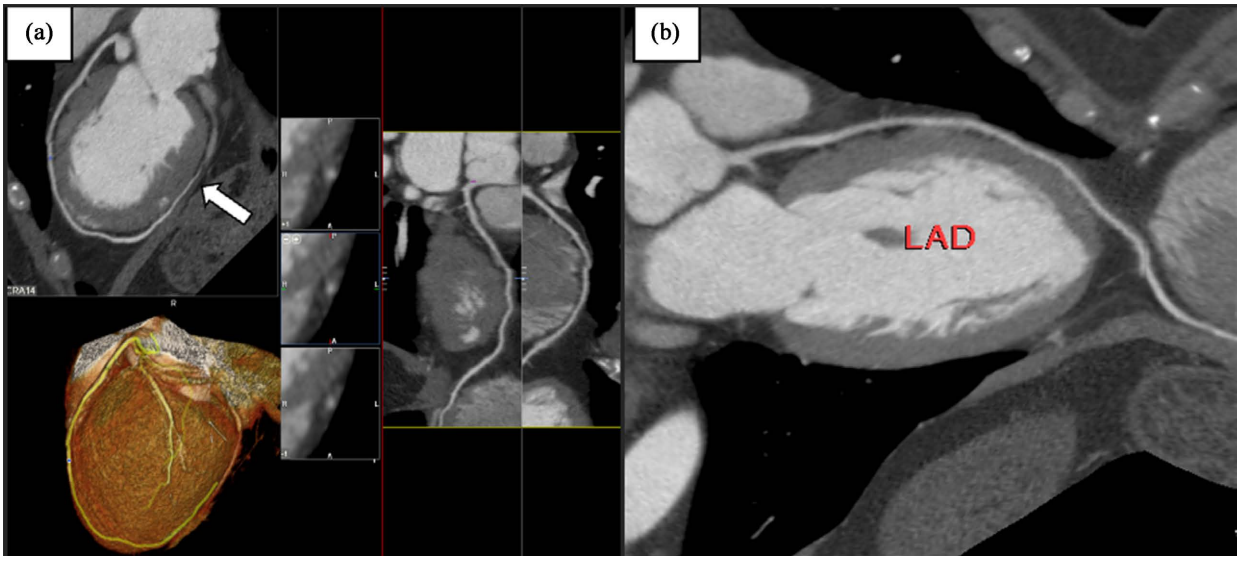
LCX: left circumflex; LM: left main; RCA: right coronary artery; PA: pulmonary artery.

Figure 1. Coronary artery anomalous origin from the opposite sinus. The following contrast enhanced MDC images showing: anomalous origin of LCX from the right coronary sinus (RCS) with a retro-aortic course (benign), (a); anomalous origin of LM from the right coronary sinus with a retro-aortic course (benign), (b); anomalous origin of RCA from the left coronary sinus (LCS) with an inter-arterial course (malignant course), ((c), (d)); the white arrow point to the slit like opening of the RCA ostium, (c); anomalous origin of LAD from the right coronary sinus with an inter-arterial course (malignant), ((e), (f)).



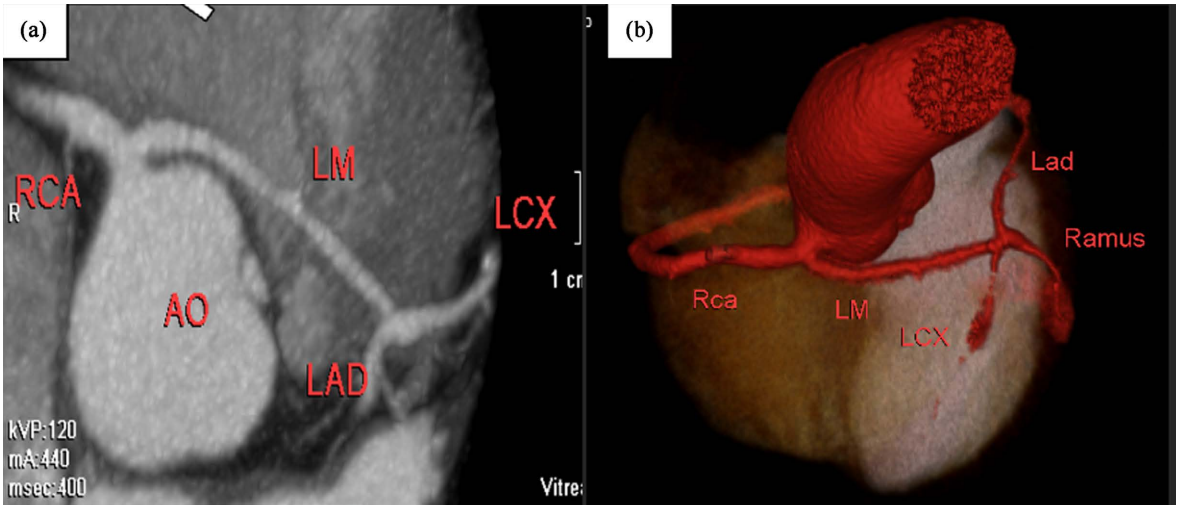
ALCAPA: anomalous left coronary artery from the pulmonary artery; RCA: right coronary artery.

Figure 2. Anomalous left coronary artery from the pulmonary artery (ALCAPA). The following volume rendering reconstructed MDCT images showing anomalous left coronary artery from the pulmonary artery (ALCAPA), along with gigantic RCA, (panel (a)); post re-implantation images (panel (b)).



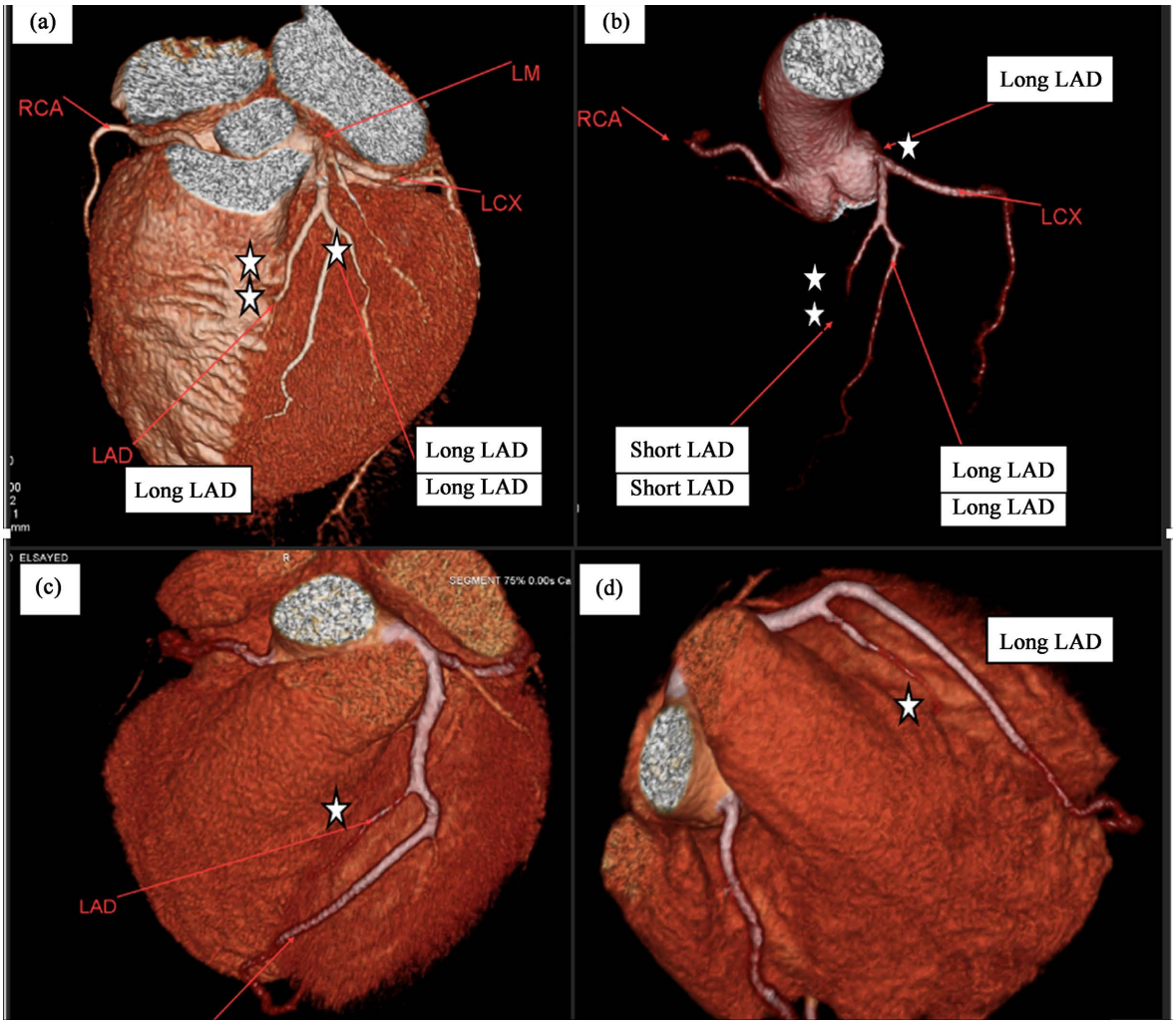
LAD: left anterior descending; PDA: posterior descending artery.

Figure 3. Supereminent LAD. The following contrast enhanced MDCT images showing super dominant LAD where LAD continues as a PDA at the posterior inter ventricular groove (arrow), 3D volume rendering reconstructed image (a); curvilinear reconstructed image (b).



LAD: left anterior descending; LCX: left circumflex artery; RCA: right coronary artery.

Figure 4. Single coronary artery. The following contrast enhanced MDCT images showing single coronary artery originates from the right coronary sinus then bifurcates into RCA that runs in the right atrio-ventricular groove and LM that takes pre-pulmonic course and bifurcates afterwards into LAD that runs in the anterior inter-ventricular groove, LCX that runs in the left atrio-ventricular groove, and small ramus branch in the multiplanar (a); and the volume rendering (b) images.



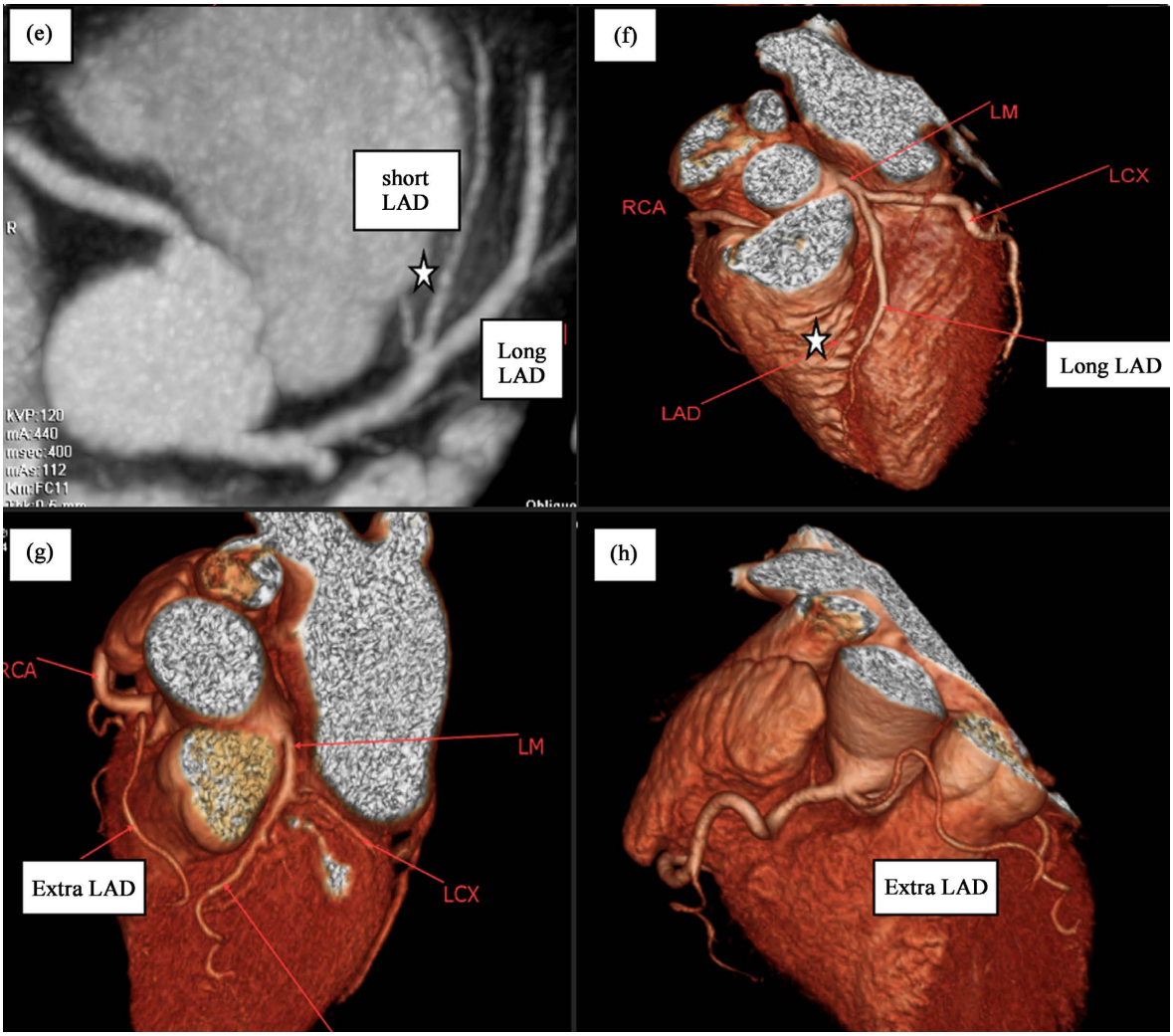


Figure 5. Duplicate LAD anomalies. The following MDCT images showing, 3D volume rendered and maximum intensity projection images of dual LAD type 1 with short LAD terminated at the proximal part of the inter ventricular septum and long LAD originating from the LAD proper then runs on the left side of the inter ventricular groove and re-entered distally to terminate at the cardiac apex, figure ((a)-(f)); asterisks point to the short LAD; type 4 Dual LAD was noted with an extra LAD originating from the right coronary sinus and takes a pre-pulmonic course, ((g) & (h)).

importance from the hemodynamic significance of the underlying anomaly. [9] In our series we reported cases with non-hemodynamically significant anomalies (anomalous origin from the opposite sinus with a retro-aortic course, super dominant LAD, single coronary artery and dual LAD Type 1 and 4) and hemodynamically significant lesions (ALCAPA, and anomalous origin from the opposite sinus with a malignant course (inter-arterial)) that warranted prompt intervention and surgical correction.

Non-hemodynamically significant lesions are usually asymptomatic and most of the cases are referred to following invasive coronary angiography due to difficult engagement or non-visualization of coronary artery or detected incidentally. [2] Conversely, hemodynamically significant lesions are usually presented early in life with, heart failure and failure to thrive as in ALCAPA patients, or

SCD in patients with anomalous origin from the opposite sinus with a malignant (inter-arterial) course, or palpitation and anginal pain [2] [10] [11].

In hemodynamically significant lesion such as in CAA with an interarterial course there are several factors that determine arterial occlusion including; the presence of intra-mural course (inside the aortic wall), a slit-like opening of the coronary ostium, and the angle between the anomalous coronary artery and the aorta. [10] MDCT allows the easy depiction of such anatomical factors along with the course and termination of the anomalous coronary artery with different reconstruction techniques that impact further decision making, surgical interventions, and overcoming limitations of invasive coronary angiography. In our series we noted the slit-like opening of the coronary ostium along with an acute angle with the aorta among two of our patients who had an anomalous origin of RCA from the left coronary sinus with an interarterial course; however no interventions were done.

Nonetheless, when the as low as reasonable achievable (ALARA) principle employed radiation dose during MDCT scan is markedly reduced in comparison to invasive coronary angiography [12] [13].

The added value of MDCT goes beyond anatomical delineation it can assess the functional significance of concomitant atherosclerotic lesions using fractional flow reserve and guiding intervention, this can be expanded to determine the functional significance of anomalous origin coronary artery with a malignant course but this needs to be tested in further prospective studies [14] [15] [16].

Furthermore, the actual prevalence of CAA markedly increased by the introduction of MDCT into the clinical arena due to high spatial resolution compared to invasive angiography and more reliance on non-invasive anatomical testing in patients with low-to-intermediate portability of coronary artery disease [17].

The role of intervention in such patient category is debatable since most patients have mild symptoms or incidentally discovered. However, patients who present with SCD, serious arrhythmia, or myocardial infarction require timely diagnosis and intervention [18] [19].

The recent European society of cardiology guidelines recommended intervention in symptomatic patients with an anomalous origin of coronary artery with evidence of ischemia in the matching territory or presence of high risk anatomy, and this recommendations shed the light on the importance of MDCT in decision making [20].

Super dominant LAD is a very rare anomaly in which RCA and LCX are non-dominant vessels and PDA arises from LAD. [7] [21] The clinical implication of such anomaly is that occlusion of the LAD may result in large infarction including; anterior wall, septum, and the inferior wall that might result in a cardiogenic shock.

ALCAPA is a very rare congenital anomaly and represents 0.025% - 0.5% of congenital heart disease. [11] Anomalous origin of RCA, LAD, and LCX from the pulmonary artery has also been reported. [22] ALCAPA usually presented during

infancy with heart failure, cardiomegaly, and failure to thrive and should be considered as a differential diagnosis of cardiomegaly in new-borns. [23] The mortality is 90% in the first year of life. [6] It can also be presented later during adulthood with arrhythmia and SCD. The presentation depends on the degree of coronary-coronary collateral and pulmonary vascular resistance. [6] [13] Our patient presented with the rare adult-type who has been resuscitated from SCD and underwent immediate surgery for re-implantation of the LM into the aorta (**Figure 2**).

The single coronary artery has an incidence of 0.024 to 1% from different reports. [24] Its significance stems from the fatality of arterial occlusion that results in massive infarction and eventually cardiogenic shock. In our case the patient did not have any significant atherosclerosis and the LM took a benign course, so no further intervention required.

Dual LAD is rare congenital heart disease. In dual LAD a short LAD usually terminates in the proximal part of the AIVS, and does not reach the cardiac apex, while a long LAD arises from the right or left coronary system, takes a variable course, enters the distal part of the AIVS, and reaches the cardiac apex. There have been four different sub-types in which the short LAD originates from LAD proper and terminates in the proximal part of the AIVS. [8] The difference between the sub-types is in the origin and course of the long LAD; wherein, Type 1 originates from the LAD proper and runs on the left side of the AIVS then terminates distally at the AIVS, Type 2 it originates from the LAD proper and runs on the right side of the AIVS, Type 3 it originates from the LAD proper then runs intra-myocardial in septum proximally and emerges in the apical septum, Type 4 it originates from the right coronary sinus and has a pre-pulmonic course. [25] Dual LAD anomalies are intrinsically benign; however, detection and understanding of its different types is important in patients referred for coronary artery by-pass surgery. Very rare the extra LAD originates from the right coronary sinus with an-interarterial course or an anomalous origin of extra LAD from the pulmonary artery [8] [26]. Our patients showed no significant coronary artery disease; hence, were advised regarding lifestyle modifications and controlling risk factors.

6. Conclusion

Coronary artery anomalies are rare congenital heart disease; however, it has a wide array of variations. Some variations are hemodynamically significant and prompt intervention is warranted. MDCT allows easy detection of coronary anomalies with high spatial resolution and overcomes limitations in conventional invasive coronary angiography. Based on our study we recommend the use of MDCT as an efficient and feasible modality for the diagnosis of coronary anomalies once this pathology is clinically suspected.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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List of Abbreviations

ALCAPA: anomalous left coronary artery from the pulmonary artery.
CAA: coronary artery anomalies
CABG: coronary artery bypass surgery.
AIVS: anterior interventricular septum.
LAD: left anterior descending artery.
LCX: left circumflex artery.
MDCT: multi-detector computed tomography.
MIP: maximal intensity projection.
MPR: multi-planar reconstruction.
PDA: posterior descending artery.
RCA: right coronary artery.
SCD: sudden cardiac death.