Evaluation of Anomalous Coronary Arteries on 64 Slice Multidetector Computerized Tomographic Angiography

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Author's Contribution

[1,5] *Conception of study*
[1] *Experimentation/Study conduction*
[1,2] *Analysis/Interpretation/Discussion*
[1,5] *Manuscript Writing*
[1,2,3,4,5] *Critical Review*
[1,4] *Facilitation and Material analysis*

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Abstract

Introduction: Anomalous Coronary arteries is a well-known congenital entity with variable effects. The majority of such patients are asymptomatic but some can have adverse effects like ischemia and arrhythmia. Its association with Sudden Cardiac Death in young is established.

Objective: To determine the frequency of ACA on MDCT in patients referred for coronary artery disease assessment and to determine the origin, course, and morphological variable of SCD of ACA on MDCT.

Materials and Methods: The study was done in the Department of Cardiovascular Imaging at the Punjab Institute of Cardiology. A retrospective data of patients undergoing CTA for CAD between a period of Jan 2009 and Dec 2017 were analyzed for the presence of Anomalous Coronary Artery (ACA). All patients having anomalous origin from opposite coronary cusp and its course were included. The patients with myocardial bridging and coronary artery fistula were excluded.

Results: Total patients analyzed with MDCT for CAD and graft assessment between Jan 2009 and December 2017 were 8028. Fifty-three patients were excluded because of poor image quality. Among these ACA were found in 166 (2.08%). Gender distributions were 126 (75.9%) males and 40 (24.09%) females, the mean age in years was 49.31 ± 13.23. The most common ACA was Right coronary artery 83 followed by Left Circumflex 44 (26.50%), Left Anterior Descending Artery 22 (13.25%), and Left Main Stem 17 (10.24%) respectively. Fifty-three (31.92%) patients had previously unknown ACA and were found to have ACA on MDCT and 82 (49.39%) patients were referred following ICA for the confirmation of ACA. The Inter-arterial course was predominant in RCA and Left Coronary Artery 97% and 77% respectively. A retro artic course was predominant (100%) in LCx. Seven patients had associated cyanotic heart disease with ACA. Two patients(one LAD and one RCA) had origin from the Main Pulmonary artery.

Conclusion: MDCT is the imaging modality of choice for the evaluation of ACA. It can identify the origin of ACA from opposite coronary cusp and defines the malignant course of ACA for the potential risk of sudden cardiac death.

Keywords: Coronary Artery, Multi-Detector Computerized Tomography.

Introduction

Anomalous coronary artery (ACA) is a well-known entity in patients undergoing invasive angiography. The patient with ACA can have a varied presentation from being asymptomatic to symptomatic. The common symptoms associated with ACA are chest pain, shortness of breath, palpitation, and syncope.[1] The adverse outcome of ACA can be sudden cardiac death. The prevalence of ACA in the general population is around 1-2% but can be variable and it can be as low as 0.3% to around 6%.[2] The diagnosis should be confirmed in a patient having a suspicion of ACA. Various Imaging modality which includes Echocardiography, Multi-Detector Computerized Tomography (MDCT), Magnetic Resonance Imaging (MRI), nuclear imaging, and Invasive Coronary Angiography (ICA) has been used for its diagnosis. This multimodality imaging has its strong points and limitations for the evaluation of ACA.[8] MDCT is an accurate and noninvasive technique to provide volume and three dimensional (3D) data for assessment of ACA. It has been found to accurately assess the origin and course of ACA. The pathophysiological significance can be assessed by defining the course of ACA.[3]

Materials and Methods

The study was done in the Department of Cardiovascular Imaging at Punjab Institute of Cardiology. A retrospective data of patients who have undergone MDCT Angiography for coronary artery disease assessment, grafts analysis in post-Coronary Artery Bypass graft (CABG) patients, and suspected a coronary anomaly in congenital heart disease were included. The study period included between January 2009 and Dec 2017. All patients who were found to have ACA were analyzed. It also included the patients which were referred for MDCT after ICA which had a suspicion of ACA. They were referred for confirmation and defining the course of the ACA. The patients having myocardial bridging and coronary artery fistula were excluded. Patients which had poor image quality due to gating or breathing artifacts were also excluded. All patients had signed pre-informed consent for using their data anonymously for research purposes.

The risk factor for coronary artery disease was noted on prescribed Performa. An indication to perform the CTA was also noted. A heart rate of 60-70 /min was set as the target heart rate. The patient having tachycardia was given beta-blocker (Tab metoprolol) at a dose of 100 mg orally and/ or Inj. Lopressor 5mg-20 mg intravenously to achieve the target heart rate of 60-70 beats /min. The study was done with nonionic contrast Ultravist® Injection (370mgi/ml). A total of 60-80 ml of contrast was injected through an 18 g cannula inserted in an anti-cubital vein at a rate of 5-6 ml/sec, followed by 40-50 ml normal saline as a chaser with a dual-head automated injector.

MDCT Imaging: Patients were scanned with a 64 slice scanner (GE Light Speed;). MDCT angiography parameters were as collimation width 64x0.6 mm, tube potential 80-120 kV, and tube effective current 200-750 mA depending on patient age and BMI, tube rotation 330 ms, table feed 4mm/rotation, temporal resolution 80-165 ms, and scanning time of 10-15 seconds. The scan field included tracheal carina to the diaphragm. After the patient was advanced into the scanner bore, the first acquisition consisted of a localizer image of the chest. The second acquisition was a non-contrast scan for calcium scoring. The third acquisition consisted of a test bolus scan, which was performed using a bolus of 20 cc of non-ionic iodinated contrast material (Ultravist) 370mg/ml.

The final acquisition was a contrast-enhanced angiogram. Patients were asked to breathe deeply and then hold their breath at end-inspiration. Image reconstruction was performed at 10% increments through the R–R cardiac cycle. After the acquisition of images, images were transferred to a dedicated GE® AW Workstation for analysis.

CT Image Analysis: The CT data set was analyzed by two independent experienced readers who were blinded to the patients' clinical data. For analysis of the coronary arteries, the original post-contrast axial, sagittal, and coronal plane dataset was examined. Three-D Volume Rendering(VR) images and curved multi-planar reconstructions were used for analysis. The data of ACA, including its origin, proximal course, and its termination as seen by MDCT angiogram, was analyzed.

Statistical Analysis: Statistical analysis was performed using SPSS, version 15.0 (SPSS Inc., Chicago, IL, USA). Normally distributed data are expressed as mean ± standard deviation frequency and percentages.

This study was approved by the clinical research ethical committee of Punjab Institute of Cardiology.

Results

The Basic demographic features of the study are shown in Table 1.

Table 1: Basic Demographic Features

Features	
Males (No. %)	126 (75.9%)
Female (No. %)	40 (24.09%)
Mean Age (in years/SD)	49.31 ± 13.23
BMI Kg/M² (157 adults)	27.57 ± 3.7
Risk factors for CAD	125 (75.30%)
HTN	98 (59%)
DM	46 (27.7%)
HTN+DM	42 (25.5%)
DM+SMOKING	18 (10.8%)
HTN+DM+SMOKING	16 (9.6%)
No Risk factor for CAD	41 (24.69%)
Contrast Mean(ml)	70.09 ± 11.38
Heart rate /min (mean)	65.13 ± 6.09

A total of 8028 patients underwent MDCT angiography to rule out coronary artery disease and for graft assessment in post CABG patients during the year 2009-2017. Among these 58 MDCT angiograms were excluded because of poor image quality and artifacts. The data of 7967 patients were included for the assessment of the presence of ACA and it was found to be present in 166 (2.08%) patients.

Among the total of 166 patients, 53 (31.92%) patients had previously unknown coronary artery anomaly. These patients were referred for assessment of coronary artery disease and were found to have ACA. Twenty-two (13.25%) patients were referred for graft assessment had known ACA. Eighty-two (49.39%) of patients were referred for the assessment ACA following difficulty in identifying the exact anomaly on ICA. These patients were referred to identify the exact origin and course of epicardial coronary artery anomaly on MDCT. Nine (5.42%) had ACA with associated congenital heart disease.

The distribution, Origin, and course of ACA are shown in Tables 2 and 3.

Table 2: Anomalous Coronary Arteries Distribution

| Artery	Number (%) (Total=166)
LMS	17 (10.24%)
LAD	22 (13.25%)
LCX	44 (26.50%)
RCA	83 (50%)

RCA was the most common ACA, with LCX and LAD being the second and third most common anomalous coronary arteries. The anomalous RCA has a predominant origin from Left Coronary Cusp(LCC) and inter arterial course which is a malignant course and can cause ischemic symptoms in the dependent myocardium (Figure 1-a, b & c). Only two patients of anomalous RCA had a pre-pulmonic course which was considered to be benign (Figure 1-d). The Left circumflex (LCX) artery the second most common coronary anomaly which had origin either from the Right coronary Cusp(RCC) or Right Coronary Artery(RCA). The predominant course of LCx. The artery was retro aortic, passing in between the aorta and left atrium (Figure 3-a,b). This was considered a benign course. Three patients had a single coronary artery being a single takeoff from the RCC, with an anomalous course. One patient had RCA continuing as LCx and giving off LAD (Figure 4-a,b). The other two patients had Left main stem arising from RCA, one had had a retro aortic course and the other had an intraarterial course. (Figure 4-c,d).
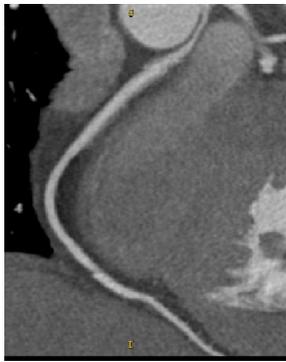
a. Curved Multi-planner Reformation image of Anomalous RCAwith origin from LCC and proximal intraarterial Course (Malignant)
Figure 1: a, b, c & d

b. Axial plane image of RCA with origin from LCC and slit-like opening with proximal intraarterial Course
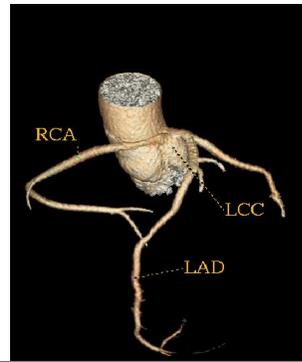
c. Volume Rendering(VR) image of RCA with origin from LCC

**d. MPR image of Anomalous RCA from LAD with pre pulmonic course**
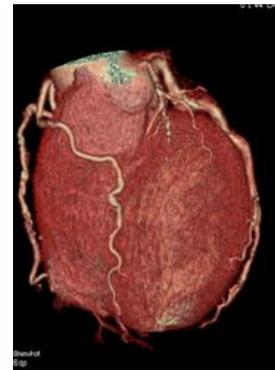
Figure 2: Volume rendering (VR) image of Anamolous LAD having origin from the RCC and inner arterial course.

Figure 3: a, b
Volume Rendering (VR) and Curved MPR image of anomalous LCx with origin from RCC and a retro aortic course between aorta and left atrium

Figure 3: c, d
**Curved MPR and VR images of AnamolousLCx with retro aortic course**
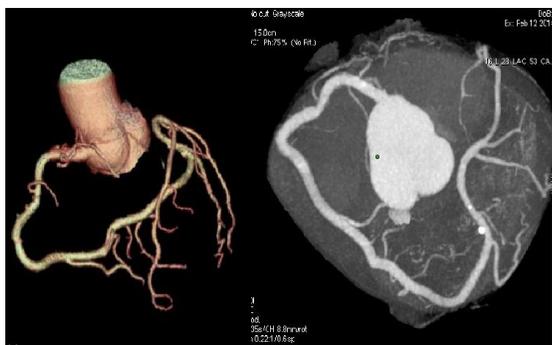
Figure 4: a, b
Volume rendering (VR) and Angiographic view of the single coronary artery as RCA is continuing as Left coronary artery and giving LCx and LAD having anomalous Course
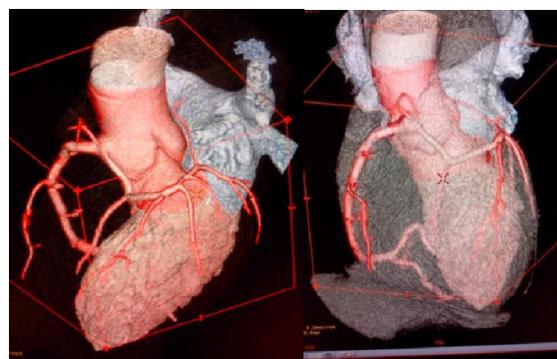

Figure 4: c, d
VR images of a single coronary artery, with LMS arising from RCA and having an anomalous inter-arterial course.

The detail of origin and course of ACA is shown in Table 3.

Table 3: Origin and Course of ACA

Artery (total) 166	Origin from RCC	Origin from RCA	Origin from LCC	Origin from NCC/STJ	Origin from LMS	Intraarterial course	Reroaortic course	Prepulmonic course
LMS(17)	14(82.35.1%)	03(17.64%)	x	x	x	08(47.05%)	03(17.6%)	06(35.29%)
LAD(22)	17(77.27%)	05(22.7%)	x	x	x	17(77.27%)	02(9.09%)	03(13.6%)
Lcx (44)	29(65.9%)	15(34.1%)	X	x	x	x	44(100%)	x
RCA(83)	X	x	75(90%)	02(2.40%)	06(7.2%)	81(97.5%)	0	02(2.4%)
Total	62	21	75	02	06	106(63.58%)	49(29.51%)	11(6.6%)

Table 4: Associated CAD in patients with ACA

Associated CAD	
SVD	29 (17.4%)
DVD	22 (13.25%)
TVD	52 (31.30%)
Normal Coronaries (non obstructive)	63 (37.95%)

Seven patients had associated congenital cyanotic heart disease with ACA. One patient each had an origin of RCA and LMS respectively from Main Pulmonary Artery (MPA). Figure 5 (A,B,C)
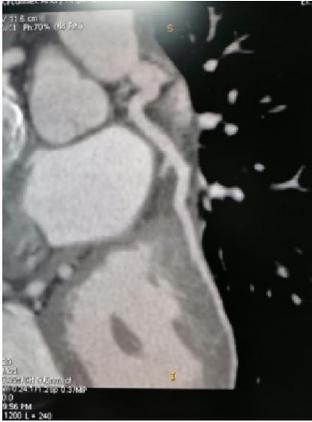
Figure 5: a
MPR image of Left Main Coronary Artery Arising from the Main pulmonary artery

Figure 5: b
3-D VR image showing Left Main coronary artery arising from MPA
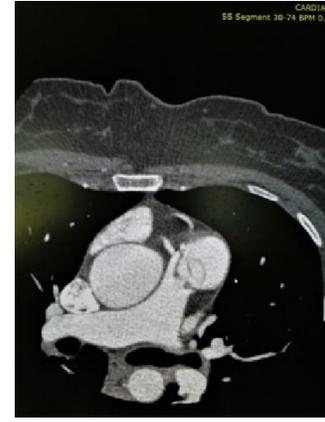
Figure 5: c
An axial plane image showing RCA arising from MPA

The predominant course in these patients was pre-pulmonic, passing in front of RCA. The distribution of ACA in patients with congenital heart disease, their origin, and the course is shown in Table 5.

Table 5: Distribution of ACA in patients with Congenital heart disease

Artery	Artery (number) Total Nine	Origin	Course (pre-pulmonic)	Course Intraarterial
RCA	01	LCC	x	01
RCA	01	MPA	01	x
LMS	02	RCC	02	01
LMS	01	MPA	01	x
LAD	04	RCC	04	x

Discussion

The hallmark of ACA, being a group of congenital abnormality, is the origin of the opposite coronary sinus and abnormal vessel course. As most of the patients having ACA remain undiagnosed because of the lack of symptoms. Symptomatic patients can have an adverse cardiac effect due to ischemia, arrhythmia, and shortness of breath. It is one of the known causes of sudden cardiac death in young athletes. The various anatomical high-risk features for SCD identified on imaging are, slit-like ostium, inter arterial course, intramural course, acute take-off angles. The prevalence of ACA is variable in different populations. The reason described in the literature is because of variable definitions for ACA and different imaging modalities used for the diagnosis of ACA.

It is difficult to define the "Normal" morphological pattern of coronary arteries. It has been proposed in the literature as "Normal" if the morphological feature of coronary arteries which includes origin and course, is found in more than 1% of the general population and as anomalous if found in less than 1 % of the general populations.[1,4,5]

A hereditary background to the etiology of ACA is yet to be determined and is unknown. The ACA is more common in males as is reported in the literature. In our study 76% of the patients were males. [6]The incidence of SCD is also more in young male athletes. ACA is the second most common cause of SCD in young athletes who remain asymptomatic during life and are only diagnosed in postmortem studies.[7]

The normal coronary anatomy consists of the left coronary artery and the right coronary artery. The left originates from LCC and divides into to left anterior descending artery and left circumflex artery, whereas the right coronary artery (RCA)originates from RCC. The essential coronary circulation consists of proximal conductive   and   distal   arteriolar   capillary

microvascular beds for perfusion of myocardial fibers. The ACA has a variable origin and proximal course which affects the distal microvascular perfusion resulting in various symptomology. The affected microvascular bed can be the cause of ischemia, arrhythmia.[8,9]

Trans Thoracic Echocardiography (TTE) is a non-invasive, patient-friendly, widely available imaging tool available for the initial screening of patients with ACA. It can identify the Ostia of an ACA and its proximal course. Transesophageal echocardiography has more sensitivity than TTE for the initial evaluation of such patients. TTE is more useful in pediatric and younger age population than in adults of more than 30 years. The color doppler can be used for the evaluation of the intramural course.[10,11]

MDCT is the imaging modality of choice for the evaluation of ACA. Due to the rapid advancement in its temporal and special resolution, MDCT is the right choice for ACA diagnosis and treatment planning. It can define the origin and course of ACA and provides excellent 3 D data for an anatomic relationship with the surrounding structures. For decades conventional Invasive Coronary Angiography (ICA) has been the standard for the evaluation of coronary arteries. Apart from being an invasive procedure, it has limitations in the assessment of ACA. ICA does not provide surrounding soft tissue information and provides a limited number of 2 D projection images. In our study, about 49% of the patients were referred after ICA for the exact delineation of origin and course of the ACA. These patients had either difficulty in the engagement of the catheter or their course was not defined because of the limitation of the ICA. It is very important to define the inter-arterial course because of it being the cause of ischemia and substrate for the SCD. The 3 D nature of MDCT data defines the origin and course of ACA most definitively. The morphological features of the ACA can be defined better by MDCT data than ICA. It has been seen the true prevalence of ACA is defined better on MDCT evaluation than ICA.[12,13]

The most common anomaly seen in our study was RCA with origin from Left Coronary Cusp and predominant inter-arterial course. The second most common ACA with an inter-arterial course was LMS and LAD. This course is mostly associated with exercise-related symptoms of ischemia and arrhythmia which can cause SCD. The other features associated with SCD in coronary anomaly are slit-like ostium, acute angulation at the origin, compression during exertion. The LAD related coronary anomaly has SCD during exertion and RCA related Coronary anomaly can have SCD during rest.[14,15]

The patients with ACA have either a malignant course or a benign course. The malignant course is an inter-arterial course between the aorta and the main pulmonary artery. The pre-pulmonic or retro aortic course was considered a benign course. which is an inter-arterial course. The various imaging modalities like Echocardiography, MDCT, and MRI help in delineating the malignant or benign course. The malignant course of ACA can case dynamic obstruction by great vessels during exertion. Hence such a course was identified in autopsies of athletes with SCD in the absence of atherosclerosis. By using these imaging modalities the patients with ACA can be risk-stratified and help in treatment planning. In our study, the benign course of ACA was seen in almost all patients with Anomalous LCx. Very few patients had a pre-pulmonic course which was also a benign course.[16,17]

Anomalous origin of the Left Coronary Artery from the main Pulmonary Artery (ALCAPA) is one of the rare forms of ACA. Two types are reported, an infant type and adult type, MDCT and MRI are the main imaging modalities for its diagnosis. Cine MR images can demonstrate retrograde flow in the coronary artery.[18,19]

Conclusion

MDCT is the imaging modality of choice for the evaluation of ACA. It can identify the origin of ACA from opposite coronary cusp and define its course due to 3-dimensional data. It identifies the high-risk morphological features associated with sudden cardiac death.

Study Limitations

Given the retrospective data, there was selection bias and certain clinical parameters such as the history of syncope and family history of SCD could not be recorded.

Acknowledgement

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