

Distribution of Coronary Artery Anomalies and Their Evaluation with Different Imaging Modalities

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Abstract

Introduction: Coronary artery anomalies (CAA) are diverse abnormalities. **Methods:** A retrospective review of coronary imaging of 17,245 patients over 2 years was performed. Patients with CAA detected on echocardiography, invasive coronary angiography (CAG) and multidetector computed tomographic angiography (MDCTA) were compared. **Results:** CAAs were detected in 257 patients (1.49%). Prevalence were: absent left main trunk- 0.319%, anomalous coronary artery from opposite sinus (ACAOS)- 0.516%, coronary fistulae- 0.203%, myocardial bridge- 0.093%, malignant anomalies- 0.3%. The commonest CAA was absent left main trunk. The yield of echocardiography negatively correlated with age ($r=-0.6$). CAG and MDCTA were equal ($p=1$) for detection of absent left main trunk. CAG had low sensitivity (58.3%) and MDCTA was better than it ($p<0.01$) for detection of abnormal high origin. For ACAOS, detection by both were not different ($p=0.5$) but the course was delineated better with MDCTA than with CAG ($p=0.05$). Both were equal for detection of intramyocardial course ($p=0.5$). However, MDCTA delineated its course better than CAG ($p<0.01$). Echocardiography had 93% sensitivity for fistula in those <12 years in age. Radiation exposure with CAG, $7.3 \pm 2\text{mSv}$, was lower than that with MDCTA, $14.5 \pm 3\text{mSv}$ ($p<0.01$). It correlated with CAA score ($r=0.3$), with CAG but not with MDCTA. Contrast exposure correlated with CAA score ($r=0.4$) for adults with CAG but not with MDCTA. **Conclusion:** Echocardiography reliably detects CAAs in children. CAG and MDCTA are comparable for detection of most CAA. MDCTA delineates the course better than CAG. For MDCTA, radiation exposure is not correlated with complexity of CAA in contrast to that with CAG.

Key words: Coronary artery anomalies; Echocardiography; Coronary Angiography; Computed Tomography; Radiation Exposure

Introduction

Coronary artery anomalies (CAA) are rare congenital conditions with an incidence ranging from 0.17% in autopsy cases to 1.2% in angiographically evaluated cases [1-3]. Most of these CAAs are not clinically important. However, nonfatal or fatal acute myocardial

infarction can occur in such patients, like those patients with Anomalous Coronary Artery from the Opposite Sinus (ACAOS) notably among young athletes [1,4-6]. In some cases the aberrant vessel, which passes between the aorta and the main pulmonary artery, can cause a sudden death [1]. Echocardiography is a non-invasive tool for detection of CAAs especially in pediatric population. Its usefulness in adults is limited by

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acoustic factors. CAAs are evaluated with catheter based coronary angiography (CAG), which is known as a gold standard [1]. Contrast-enhanced electron beam computed tomography (EBCT) offers excellent spatial resolution and identifies most of the course anomalies

[1,7]. Multidetector row-computed tomography (MDCT) is a new imaging technique. Its importance is gradually increased in the area of cardiac imaging [1]. Magnetic resonance imaging (MRI) has often been used to determine the CAA in equivocal cases.

Materials and Methods

Retrospective review of 17,245 patients, who underwent coronary imaging at our institute over consecutive 2 years was performed. Indications for evaluation included angina, dyspnea, syncope or cyanosis. Patients diagnosed to have any CAA were retrospectively included in the study.

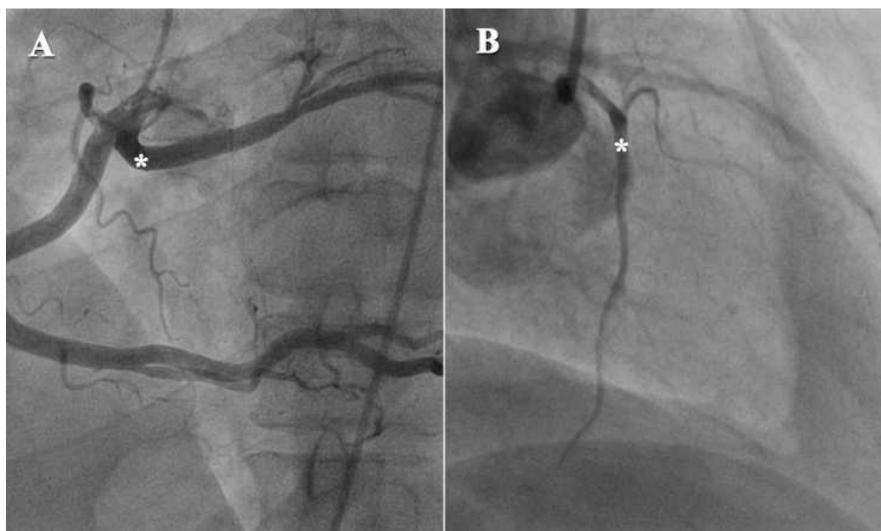
All patients underwent transthoracic echocardiography (iE33 xMATRIX, Philips Healthcare, Andover, USA). Invasive CAG was performed in flat-panel cath-labs (Philips Medical systems, Nederland B.V.) under mono-plane fluoroscopy from femoral or radial arterial route.

(Figure-1) Absent left main trunk was revealed on left coronary angiogram with left anterior oblique view with caudal angulation. The anomalous course of ACAOS was determined on the basis of 'dot' and 'eye' signs in right anterior oblique view. Intra-myocardial course was detected on the basis of systolic constriction of the particular vessel. Coronary fistulae were detected from visualization of communication of coronary artery with any chamber.

Figure 1: Invasive coronary angiograms showing coronary anomalies

A: Left anterior view showing left coronary artery (*) arising from right sinus of valsalva with anterior course

B: Right anterior oblique view showing right coronary artery (*) arising from left sinus of valsalva with interarterial course



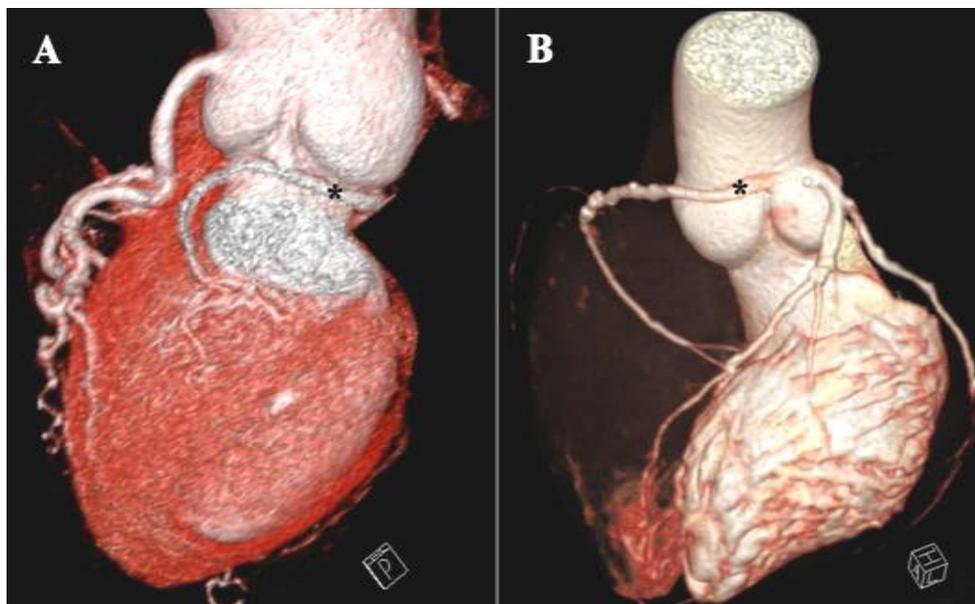
Patients underwent MDCT angiography (MDCTA), performed with 128 slice MDCT scan (Somatom definition AS+ CT scanner machine, Siemens Healthcare, Malvern, USA). A native, prospectively electrocardiogram (ECG)-triggered scan for coronary artery calcium scoring was followed by a contrast-enhanced, retrospectively ECG-gated coronary MDCTA. Out of initially obtained raw-data sets, standardized image reconstructions were performed at 25%, 45%, and 65% of the RR-Interval, respectively and, if necessary, additional reconstructions throughout the whole cardiac cycle were performed.

All acquired MDCTA images were transferred to a dedicated CT 3-dimensional post-processing workstation (Leonardo, Siemens Healthcare, Malvern, USA). Axial and curved multiplanar reformatted images, Maximum Intensity Projections, and Volume Rendered images were analyzed for the determination of the origin and course of coronaries, the take-off angles from the aorta, and size of the orifice. (Figure-2)

Figure-2: Volume rendered 3-dimensional Multidetector computed tomographic angiogram images showing coronary anomalies

A: Left circumflex artery (*) arising from right sinus of valsalva with retroaortic course

B: Right coronary artery (*) arising from left sinus of valsalva with interarterial course



According to Angelini, 2007,[8] CAAs were defined and classified depending on anomalous origin and vessel course and the dependent myocardial territory. In addition to anatomical classification, anomalies were classified according to functional classification in benign and malignant types. Scoring of anomalies was performed according to Rigatelli et al. 2012[9].

Statistical analysis- Continuous data were expressed as mean \pm standard deviation (SD), and were compared using the Student paired- t-test (2-tailed). Categorical variables were expressed as percentages, and were compared (p-values) using the Chi-square test with Yates correction or Fisher's exact test. A p-value <0.05 was considered to indicate significant difference. Pearson's correlation analysis was used to explore correlations (r) between CAA score, radiation exposure, contrast expenditure etc. All statistical calculations were performed with SPSS software (IBM VERSION 20, Chicago, USA).

Results

Prevalence-A total of 17,245 coronary artery evaluations were performed, of which 257 were found to have CAAs, at a prevalence rate of 1.49%.

Age Distribution- The commonest anomaly detected in infants was Anomalous Left Coronary Artery from Pulmonary Artery (ALCAPA) (26.7% of CAAs in that age-group). The commonest anomaly in pediatric age group (1-12 years) was coronary artery fistula (52%). The commonest anomaly in the entire pediatric age group (<12 years) was ACAOS (42% of CAAs of that age-group). The second most common CAA in pediatric age group was coronary artery fistula (37.5%). The commonest anomaly in young adults (12-40 years) was anomalous high origin of coronary artery from same sinus. The commonest anomaly in elderly population (>40 years) was anomalous separate origin of Left Anterior Descending artery (LAD) and Left Circumflex artery (LCX) from Left Sinus of Valsalva (LSV) (29.7% of anomalies in that age-group) followed by anomalous origin of LCX from Right Sinus of Valsalva (RSV) (17.58%).

Sex Distribution-From 17,245 patients; 12,608 were male, out of which 194 had CAAs. Sixty-three females out of 4637 had CAAs. The prevalence of CAAs in males was 1.538% and prevalence in females was 1.359%. The difference between the prevalence in two genders was statistically insignificant ($p=0.43$).

Association with other congenital anomalies-In 28 patients (10.89%), the CAAs were associated with other congenital heart diseases (CHD). In 229 patients (89.12%) it was not associated with any CHD. Association with other CHD was extremely significantly higher in pediatric population as compared to that in adults ($p < 0.0001$).

Anatomical Classification-Distribution and prevalence of all types and subtypes of coronary anomalies was as per Table-1. Nine patients had more than one type of CAAs. The commonest anomaly was separate origin of LAD and LCX from LSV (0.319%). Second commonest one was anomalous origin of LCX from RSV (0.231%). The third commonest anomaly was coronary fistula (0.203%).

Table-1: Distribution and prevalence of all subtypes of coronary anomalies

Anomaly		Frequency	Prevalence (%)	
Anomalies of origination and course		A	202	
Absent left main trunk		A1	55	
Anomalous location of coronary ostium within aortic root or near proper aortic sinus of Valsalva (for each artery)	High	A2a	31	
	Low	A2b	4	
Anomalous location of coronary ostium outside normal coronary aortic sinuses	PSV	A3a	14	
	ascending aorta	A3b	3	
	PA	LCA	A3e1	5
		LAD	A3e3	0
		LCX	A3e2	1
RCA		A3e4	0	
Anomalous location of coronary ostium at improper sinus	RCA that arises from LSV	Course between aorta and PA	A4a3	26
		Course anterior to PA	A4a5	4
	LAD that arise from RSV- anterior to PA	A4b3	2	
	LCX that arises from RSV	Posterior atrioventricular groove	A4c1	1
		Retroaortic	A4c2	39
	LCA that arises from RSV	Retroaortic	A4d2	1
		Intraseptal	A4d4	4
		Anterior to PA	A4d5	1
		Posterior atrioventricular groove	A4d1	1
	Single coronary artery		A5	10
Anomalies of intrinsic coronary arterial anatomy		B	26	
Split RCA		B10a	8	
Split LAD		B11b	1	
Coronary hypoplasia		B5	1	
Intramural coronary artery		B6	16	
Anomalies of coronary termination		C	35	
Coronary cameral/ Coronary to PA fistula	To right ventricle	C2a	15	
	To right atrium	C2b	13	
	others	C2	7	
Anomalous anastomatic vessels		D	3	

LAD- Left Anterior Descending Artery; LCX- Left Circumflex artery; LSV- Left Sinus of Valsalva; PA- Pulmonary artery; PSV- Posterior Sinus of Valsalva; RCA- Right Coronary Artery; RSV- Right Sinus of Valsalva.

Functional Classification- Amongst the patients with CAAs, 204 (79.4%) (Prevalence, 1.183%) had benign anomalies while 20.6% (prevalence, 0.307%) of patients had malignant anomalies. Malignant anomalies were detected extremely significantly more commonly in patients younger than 40 years than that in patients older than 40 years ($p < 0.0001$).

Evaluation of CAAs on different modalities

Absent left main trunk- CAG was performed in all 55 patients with absent left main trunk. It detected the anomaly in 54 patients. Amongst those 55 patients, 37 patients also underwent MDCTA and the anomaly was identified in all those patients. For diagnosis of anomalous separate origin of LAD and LCX; CAG and MDCTA were equivalent with no significant difference ($p = 1.0$). Origin of LAD and malignant intramural course were not identified in one patient with CAG.

Anomalous location of coronary ostium within aortic root or near proper aortic sinus of Valsalva-Thirty-five patients had this anomaly. Invasive CAG was performed in 21 patients amongst those. It detected the anomaly in only 12 patients with a sensitivity of 58.3%. MDCTA detected the anomaly in all 32 patients in whom it was performed. It had sensitivity of 100% for detection of this anomaly. Both, CAG and MDCTA had specificity of 100%. For detection of anomalous origin of from similar sinus, MDCTA was better than CAG ($p = 0.0001$).

ACAOS- Amongst 87 patients with ACAOS, CAG was performed in 78 patients. It detected the anomaly in 76 patients with sensitivity of 98.6% and specificity of 100%. However, it delineated the course properly in only 73 patients. On the contrary, MDCTA detected and delineated the course in all 73 patients in whom it was performed. So, it had a sensitivity of 100% and specificity of 100% for ACAOS. For ACAOS, the difference between diagnostic accuracy of CAG and MDCTA was not significant ($p = 0.49$). Proper delineation of course after anomalous origin was significantly better with MDCTA than with CAG ($p = 0.05$).

Intra-myocardial course- Intra-myocardial course of a coronary artery was there in 16 patients, out of which 15 patients underwent CAG. The anomaly was detected in 13 patients amongst those with a sensitivity of 88.89% and specificity of 100%. MDCTA was performed in 12 patients and the anomaly was diagnosed in all those patients with a sensitivity of 100% and specificity of 100%. CAG and MDCTA were comparable for diagnosis of myocardial bridge, and the difference was statistically insignificant ($p = 0.49$). However, MDCTA delineated the intra-myocardial course (length of segment and depth) significantly better than CAG ($p = 0.0002$).

Anomalies of coronary termination-Thirty-four out of 35 patients with coronary fistulae underwent CAG. This CAA was diagnosed in all those patients with CAG but the proper course was delineated in only 31 patients. MDCTA was performed in 33 patients. The CAA was diagnosed in 32 patients amongst those and the course of fistulous tract was delineated in all those 32 patients.

For diagnosis and course delineation of termination anomalies, CAG and MDCTA were equivalent ($p = 0.49$ and 0.61 respectively). Echocardiography had sensitivity of 51%, specificity of 99.9%, for entire population. However, in pediatric age group, it had sensitivity of 92.8%, specificity of 99.6%. Its diagnostic accuracy for anomalous termination was very significantly higher in pediatric population (< 12 years) than that in adults ($p = 0.0016$) and in patients with proximal and larger fistulae than in those with smaller fistulae from distal vessels and branches ($p < 0.0001$).

Anomalous anastomotic vessels-Out of 3 patients with abnormal anastomotic vessels, all 3 had their anomalies detected on CAG and 2 had the anomalies apparent on MDCTA. For diagnosis of abnormal anastomotic vessels, CAG had higher sensitivity (100%) than that with MDCTA (66.67%). Both had equal specificity (100%). Proper course delineation of abnormal anastomotic vessel was successful in 2 patients with both of these modalities. For detection and proper delineation of course, the difference between MDCTA and CAG was statistically insignificant ($p = 1.0$).

Comparison of different modalities-The yield of echocardiography negatively correlated with age ($r=-0.6$). Mean heart rate at the time of MDCTA was 74.37 ± 8.21 beats per minute (bpm), which was very significantly lower than mean heart rate of 85.44 ± 15.23 bpm during CAG ($p=0.0001$). Need of per procedural beta-blockers to control heart rate was significantly higher with MDCTA than that with CAG ($p<0.0001$). Mean fluoroscopy-time with MDCTA (2.28 ± 0.82 min) was significantly lower than that with CAG (3.44 ± 2.5 min) ($p=0.0001$). Radiation exposure with CAG, 7.3 ± 2 mSv, was lower than that with MDCTA, 14.5 ± 3 mSv ($p<0.0001$). Radiation exposure for ACAOS was more than that for other anomalies with CAG ($p<0.001$), but not with MDCTA ($p=0.18$). (Figure-3) Radiation exposure with CAG correlated with CAA score ($r=0.3$), especially for origin and course anomalies ($r=0.6$). With MDCTA, the radiation exposure did not correlate with CAA score ($r=-0.019$). (Figure-4) Mean contrast-expenditure during CAG (65.55 ± 19.9 ml) and MDCTA (63.15 ± 15.6 ml) were not different ($p=0.52$). Contrast-expenditure correlated with CAA score with CAG for adults ($r=0.42$) but not with MDCTA ($r=-0.04$).

Figure-3: Bar diagram showing radiation exposure with different coronary anomalies with invasive X-ray angiogram and computed tomogram

A1- Absent left main trunk; A2- Anomalous location of coronary ostium within aortic root or near proper aortic sinus of Valsalva; A3- Anomalous location of coronary ostium outside normal coronary aortic sinuses; A4- Anomalous location of coronary ostium at improper sinus, A5- Single coronary artery; B- Anomalies of intrinsic coronary arterial anatomy; C- Coronary cameral/ Coronary to pulmonary artery fistula; D- Anomalous anastomatic vessels

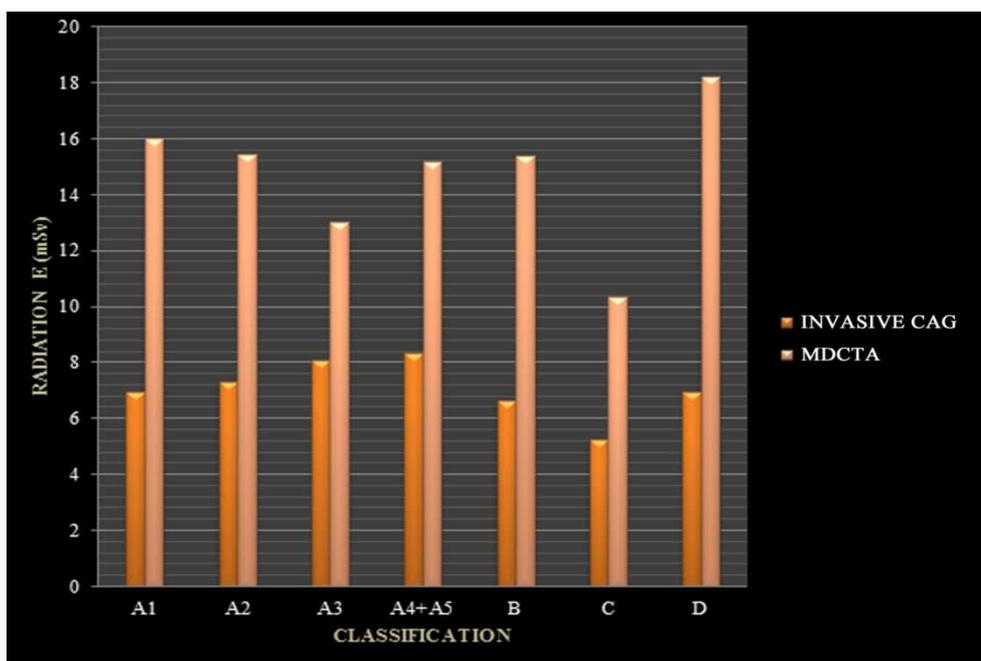
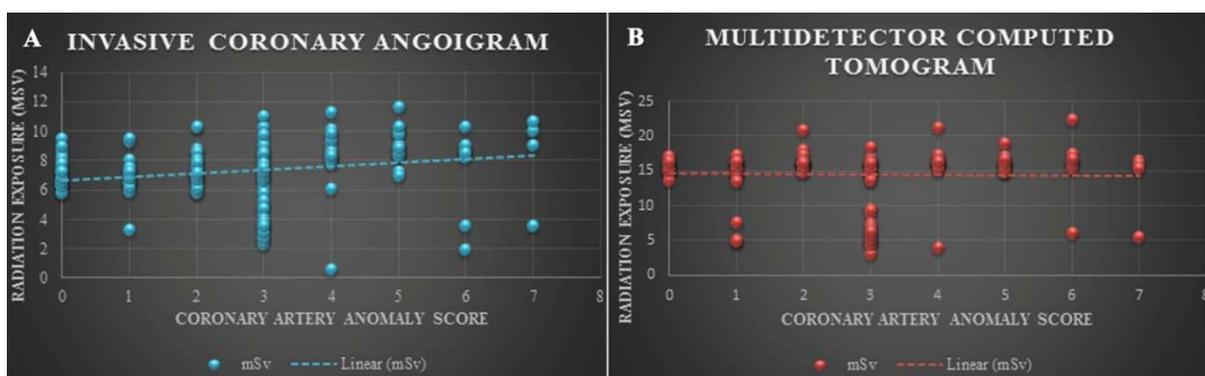


Figure-4: Scattered diagrams showing correlation of radiation exposure (E) with Coronary Artery Anomaly score



A: Correlation on invasive coronary angiogram ($r=0.3$)

B: Correlation on multidetector computed tomographic angiogram ($r=-0.019$)

Discussion

Prevalence-According to the current literature, CAAs occur in approximately 1% of the general population. This prevalence is derived from invasive CAG studies performed for suspected CAD. Necropsy studies report even lower numbers: Alexander and Griffith observed only 54 CAAs in 18,950 cases (0.3%). [2] These studies were limited by entry bias and lack of clear diagnostic criteria, which both are prerequisites for defining the true prevalence in a population. The first study adopting strict criteria for assessing CAAs was performed by Angelini and co-workers [10]. They reported a 5.64% prevalence of CAAs, which was higher than the usually cited prevalence derived from angiographic reports, but comparable to one of the first reports using 64-slice CT [10]. The later study reported a prevalence of 7.9% of CAAs of origin and further course, in mainly symptomatic patients [10]. De Jonge and co-workers also described a prevalence of 7% of CAAs including coronary fistulae [11]. In our study, an overall of 257 patients (1.49%) with CAAs were identified amongst 17,245 patients. This result is quite similar to that observed in a large angiographic series [12] as well as in two large MDCTA studies dealing either with 4- or 16-slice CT scanner and including 1758 patients [6] or with 64-slice CT in 1495 patients [13]. However, even such large studies do not reflect general population as only symptomatic patients with indications for either CAG or MDCTA were considered. Our findings are similar to previously published angiographic studies [10,13,14] although Wilkins et al (1988), [15] as well as Yamanaka et al (1990), [12] in the largest angiographic trial including 126,595 patients, reported a different prevalence in their study population. Nevertheless these inconsistent findings concerning the prevalence of CAAs and, moreover, different subgroups suggest that the described numbers are only relevant for those particular study populations. These discrepancies in reported prevalence might be caused by referral bias. Some of these patients with CAAs might have been or were referred because of known presence of CAA and not because of unrelated factors as in the general population. Therefore, a general conclusion for asymptomatic individuals cannot be drawn. Recently Cademartiri and colleagues (2008) reported a 1.5% prevalence of ACAOS as detected by MDCTA in a series of 543 patients [16] Our study also showed the results similar to that CT angiographic study.

The findings from angiograms performed for suspected ischemic disease indicate that CAAs were more common in women (7.6% versus 4.8% in men; $p=0.01$) [10]. However, the difference between the prevalence in two genders was statistically insignificant in our study.

Classification-CAAs were found in 1,686 patients (1.3% incidence) undergoing CAG at the Cleveland Clinic Foundation from 1960 to 1988. Of the 1,686 patients, 1,461 (87%) had anomalies of origin and distribution, and 225 (13%) had coronary artery fistulae [12]. Similarly, 88.72% of our patients had anomalies of origin and/or course; while, 11.3% had anomalies of termination, anastomosis.

Anomalies of origination and course- Table-2 shows the prevalence of CAAs, according to imaging modalities in various studies, [8,12,17-32] including our study. For anomalies of coronary structure like myocardial bridge; depth and length of intra-myocardial segment are important for risk scoring and stratification [9]. In our study, MDCTA was better than CAG for the diagnosis of anomalous location of coronary ostium within aortic root or near proper aortic sinus. Both were equivalent for identification of absent left main trunk, ACAOS and myocardial bridge. However, MDCTA was better than CAG for proper course delineation for ACAOS and intramural coronary artery, in our study.

Anomalies of coronary termination and anastomosis-Owing to the potentially complex 3-dimensional natures of these anomalies, conventional CAG, not infrequently, incompletely delineates the anatomical course of the coronary artery. CAG for fistulous anomalies requires a catheter in the right ventricular outflow tract and multiple views to define the course [33]. Reliable, complete, non-invasive assessment (or indeed reliable exclusion) of CAAs is therefore desirable and advantageous [34]. There was no significant difference CAG and MDCTA for identification of CAAs of termination and anastomosis in our study.

Table-2: Prevalence of CAAs in different studies according to imaging modalities

ACAOS- Anomalous Coronary Artery from Opposite Sinus; ALCAPA- Anomalous Left Coronary Artery from Pulmonary artery; CAA- Coronary Artery Anomaly; CAG-Coronary Angiogram; CTCA- Computed Tomographic Coronary Angiogram; LAD- Left Anterior Descending Artery; LCA- Left Coronary Artery; LCX- Left Circumflex Artery; LSV- Left Sinus of Valsalva; PSV- Posterior Sinus of Valsalva; RCA- Right Coronary Artery; RSV- Right Sinus of Valsalva

Study	Detection Modality	Study Population	Prevalence (%)										
			CAA	Absent Left Main Trunk	ACAOS	RCA from LSV	RCA from PSV	LCA from RSV	LCA from PSV	LAD from RSV	LCX from RSV	RSV Fistulae	ALCAPA
Yamanaka et al ¹²	CAG	126,595	1.3	0.41	0.155	0.107	0.003	0.017	0.0008	0.030	-	1.12	0.008
Lipsett et al ¹⁷	Autopsy	7,857 (pediatric)	0.5	-	0.216	-	-	-	-	-	-	-	-
Frescura et al ¹⁸	Autopsy	1200 (Congenital heart disease)	2.2	-	1.0	0.58	-	0.33	0.083	-	0.25	-	0.004
Davis et al ¹⁹	Echocardiography	2,388 (pediatric)	-	-	0.167	0.084	-	0.084	-	-	-	-	-
Harikrishnan et al ²⁰	CAG	7,400	0.460 (excluding, congenital heart diseases fistulae)	0.162	0.216	0.095	-	0.028	-	0.014	0.081	-	-
Gianluca et al ²¹	CAG	5,100	1.216	-	0.294	0.235	-	0.039	-	-	-	0.039	-
Aydinlar et al ²²	CAG	12,059	0.829	-	0.232	0.058	-	0.075	-	0.008	0.091	0.0414	-
Angelini et al ⁸	CAG	1950	5.64	0.67	1.07	0.92	-	0.15	-	-	0.67	0.87	-
von Ziegler et al ²³	CTCA	748	2.3	-	-	1.070	-	0.134	-	-	0.936	-	-
Ten Kate et al ²⁴	CTCA	1000	0.9	-	0.8	0.05	-	0.02	-	-	0.01	-	0.01
Kosar et al ²⁵	CTCA	700	1.4	0.4	1.0	0.5	-	0.2	-	-	0.1	-	-
Yildiz et al ²⁶	CAG	12,457	0.9	0.57	0.168	0.080	-	0.008	-	0.000	0.080	0.096	-
Eid et al ²⁷	CAG	4,650	0.73 (excluding ALCAPA, fistulae, and aneurysms)	-	0.387	0.194	-	0.108	-	0.022	0.065	-	-
Zhang et al ²⁸	CTCA	1,879	1.3	0.85	0.905	0.639	-	0.053	0.160	0.000	0.053	-	-
Karabay et al ²⁹	CTCA	745	4.96	0.93	-	-	0.13	-	-	-	0.79	0.13	-
Ghadri et al ³⁰	CTCA	1759	7.85	0.909	-	0.625	-	-	-	0.227	1.08	0.341	0.114
Ghadri et al ³⁰	CAG	9782	2.08	0.746	-	0.133	-	-	-	0.076	0.005	0.184	0.01
Altin et al ³¹	CAG	5548	2.7	0.9	-	0.72	-	0.018	-	-	-	0.2	-
Gräni et al ³²	CTCA	5634	2.6	0.48	1.17	0.59	0.02	0.04	0.09	0.08	0.38	0.09	0.02
Present study	Echocardiography, CAG, CTCA	17245	1.49	0.319	0.499	0.197	-	0.075	-	0.012	0.231	0.203	0.029

Functional Classification-Most CAAs did not result in signs, symptoms, or complications, and usually were discovered as incidental findings at the time of catheterization. Eighty-one percent were benign anomalies whereas; other anomalies were potentially serious in a study [12]. In our study, 79.4% patients had benign anomalies and 20.6 % patients had potentially serious anomalies.

Imaging Modalities

Echocardiography-Echocardiography is an alternative noninvasive imaging modality. Transthoracic echocardiography is a practical and often diagnostic test if specific attention is paid to the coronary arteries. Evaluation by echocardiography is limited to the proximal part of the coronary arteries [35]. Similarly, in our study, the diagnostic yield of echocardiography was more in pediatric patients and in those with proximal and larger abnormalities than in adults and those with distal and smaller anomalies.

Invasive CAG- CAG has traditionally been the imaging test of choice for the diagnosis and characterization of CAAs. The presence of a CAA can be a differential diagnosis in patients with suspected coronary disease, chest pain, or syncope. Accurate diagnosis of CAAs with CAG, however, is limited by the inability to define the anatomic course in relation to surrounding structures. Owing to the potentially complex three-dimensional nature of these anomalies, CAG, not infrequently, incompletely delineates the anatomical course of the coronary artery [33]. However, the presence of an anomalous coronary artery origin is sometimes only suspected after the invasive procedure, particularly in the case of unsuccessful engagement or visualization of a coronary artery. In addition, the declining use of pulmonary artery catheters during routine x-ray CAG has made it more difficult to discern the anterior versus the posterior trajectory of the anomalous vessels. The information obtained via catheter-based CAG pertains to the coronary arterial lumen alone [36]. In one study, CAG alone achieved correct identification of the abnormality in only 53% ($p=0.016$) [1].

Table-3: Comparisons of CTA and invasive CAG for CAA Evaluation on different studies

Study	Imaging Technique	Correctly Classified CAA/ Total patients with CAA	Percentage
Ropers et al ⁷	EBT	29/30	97
Memisoglu et al ³⁷	EBT	14/14	100
Shi et al ³⁸	MDCT	16/16	100
Schmid et al ³⁹	16 MSCT	35/ 35	100
Datta et al ⁴⁰	16 MSCT	20/ 20	100
Schmitt et al ⁴¹	16 MDCT	44/ 44	100
Sato et al ⁴²	MSCT	5/5	100
van Ooijen et al ⁴³	16 MSCT	13/13	100
Berberie et al ⁴⁴	MDCT	16/16	100
Deibler et al ⁴⁵	MDCT	8/9	89
Kacmaza et al ¹	ECG gated 16 MDCT	23/23	100
Present study	ECG gated 128 MDCT	206/207	99.5

CAA- Coronary Artery Anomaly; CT- Computed Tomography; EBT- Electron Beam Tomography; ECG- Electrocardiogram; MDCT- Multidetector CT; MSCT- Multislice CT

CTA- On comparison with invasive CAG, EBCT correctly identifies all normal controls and all patients with CAAs. The anatomic course of the coronary arteries was correctly classified with 97% accuracy, including ACAOS and coronary cameral fistula in a study of 30 patients. That study demonstrated that contrast-enhanced EBCT is a reliable noninvasive technique to identify CAAs and their course [35]. Multiple published series (Table-3) for comparison of coronary CTA data with CAG for evaluation of CAAs exist [1,7,37-45]. Early reports of using CTA to evaluate coronary artery have emphasized EBCT. MDCTA is a new imaging method to delineate clearly the origin and course of the CAAs. As we

have demonstrated in this study, MDCTA demonstrates precise origin and course with excellent spatial resolution. Some reports in current literature have supported our findings [1]. CTA is recommended for evaluation of suspected CAAs [38,46]. The assessment of anomalous coronary artery origin with cardiac CT has been shown to be accurate and of benefit in detecting and characterizing CAAs compared to CAG [7,36,39]. Radiation exposure, though higher with MDCTA than that with CAG; does not correlate with complexity of CAA in our study.

Other Modalities- The coronary MRI studies uniformly reported excellent specificity, sensitivity, accuracy; superiority over CAG with superior reconstruction capabilities with similarly excellent results in patients with CAAs [14,36,47]. Its limitations are low spatial resolution, artifacts, incomplete visualization of the distal arterial course, technical challenges, time consumption especially in comparison to MDCTA [16,47]. Intravascular Ultrasound (IVUS) gives idea regarding size and shape of ostium, tangentiality of proximal part of coronary artery in cases with abnormal origin. Virtual angiography analysis is useful for visualization and measurement of the coronary ostia, and localization relative to the intercoronary commissure, which is not possible with CAG. Distinct aortic origins of the RCA and LCA were seen in all 56 studies with virtual angiography [48].

Limitations- A relatively small number of patients and a retrospective nature of the study make generalization of results and conclusions questionable. The patients who underwent coronary work-up were actually referred for evaluation for symptoms. So they may not truly represent the community as it may also include asymptomatic individuals. Other imaging modalities e.g. coronary MRI, IVUS etc. were not evaluated. This study compared only anatomical modalities of coronary evaluation. Physiological studies like nuclear imaging, stress testing which give more information regarding impact of that particular anomaly; were not included.

Conclusion

Echocardiography adequately detects proximal CAAs, especially in pediatric patients. Its usefulness declines with increased body mass due to acoustic factors. CAG and MDCTA are comparable for detection of most CAA (except high origin near proper sinus). MDCTA better delineates 3-dimensional natures of anomalies and course. Radiation exposure is significantly more with MDCTA than with CAG, but this is not correlated to complexity of anomaly in contrast to CAG. MDCTA can be used for detection and delineation of most of CAA if patient is not at increased radiation risk (e.g. extremes of age) and who are prone to complications of CAG.

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