Original Article

Prevalence of Coronary Artery Anomalies Detected by Coronary Computed Tomography Angiography In-a Tertiary Care Center

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Objective: The aim of our study was to assess the prevalence of coronary artery anomalies in patients who underwent coronary computed tomography angiography (coronary CTA) for suspected or known coronary artery disease.

Materials and Methods: A retrospective study included a total of 842 patients who underwent coronary CTA because of known or suspected coronary artery disease. Coronary CTA were retrospectively reviewed by two radiologists experienced in cardiovascular and thoracic radiology. In each study, coronary artery anomalies [CAs] were investigated.

Results: A total of 842 patients (mean age 50.5±10.9) were reviewed for coronary artery anomalies. The overall prevalence of CAs in the present study is 3.9%, with the following distribution: 5 single coronary artery, 11 anomalous origins from opposite sinus of Valsalva, 2 absent left main, 3 high take-off coronary artery, 3 anomalous left coronary arteries from-the pulmonary artery, and 9 coronary artery fistulas.

Conclusion: Coronary CTA is a reliable noninvasive tool that allows accurate delineation of coronary arterial anomalies in an appropriate clinical setting and provides detailed 3-dimensional anatomic information that may be difficult to obtain with invasive coronary angiography.

Keywords: Anomalous coronary artery, Prevalence, Coronary CTA

J Med Assoc Thai 2018; 101 [Suppl. 7]: S63-S70
Website: http://www.jmatonline.com

Coronary artery anomalies [CAs] are uncommon with a prevalence of 1%, but figures between 0.3 to 5.6 % were reported in the literature[1-4]. For several decades, the diagnosis of coronary artery anomalies [CAs] is usually established by invasive coronary angiography [ICA]. However, due to the two-dimensional projection nature of ICA, the visualization of a complex three-dimensional vessel course as well as clarification of the exact relationship to surrounding anatomical structures may be difficult, and misinterpretation is reported in up to 50% of the cases[1,5]. Recently, coronary computed tomography angiography (coronary CTA) has emerged as a noninvasive alternative for the evaluation of the CAs[6]. The recently developed computed tomography scanner with 128-slice detectors able to achieve an improved temporal resolution up to 83 ms. It is now possible and practical to have high-quality cardiac imaging without beta-blocker premedication even in patients with high heart rates particularly after the introduction of modern protocols[7,8] that allowed performing coronary CTA with a radiation dose substantially lower than that of ICA[9]. Therefore, coronary CTA has been recommended as the first-line method for the assessment of known or suspected coronary artery anomalies [CAs][10]. Most of the CAs have been detected incidentally during the evaluation of patients with suspected coronary artery disease. Although CAs lack clinical significance in the majority of these patients, certain abnormal patterns, like the anomalous origin of a coronary vessel from the opposite sinus have been associated with sudden cardiac death and ischemic complications[2,3,5]. In 17% of athletes deaths, 12% of sport-related deaths in 14 to 40-year-old individuals are due to CAs[3,4]. As far as we know, this

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How to cite this article: Chaosuwannakit N, Makarawate P. Prevalence of Coronary Artery Anomalies Detected by Coronary Computed Tomography Angiography In-a Tertiary Care Center. J Med Assoc Thai 2018;101;Suppl.7: S63-S70.

is the first study to determine the prevalence and describe the coronary artery anomalies in referred patients undergoing coronary CTA in a tertiary care center–in Thailand.

Materials and Methods

Patient population

This retrospective study included 842 patients who underwent coronary computed tomography angiography (coronary CTA) during February 2011 to February 2012. The indications for coronary CTA were an abnormal, equivocal or non-diagnostic stress test, atypical chest pain, patients awaiting valvular surgery to detect or exclude associated coronary stenoses, complex congenital heart disease as well as the evaluation of cardiac etiology of syncope. The above are considered appropriate indications for coronary CTA based on the criteria of the American College of Cardiology [ACC] [10]. Exclusion criteria for coronary CTA included the presence of multiple ectopic beats, atrial fibrillation, pregnancy, renal failure, and a history of allergic reaction to iodine-containing contrast agents. The present study was approved by the Ethics Committee of the Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand, and informed consent was obtained from all patients.

CT coronary angiography scanning protocol

Imaging was performed on a 128-slice MDCT (Brilliance 128, Philips Healthcare, Netherland) using prospective or retrospective electrocardiographic [ECG] gating with the following parameters: 128x0.6 collimation, 0.3 sec rotation time, pitch of 0.32, 120 kV tube voltage and 185 reference mAs. Non-contrast scan for calculation for coronary calcium score was taken from the carina to the apex of the heart. The scan was followed by a test bolus injection to calculate the peak of contrast enhancement time. Then the final coronary angiogram was taken. A bolus of iodinated contrast material (350 mg/mL, Omnipaque; GE Healthcare) at a dose of 1.5 ml/kg with dual-head power injector followed by a 10 to 20 ml of saline flush at the same rate to that of the contrast was injected. Axial images were reconstructed with 0.75 mm slice thickness and 0.5 mm increment using a medium sharp convolution kernel (B26) and retrospective ECG gating. The reconstructions were performed in 5% steps over the entire R-R cycle using a single-segment algorithm that utilizes a quarter segments of projection data from both detectors. Patients were scanned in the supine position.

Coronary computed tomography angiography (coronary CTA) image analysis

All acquired coronary CTA images were transferred to a dedicated 3D-postprocessing workstation. Coronary CTA image analysis was performed by two cardiovascular and thoracic radiologists (with a respective 11 and 10 years of experience in examining cardiovascular and thoracic CT scans) in consensus and blinded to the clinical data. Two experienced radiologists evaluated the CAs by performing the Maximum Intensity Projections [MIPs], curved Multiplanar Reformats [cMPRs], and Volume Rendering Technique [VRT]. The CAs were classified into anomalies of origin (number of coronary ostia, high take-off, ectopic coronary origin, anomalous origin from pulmonary artery), anomalies of course (myocardial bridging) and anomalies of termination (coronary artery fistula).

Statistical analysis

Continuous data were expressed as mean $\pm$ SD. For the categorical variable, count(n) and percentage (%) are presented. Statistical analyses were performed using SPSS software version 22 (SPSS, Inc., Chicago, IL, USA).

Results

In total, 842 patients were included (446 men and 396 women) with a mean age of 50.5$\pm$10.9 years (1 day-88 years). Prevalence and type of anomalies of coronary arteries observed in this study population are outlined in Table 1. The prevalence of coronary anomalies in the present study was 3.9% (excluded

Table 1. Prevalence of coronary artery anomalies (CAs), n (%)

Anomalies of origin and course	
Absent left main	2 (0.2)
High takeoff	3 (0.3)
Anomalous left coronary artery from pulmonary artery [ALCAPA]	3 (0.3)
Anomalous origin from the opposite sinus	
RCA originating from the left coronary sinus	9 (1.0)
LCA originating from the right coronary sinus	2 (0.2)
Single coronary artery	5 (0.5)
Anomalies of intrinsic coronary arterial anatomy	
Myocardial bridging	18 (2.0)
Anomalies of coronary termination	
Coronary artery fistulas	9 (1.0)

myocardial bridging).

In 532 cases (76%), the RCA was dominant; in 64 cases (9.1%), the LCA was dominant; and in 104 cases (14.8%) co-dominance was observed. In 221 cases (31%), the LCA trifurcated to include a third vessel between the left anterior descending artery [LAD] and LCx, termed ramus intermedius.

The left main coronary artery [LM] was absent in 2 cases (0.2%) in which the left anterior descending artery [LAD] and left circumflex [LCx] originated from the left sinus of Valsalva with separate ostia. In 9 cases (0.5%), the RCA originated from the left sinus of Valsalva: all had an inter-arterial course (Figure 1). In two cases (0.2%), the LM originated from the right sinus of Valsalva: one had an inter-arterial course, and the other had a pre-pulmonic course. There were 2 cases of the right coronary artery with high take-off origin and 1 case of the left coronary artery with high take-off origin. In 5 cases (0.5%), a single coronary ostium was found (Figure 2). In 3 cases, an anomalous left coronary artery from pulmonary artery [ALCAPA] was detected (Figure 3). Myocardial bridging was observed in 18 cases (2.0%). All were identified at mid LAD. Nine cases (1.0 %) had fistulous tract connection branches from the RCA connected to the PA or right ventricle (Figure 4).

Discussion

Conventional invasive coronary angiography [ICA] has been the technique of choice for visualization of the coronary artery system for several decades. Despite its common use, alternative methods of visualizing the coronary arterial system are desired; in addition to being invasive, ICA has disadvantages in detecting coronary artery anomalies because of the limited number of 2D projection images obtained during catheterization and because of the absence of soft tissue information.

The overall prevalence of CAs in the present study is 3.9%. Myocardial bridging was not included in the prevalence calculation as it was excluded from most of the previous studies in the literature. This percentage prevalence includes cases of anomalous origin and course as well as cases of anomalous termination. Although our results are near to the results of von Ziegler et al[11] who reported a prevalence of 3.2% yet it is still high as compared to other studies[12,13]. The high prevalence in this study may be attributed to the greater advances in imaging that made it less invasive and easier to image CAs accurately in the present study patient population. Another reason is that coronary CTA is considered as part of the preoperative assessment in congenital heart disease in our institution, which allowed us to examine a large number of congenital heart disease patients and, in turn, expanded the prospects of detecting coronary artery anomalies.

Some classification systems of the CAs have been suggested[3,14,15]. According to these systems, anomalies of the CAs are divided into anomalies of

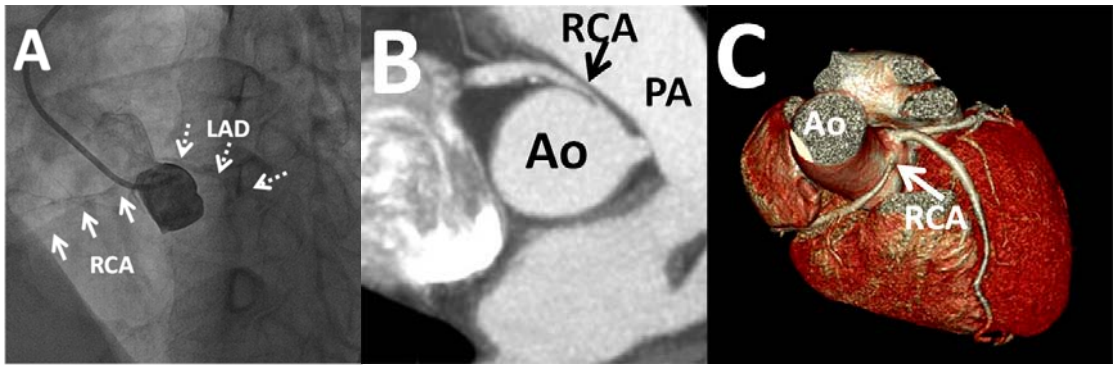

Figure 1. Images obtained in the patient with an anomalous origin of the RCA from the left sinus of Valsalva. Aortic root angiogram (A) shows the anomalous origin of the RCA (arrows), but the exact location of the ostium is not identified. Dual-source computed tomography coronary angiography with a maximum-intensity projection (B) and three-dimensional volume-rendered (C) images showed the RCA originating from the left sinus of Valsalva with the slit-like ostium (arrows) of the RCA is evident where the artery passes between the aortic root and the main pulmonary artery (RCA = right coronary artery, Ao = aorta, PA = pulmonary artery, LAD = left anterior descending artery).

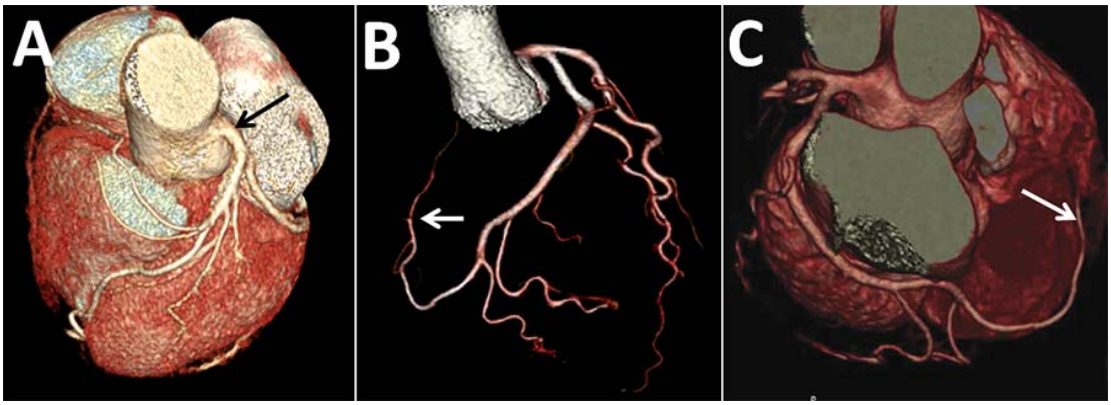

Figure 2. A 35-year-old woman presented to the emergency department with chest pain. Dual-source computed tomography coronary angiography- three-dimensional volume-rendered (A, B and C) images depicting the single coronary artery ostium off of the left sinus of Valsalva (A, black arrow) and left circumflex artery extending around the right atrioventricular groove supplied RCA territory (B and C, white arrows). Volume-rendered 3-dimensional reconstruction of the coronary arteries showing the single coronary artery ostium off of the left sinus of Valsalva and the extensive left circumflex artery.

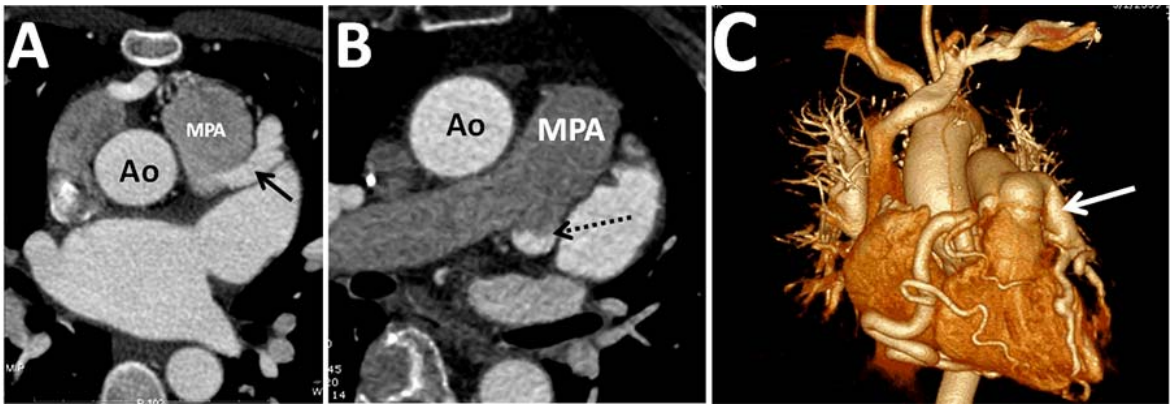

Figure 3. Dual-source computed tomography coronary angiography axial (A and B) and three-dimensional volume-rendered (C) images showing anomalous left coronary artery (A and C; arrow) from a main pulmonary artery (ALCAPA) and retrograde of contrast from the left coronary artery into the pulmonary artery (B; dashed arrow) due to steal phenomenon. (Ao; aorta, MPA; main pulmonary artery).

origin and course, anomalies of intrinsic coronary arterial anatomy, and anomalies of termination. In our study, we used the anomalies of origin, course, and termination in addition to the CA variants. Some authors consider the multiple ostia or absent LM as normal variants[16]. While others include it under the category of anomalous origin[17,18], as we did in the current study.

We detected 5 cases (0.6%) showed absent of left main. Instead, the LAD and LCX had separate ostia from the left sinus of Valsalva which is in line with the previous studies[19,20]. Clinically, it is important to recognize this anomaly to prevent complications in patients undergoing cardiac surgery who require selective coronary cardioplegia such as aortic valve replacement[20]. Although the inability to separately cannulate the LCX or LAD may result in the erroneous assumption that the vessel is absent or occluded on invasive coronary angiography, the anatomic display of coronary CTA makes this diagnostic error uncommon[18,20].

An anomalous coronary artery can arise from the non-coronary sinus or the opposite sinus. The abnormal CA then takes one of the four following paths depending on the anatomic relationship of the

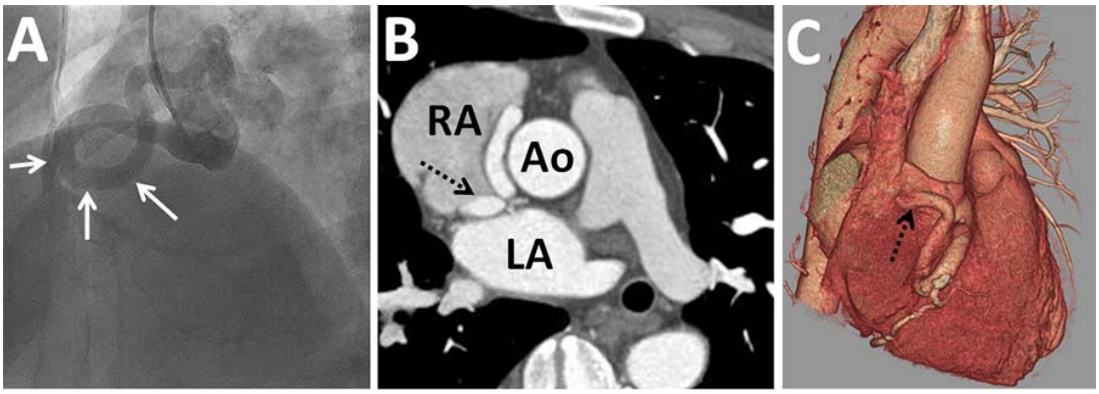

Figure 4. Images obtained in the patient with coronary artery fistula from RCA to the right atrium. Aortic root angiogram (A) shows the abnormal tortuous vessel from RCA (A, arrows), but the exact location of the termination is not identified. Dual-source computed tomography coronary angiography with oblique axial (B) and three-dimensional volume-rendered (C) images showed communication of fistula from mid-RCA with right atrium (B and C, dashed arrows) (RA; right atrium, LA; left atrium, Ao; aorta).

anomalous vessel to the aorta and the pulmonary trunk. It may proceed into inter-arterial (between the aortic root and the pulmonary trunk), retro-aortic (dorsal to the aortic root), pre-pulmonic (anterior to the PA or right ventricular outflow tract), or trans-septal or sub-pulmonic (beneath the right ventricular outflow tract) course[15]. The inter-arterial course is considered to be a malignant subtype, with a high risk of sudden cardiac death, especially when the LCA originates from the right coronary sinus. Theories about this anomaly's malignant potential include ischemia from compression of the vessel by the great vessels at the inter-arterial component of the artery, acute take-off from the aortic wall, an associated ostial ridge, a slit-like ostium, intramural (inside the wall of the aortic root) course, superimposed spasm, intimal plaque and clotting[21-25]. Although many patients are asymptomatic at the time of presentation or diagnosis, surgical correction is recommended due to the risk of ischemic sudden death[21-25].

In our sample population, we observed nine cases of anomalous RCA origin from the left sinus of Valsalva and one case of anomalous LCA origin from the right sinus of Valsalva with inter-arterial course between the aortic root and PA. We had one case in which the left coronary artery originated from the right sinus of Valsalva with the trans-septal subtype. The single coronary artery is a situation where the LCA and RCA arise with a common ostium from the right, left or non-coronary sinus. The single coronary artery is among the rarest of coronary artery anomalies that is seen in only 0.024 to 0.044% of the population[26,27]. A single coronary artery is thought to be associated with a risk of sudden cardiac death, even in patients without a malignant arterial course. Demonstration of significant ischemia in symptomatic patients therefore warrants further clinical attention[26,27]. The single anomalous trunk supplies blood to the entire heart and is classified according to its origin, branching pattern, and course. In the current study, we had 5 (0.5%) cases of single coronary artery which higher prevalence than previously publish. The presence of a single CA can be an isolated finding (2 cases in the present study) or associated with additional cardiac anomalies (3 cases in the present study associated with complex congenital heart disease)[28]. As previously mentioned with the ectopic origin of the CA, the course taken by the vessels after the division of single vessel to right and left has more clinical significance[29].

Myocardial bridging [MB] is a congenital condition in which a segment of major epicardial CA proceeds intramurally through the myocardium beneath the muscle bridge[30]. The MB was the most frequently found anomaly as it was diagnosed in 18 cases (2%) in the current study. Myocardial bridging is considered a benign condition that most commonly affects the middle segment of the LAD[30,31]. However, the relationship between MB anomaly and increased cardiovascular morbidity is still unclear.

Coronary artery fistulas are present in 0.002% of the general population and are visualized in nearly 0.25% of the patients undergoing cardiac catheterization[33]. The majority of the fistulas drain into the PA or right ventricle, but fistulae may also drain into

anywhere from between the vena cava or CS to the PA or LA[32]. Multiple fistulae may also occur. Over 90% of fistulae drain into the right side of the heart causing right to left shunt. Chronic large volume shunts through these fistulae may cause major aneurysmal enlargement of the proximal feeding CA in addition to enlargement of the receiving vessel or chamber. The uninvolved CAs are usually normal[33]. A study by Zhou et al[34]. reported that fistulae more commonly (50.0%) originate from both the LCA and the RCA followed by the LCA in 30.4% and RCA in 12.0%. The remaining 7.6% of the cases were associated with extra-cardiac communications. In the current study, we encountered 9 cases of coronary-pulmonary artery-cameral fistula (1%). The diameter of the RCA was relatively increased as it is the primary feeder of the fistula. Clinical symptoms are proportional to the amount of induced hemodynamic abnormality. Patients with small CA fistulas remain asymptomatic, whereas those with high-flow fistulas may develop hemodynamic steal phenomenon with consequent myocardial ischemia[35]. This study has several limitations that artificially may have raised the incidence of the anomalies reported. One limitation was the retrospective design of the trial, which was prone to confounding factors and bias. Moreover, the small sample size and the study population was highly selected our sample does not represent the true prevalence in a more general population since the cases were collected from a tertiary care referral medical school hospital. Further, the study may have included patients included that underwent coronary CTA because of an anomaly that was seen or suspected in catheterization. Surgical confirmation of coronary CTA finding was not available since not all of them underwent a surgical correction, especially those who are with benign anomalous origin and small fistulas.

Conclusion

The present study shows that coronary CTA has good diagnostic performance in diagnosis of coronary artery anomalies. The complex anatomy of the coronary arteries in 3D can be accurately depicted by coronary CTA. It is a valid alternative to invasive coronary angiography in the diagnosis of the coronary artery anomalies. It also acts as a road-map to the interventional cardiologist and cardiovascular surgeon, providing information about variations and anomalies in a patient before cardiac intervention or surgery to prevent possible complications of the procedure. The prevalence of CAs in the subjects referred to the tertiary care hospital in the present study was 3.9% that is relatively higher than the average percentage reported in the literature. A further elaborate follow-up study is needed to analyze the exact prevalence of congenital coronary anomalies in the whole Thailand population.

Acknowledgements

The authors thank the Faculty of Medicine for its support, Panaya Tumsatan for her substantial contribution to the present study including image analysis and manuscript revision.

What is already known on this topic?

Coronary computed tomography angiography yield excellent diagnostic tool for the comprehensive assessment of a patient with suspected coronary artery anomalies [CAs].

What this study adds?

This is the first study to determine the prevalence and describe the coronary artery anomalies in referred patients undergoing coronary CTA using the 128 slice computed tomography scanner in a tertiary care center in Thailand. The present study shows that the prevalence of CAs in the subjects referred to the tertiary care hospital in the present study was 3.2% that is relatively higher than the average percentage reported in the literature. The coronary computed tomography angiography (coronary CTA) has good diagnostic performance in diagnosis of coronary artery anomalies. It is a valid alternative to invasive coronary angiography in the diagnosis of the coronary artery anomalies.

Potential conflicts of interest

The authors declare no conflict of interest.

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