ORIGINAL ARTICLE

Anatomic variants and anomalies of coronary arteries detected by computed tomography angiography in southern Thailand

Kultida Chaiyagool, MD, Ruedeekorn Suwannanon, MD, Keerati Hongsakul, MD

Division of Diagnostic Radiology, Department of Radiology, Faculty of Medicine, Prince of Songkla University, 15 Kanchanavanit Road, Hat Yai, Songkhla, Thailand

ABSTRACT

Objective: To evaluate the prevalence of coronary artery anatomic variants and anomalies detected by computed tomography angiography (CTA)

Materials and methods: A retrospective study was conducted on all patients undergoing coronary CTA using a 64-detector row CT in the Radiology Department, Songklanagarind Hospital, from January 2010 to January 2013. Data were recorded and analyzed.

Results: The imaging results of 279 patients were reviewed. One hundred and twenty-two females (43.7%) and 157 males (56.3%) [age range, 26-82 years] were reviewed for coronary artery variants and anomalies with post-processing images. The right coronary dominance was the most common dominant type (91.4%). The prevalence of ramus intermedius was 68.8%; those of the absence of the left main coronary artery and left circumflex artery were 0.4%, respectively; and of the high takeoff of the coronary artery was 3.6%. Anomalies of origin and course were detected as the right coronary artery originating from the left coronary sinus in 1.1% of the patients. Myocardial bridging and coronary fistulas were demonstrated in 55.6% and 0.7% of our subjects, respectively.

Conclusion: A coronary CTA can effectively represent the complex anatomy of the coronaries as well as their anatomic variations and anomalies. The prevalence of most coronary variations were in concordance with the data of previous reports.

KEY WORDS:
anatomical variation, anomaly, coronary artery, computed tomography angiography

INTRODUCTION

The small dimensions and rapid movement of coronary arteries have made their evaluation with computed tomography (CT) challenging. However, because of the dramatic developments in the multidetector computed tomography (MDCT) technology in the last decade, coronary CT angiography (CTA) has become an increasingly important noninvasive modality in the diagnosis of coronary artery diseases.[1]

CTA is a noninvasive, two-dimensional (2D) and three-dimensional (3D) imaging technique that has recently been used to visualize coronary arteries and detect coronary artery pathology.[2] It is now possible to examine the coronary arteries and heart structures in a single and short breath-hold with high spatial and temporal resolutions.[3] The advantages of CTA lie primarily in its high-level vascular diagnosis and anatomical accuracy. The technique offers excellent spatial resolution with the possibility of performing flexible post-processing images like multiplanar reconstruction (MPR), maximal intensity projection (MIP) and volume rendering (VR).[3]

The high temporal and spatial resolution capabilities of MDCT scanners enable detailed 3D visualization of the complex coronary artery anatomy without motion artefact.[1] To be able to interpret the coronary CTA correctly, radiologists should be familiar with the normal anatomy, anatomic variants, and anomalies of the coronary arteries as well as their cross-sectional appearances.[1] The incorrect interpretation of coronary variants or anomalies might cause technical difficulties during cardiac interventions or lead to clinical misdiagnoses or major complications during surgical interventions.[3]

The prevalence of coronary artery anomalies is rare, affecting about 0.3%-1% of the general population.[4,5] However, coronary anomalies can be divided into benign and malignant types. The malignant type, e.g., the acute coronary occlusion, can be life-threatening.[3] Sometimes coronary anomalies have the potential of producing fatal consequences other than those strictly related to myocardial ischemia. These consequences might include volume overload (related to coronary fistulas), aortic-root distortion (related to very large coronary fistulas or aneurysms), bacterial endocarditis, complications during aortic valve surgery or coronary angioplasty, and misdiagnosis (as in many cases of "missing" coronary artery).[4]

Over the years, several studies on coronary artery anomalies performed using 64-MDCT have been reported.[1,3,6,7] In our hospital, which is the biggest tertiary hospital in Southern Thailand, the 64-MDCT has been in use since 2010. However, to date, there are no prior studies on coronary artery anatomic variation and anomalies from this region. The objective of this study was to retrospectively review the

This article was accepted: 19 April 2018
Corresponding Author: Keerati Hongsakul
Email: keeratihongsakul@yahoo.com

appearance of coronary artery anatomic variants and anomalies on 64-slice CTA images.

MATERIALS AND METHODS

Population

This was a retrospective study of all patients who underwent coronary CTA using a 64-detector row CT in our hospital from January 2010 to January 2013. The data were retrieved from the Radiology Department records and the hospital databases. The inclusion criteria were patients who were more than 15 years old and underwent coronary CTA in our hospital from January 2010 to January 2013. The exclusion criteria consisted of patients who were less than 15 years old and had incomplete information or poor quality images. In our hospital, the protocol for coronary and cardiac CTA of patient less than 15 years old is different from that for patients more than 15 years old, which is a reason to exclude. The study was approved by the Research Ethics Committee, Faculty of Medicine, Prince of Songkla University.

Imaging Data Acquisition and Reconstruction Protocol

CTA Technique

All examinations were performed using a 64-MDCT scanner (Brilliance TMCT, Philips, Netherlands) with retrospective ECG gating. The images were obtained with detector collimation 64 x 0.625 mm; voltage 100 kVp or 120 kVp; tube current 800 mAs; pitch range 0.2; and gantry rotation time 0.4 seconds. If there was no contraindication, patients with a heart rate of > 60 beats per minutes received oral beta-blockers (50-100 mg of metoprolol) about 1 hour before the examination. An 18 or 20- gauge intravenous cannula was used for venous access in the upper extremity. A bolus of a non-ionic contrast medium with a high iodine concentration (370 mg/mL), approximately 80 to 100 mL, was injected at a flow rate of 5-6 mL/s followed by an injection of 50 mL saline with the same flow rate. A bolus-tracking technique was used by placing the region of interest over the descending aorta and setting the trigger threshold to 150 Hounsfield units (HU) to determine the scan time. The field from the tracheal carina to the diaphragm was covered. The scan was started manually and acquired during one breath-hold in 5–6 seconds with simultaneous ECG-gating. The coronary CT angiography with the synchronous electrocardiographic tracing of the patients was performed.

Image reconstruction

In most patients, the reconstruction performed at the 75% phase of the R-R interval was found to be optimal for image analysis. The stored CT images in the picture archiving and communication system (PACS) were transferred and processed on a separate cardiac workstation (Extended Brilliance Workspace, V4.5.2 40007, Philips, Netherlands). All data were analyzed using multiplanar reconstructions (MPR), curved MPR (cMPR), thin-slab maximum intensity projections (MIP), and three-dimensional volume rendering (3D-VR) reconstructions in addition to the axial source images.

Image interpretation

The MDCT-angiography images of the patients were interpreted independently by a radiologist with two years of experience in cardiac CTA (RS) and a 3rd -year resident in radiology training (KCh). In the case of interpretation disagreement, the case was discussed with a third radiologist, who had four years of cardiac imaging experience (KH) to reach a consensus.

The definition of normal coronary arteries was described[5] as follows; the right coronary artery (RCA) is an artery that arises from the anterior right coronary sinus and locates in the right atrioventricular groove toward the posterior interventricular septum. The end of this artery divides into the posterior descending artery (PDA) and the posterolateral branch (PLB) as a right dominance. The left main coronary artery (LMCA) is an artery that arises from the left posterior coronary sinus with a 5–10 mm length and dividing into the left anterior descending (LAD) and left circumflex (LCx) arteries. The LAD is an artery that turns anteriorly to course in the anterior interventricular groove toward the apex. The LCx is an artery located in the left atrioventricular groove. In some cases, the LCx artery gives to the PDA or PLB as a left dominance or co-dominant variation.

The anatomic variations and anomalies of coronary arteries, i.e. the origin and course of coronary arteries as well as their branches and territories, were identified in all patients. Variants were considered in term of coronary dominance (right, left and co-dominance), origin of the conus artery and the sinoatrial node artery (SNA), and the presence of ramus intermedius. Coronary artery anomalies were classified according to the classification system developed by Angelini et al.[2] as anomalies of origination and course, anomalies of intrinsic coronary arterial anatomy, and anomalies of coronary termination. The coronary segments were classified according to the American Heart Association scheme.[8]

Statistical analysis

The patient data like gender and age were entered individually into a database. The coronary artery variations and anomalies were numbered and analyzed using percentage. Cohen's kappa coefficient was employed for the statistical measurement of inter observer agreement.

RESULTS

Three hundred and twelve consecutive patients underwent coronary CTA using a 64-detector row CT in our hospital from January 2010 to January 2013. Five patients, who were less than 15 years old, were excluded. Another 28 patients with incomplete information or poor quality images were also excluded. Consequently, the imaging results of 279 patients, consisting of 122 females (43.7%) and 157 males (56.3%) [age range, 26-82 years] were reviewed to identify the anatomy of their coronary arteries and anatomic variants. Most of them (96.0%) were referred for coronary CTA because of a known or suspected coronary artery disease. The other indications (3.9%) were preoperative evaluation for non-coronary surgery, confirmed prior diagnosis of coronary fistula or aneurysm.

The anatomic variants of the coronary arteries that were detected in this study population are listed in Table I. The most common dominant coronary circulation was right

Table I: Prevalence of anatomic variants of coronary arteries (n = 279)

Anatomic variants of the coronary arteries	Patients (%)
Right dominance	255 (91.4)
Left dominance	20 (7.2)
Co-dominance	4 (1.4)
Conus artery originating from right coronary artery	265 (95)
Conus artery originating from aorta	14 (5)
Sinoatrial node artery originating from right coronary artery	155 (55.6)
Sinoatrial node artery originating from left circumflex artery	91 (32.6)
Sinoatrial node artery originating from left main coronary artery	1 (0.4)
Sinoatrial node artery originating from aorta	1 (0.4)
No demonstration of sinoatrial node artery	31 (11.1)
Ramus intermedius	192 (68.8)

Table II: Prevalence of coronary artery anomalies (n = 279)

Anomalies of coronary arteries	Patients (%)
Absence of left main coronary artery	1 (0.4)
Absence of left circumflex artery	1 (0.4)
High takeoff of left main coronary artery	10 (3.6)
Right coronary artery originating from the left coronary sinus with an interarterial course	3 (1.1)
Myocardial bridging	155 (55.6)
Coronary artery fistula	2 (0.7)

dominance (91.4%) as seen in Figure 1. The left dominant and co-dominant types were found in in 7.2% and in 1.4% of the patients, respectively. The conus artery originated from the RCA in 95% of the cases and the remaining 5% from the aorta. The proportion of the SNA arising from the RCA was 55.6%, from the left circumflex (LCx) 32.6%, from the LMCA and aorta 0.4% each, while, in 11.1% of the patients, it was not seen. Ramus intermedius arising from the LMCA as a third branch between the LMCA and LCx and supplying the area of the antero-lateral wall of the left ventricle, was observed in 68.8% of our subjects (Figure 2).

The data concerning the prevalence of coronary artery anomalies are shown in Table II. The prevalence of both the absence of the LMCA and LCx was identified at 0.4%. A high take-off was present in 3.6% of cases, and was only seen at LMCA. An anomalous origin and course was detected in 1.1% of our population. All of such cases involved the anomalous origin of RCA from the left coronary sinus (LCS) with an interarterial course (Figure 3).

Myocardial bridging, defined as an intra-myocardial segment in the course of a major epicardial coronary artery, was visualized in 55.6% of the images. The majority of myocardial bridging (83.2%) was localized in the mid LAD (Figure 4).The myocardial bridging of the proximal and distal LAD were depicted in 9.7% and 1.8% of CTAs, respectively. Two cases of coronary-to-pulmonary artery fistulas were found. One of them was a coronary-to-pulmonary artery fistula where the conus branch from the proximal RCA and the branch of the LAD connected to the main pulmonary trunk (MPA). The other one was an RCA-to-MPA fistula (Figure 5).

The interobserver agreement using Cohen's kappa statistic ranged from 0.322 to 1. Most of the interobsever agreement involved perfect agreement (Kappa = 0.81-1.00). Substantial agreement (Kappa = 0.61-0.8) was detected in the diagnosis of conus artery, SNA and ramus intermedius. Fair interobserver agreement (Kappa = 0.21-0.40) was observed in the case of a high takeoff of the LMCA.

DISCUSSION

The MDCT of coronary arteries has become an increasingly important noninvasive modality in the diagnosis of coronary artery disease. The advantages of CTA lie primarily in its high-level anatomical accuracy and vascular diagnosis.[3] Basic knowledge of the normal coronary anatomy and familiarity with its common variations and anomalies are essential for radiologists in order to assess coronary CTA accurately.[6] The classification systems of the coronary artery anomalies were developed by Angelini et al.[4] and have been shown reliable by previous studies.[1,2,5,7] According to these systems, the coronary artery anomalies are generally classified into anomalies of origination and course, intrinsic coronary arterial anatomy, and termination.[4]

The interpretation of the coronary CTA should be initiated by the determination of the coronary dominance.[1] The prevalence of coronary artery dominancy is variable in literature due to the different definitions of co-dominance employed.[1,6] This study defined co-dominance as a state where the PDA originates from the RCA, and the PLB artery arises from the LCx.[1,9] In this study, the right dominance had the highest prevalence (91.4%), followed by left dominance (7.2%) and co-dominance(1.4%). These findings concurred with the previous studies by Angelini et al.[4] and Cengiz et al.[6] However, the study of Kosar et al.[1] reported that the prevalence of co-dominant type (14.8%) was higher than that of left dominant type (9.1%), which was the opposite to the results of the study of Angelini et al.,[4] Cengiz et al.[6] as well as our study.

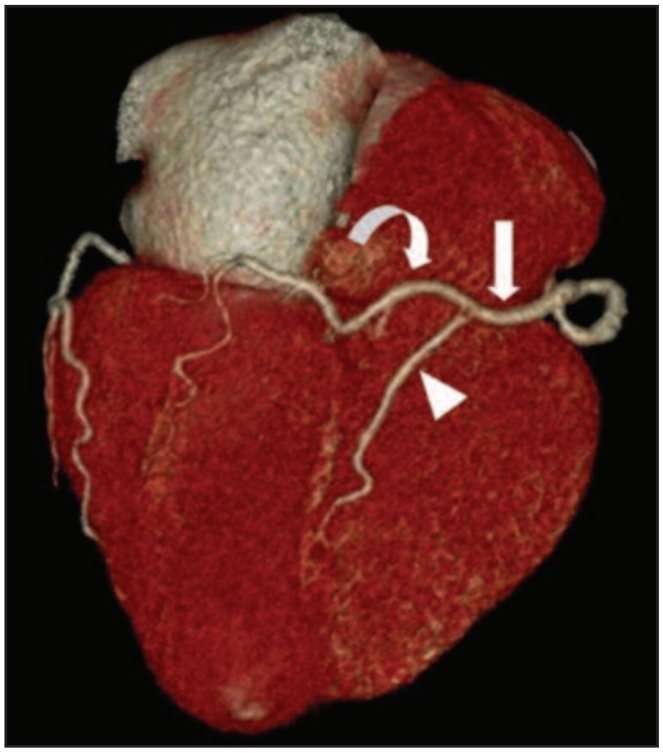

Fig. 1: Inferior view of a 3D volume-rendered CT angiography showing a right dominant coronary circulation that refer to the RCA (arrow) and divides into the PDA (arrowhead) and the PLB (curved arrow).

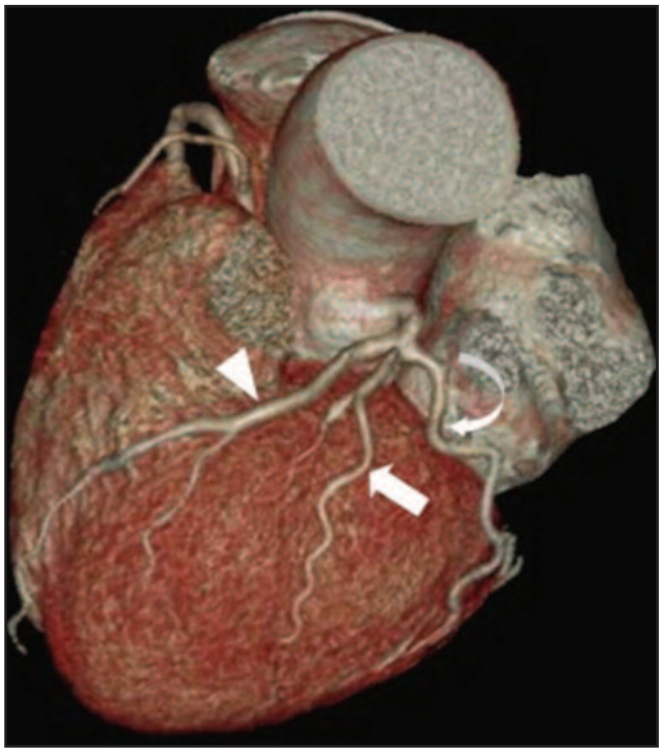

Fig. 2: A 3D volume-rendered CT angiography showing ramus intermedius (arrow) identified between the LAD (arrowhead) and LCx (curved arrow).

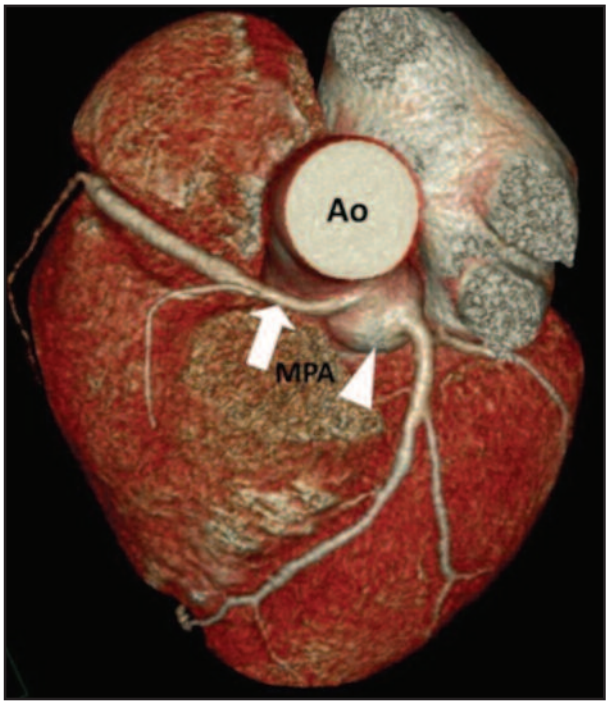

Fig. 3: A 3D volume-rendered CT angiography displaying an anomalous of origin and course of RCA (arrow), originating from the LCS (arrowhead) and with an interarterial course. Ao = aorta, MPA = main pulmonary artery.

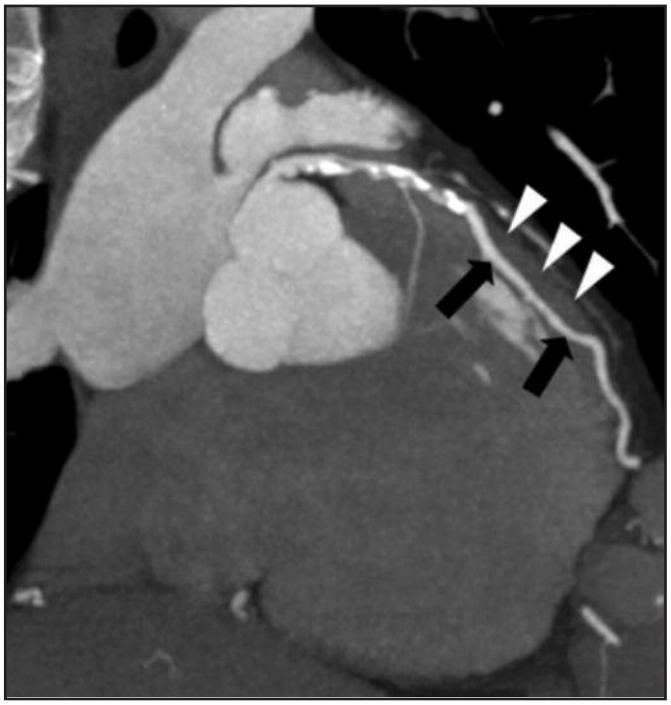

Fig. 4: An MIP sagittal-oblique view of a CTA showing myocardial bridging referring to the middle segment of the LAD (arrows) and embedding in the myocardium (arrowheads).

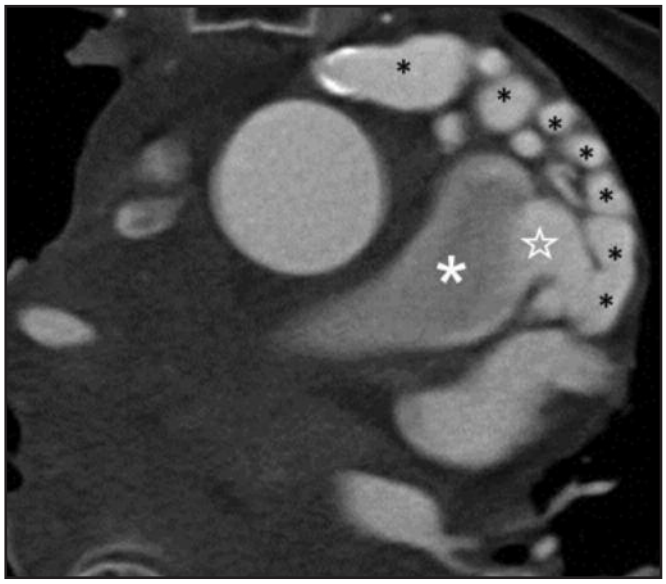

Fig. 5: An MIP axial view of a CTA showing a coronary-pulmonary fistula (star) seen as a tortuous feeding artery from the RCA (small asterisk) and draining into the MPA (large asterisk).

This study found the conus artery arising as the first branch from the proximal RCA in the majority of cases (95%), followed by arising directly from the right coronary sinus with a separate ostium (14%). This finding was in concordance with those of previous studies that reported a rate of 64.1%-83% for the conus artery arising from the proximal RCA, and a rate of 11.6%-22% for it arising directly from the aorta.[1,3,6] In our study, SNA originated most commonly from the RCA (55.6%), followed by originated from the LCx (32.6%), the LMCA (0.4%), and directly from the aorta (0.4). Our results were similar to those reported by the previous studies.[1,3,6,10,11] In particular, Cengiz et al.(2012)[6] reported a rate of 65.6% of origination from the RCA, 33.7% from the LCx, 0.4% from the right coronary sinus, 0.2% from the descending aorta, 0.05% from the LMCA, and 0.05% from the left coronary sinus. However, in 11.1% of the cases, the SNA could not be determined in our study, possibly due to its very small size and/or motion artifact.

The LMCA normally arises from the LCS. The most common variation of the LMCA anatomy is an intermediate artery, which arises from the LMCA as a third branch between the LAD and LCx, which is termed ramus intermedius. The prevalence of ramus intermedius in the present study was 68.8%, which is much higher than that the prior studies (21.9%-31.3%).[1,3,6]

The prevalence of coronary artery anomalies has a wide range (0.7% to 18%)[1,4,12] that can be attributed to the availability and wide use of coronary CTA. The absence of the LMCA causing the LAD and LCx to originate separately from the LCS was found in one case of our study (0.4%). In accordance with the previous reports, the prevalence of LMCA absence was about 0.4%-3.3%.[1,3,4,7] An absent LCx was detected in one patient (0.4%) of this study, which was similar to the reported finding of a prior study.[1] High takeoff refers to the origin of either the RCA or the LMCA at a point above the junctional zone between its sinus and the tubular part of the ascending aorta.[5] However, some controversy regarding the position of origin exists. Some studies[14,15] defined 5 mm above the aortic sinotubular junction as a high position of ostium. Some others have defined 10 mm above sinotubular junction as a high position of ostium.[1,12,16] Finally, we used the cut-off of 5 mm above the sinotubular junction as the consensus. In this study, this was found in 10 cases (3.6%), and all of them were seen at only the LMCA. However, its prevalence was much higher when compared with that of previous reports (about 0.7%).[1,3,4,7]

The prevalence of an anomalous origin from the opposite sinus was also evaluated in this study. We found three cases (1.1 %) with an anomalous RCA origin from the LCS, and all of them had interarterial courses. The prevalence of this anomaly in this study was twice as high as that of previous reports (0.44%-0.5%).[1,7] The small number of patients, included in our study may explain this discrepancy.

Myocardial bridging, which is defined as an intra-myocardial segment in the course of a major epicardial coronary artery[7], is included in the anomalies of the intrinsic coronary arterial anatomy.[1,3] In this study, myocardial bridging was found in 55.6% of the cases. It was most often seen at the mid LAD (83.2%). Again, the prevalence of this anomaly was much higher than that of prior studies, which ranges from 10.9% to 37%.[1,3,4,7] Coronary artery fistula, which has been described as one of the anomalies of coronary termination4, was observed in two cases (0.7%) in this study. Its prevalence was higher than those found in previous reports (0.07%-0.87%).[3,4,7]

In this study, the prevalence of some variations or anomalies such as ramus intermedius, high takeoff coronary artery, anomalous origin from the opposite sinus, myocardial bridging and coronary artery fistula was higher than those reported in previous studies. This can be explained by the fact that the total number of patients in this study was smaller than that of previous studies. Moreover, the higher resolution of the new-generation CTs and the differences in reviewer experience are factors that affect interpretation.

Coronary variations and anomalies are associated with a variety of clinical symptoms, from asymptomatic to sudden death. All anatomical variations of coronary arteries in our study's patients were not associated with any symptoms. They were detected as incidental findings in the CTA. The patients who had coronary anomalies in this study experienced various symptoms like chest pain, dyspnea and heart failure; however, some reported no symptoms. These findings were similar with those of the study of Oon et al.(2107),[13] which showed that the common presenting symptom in patients with coronary anomalies were chest pain (65.4%), dyspnea (34.6%) and heart failure (11.5%). Furthermore, an absent or hypoplastic coronary artery is unlikely to be associated with myocardial ischemia.[17] However, previous case studies[18,19] have reported angina-like symptoms related to this anomaly due to the steal phenomenon; our cases did too. A high takeoff of a coronary artery and myocardial bridging are usually benign anomalies with no major clinical problems. However, these anomalies can cause acute coronary attack and sudden

cardiac arrest.[5,16] Both cases of these two anomalies in this study were incidental findings from CTA without clinical symptoms. Both patients with an anomalous origin from the opposite sinus in our study presented with occasional chest pain, which may be due to the compression between the aorta and pulmonary artery. This type of anomaly carries a high risk for myocardial ischemia and is the most common cause of sudden death in athletic young adults.[20] Two cases of a coronary artery fistula in this study presented with dyspnea and heart failure due to volume overload. However, most of the adult cases of a coronary artery fistula have no clinical symptom, and the severity of the left-to-right shunt determines the clinical presentation.[16,21]

The interobsever agreement in this study was varied, ranging from 0.322 to 1. However, most interobserver agreement in this study was perfect, which reflected a low difference in experience between interpreters. Additionally, the resolution of current CTA is high, so it is not difficult to interpret the anomalies related to the coronary arteries. Rarely, some arterial variants were interpreted with substantial and fair interobserver agreement. In this study, substantial agreement in the interpretation of such anomalies concerned conus artery, SNA, and ramus intermedius. This can be explained by the small size of some vessels, which made their detection and interpretation difficult. The high takeoff of the LMCA was interpreted with fair agreement, possibly due to controversies in definition. Lastly, the small number of enrolled patients compared with previous studies and differences in reviewer experience were limitations in this study. However, these findings can serve as a database in this region.

CONCLUSIONS

The coronary CTA is a non-invasive study, which can effectively represent the complex coronary anatomy along with their anatomic variations and anomalies. The prevalence of coronary variations and anomalies vary and may lead to mortality. The basic knowledge of the normal coronary anatomy and familiarity with its common variations and anomalies are essential for correct diagnosis and prevention of potential errors during interventional and surgical procedures. According to the results of this study, the prevalence of coronary variations and anomalies among Southern Thai people was mostly similar to the one reported by previous studies from different regions.

REFERENCES

1. Kosar P, Ergun E, Ozturk C, Kosar U. Anatomic variations and anomalies of the coronary arteries: 64-slice CT angiographic appearance. Diagn Interv Radiol 2009; 15(4): 275-83.
2. Shi H, Aschoff AJ, Brambs HJ, Hoffmann MH. Multislice CT imaging of anomalous coronary arteries. Eur Radiol 2004; 14(12): 2172-81.
3. Cademartiri F, La Grutta L, Malagò R, Alberghina F, Meijboom WB, Pugliese F ,et al. Prevalence of anatomical variants and coronary anomalies in 543 consecutive patients studied with 64-slice CT coronary angiography. Eur Radiol 2008; 18(4): 781-91.
4. Angelini P, Velasco JA, Flamm S. Coronary anomalies: incidence, pathophysiology, and clinical relevance. Circulation 2002; 105(20): 2449-54.
5. Kim SY, Seo JB, Do KH, Heo JN, Lee JS, Song JW, et al. Coronary artery anomalies: classification and ECG-gated multi-detector row CT findings with angiographic correlation. Radiographics 2006; 26(2): 317-33.
6. Cengiz E and Mehmet S. The prevalence of coronary artery varations on coronary computed tomography angiography. Acta Radiol 2012; 53(3): 278-84.
7. Shabestari AA, Akhlaghpoor S, Tayebivaljozi R, Fattahi Masrour F. Prevalence of congenital coronary artery anomalies and variants in 2697 consecutive patient using 64-detector row coronary CT-angiography. Iran Radiol 2012; 9(3): 111-21.
8. Austen WG, Edwards JE, Frye RL, Gensini GG, Gott VL, Griffith LS, et al. A reporting system on patients evaluated for coronary artery disease. Report of the Ad Hoc Committee for Grading of Coronary Artery Disease, Council on Cardiovascular Surgery, American Heart Association. Circulation 1975; 51(4 Suppl): 5-40.
9. Kini S, Bis KG, Weaver L. Normal and variant coronary arterial and venous anatomy on high-resolution CT angiography. Am J Roentgenol 2007; 188(6): 1665-74.
10. Jacobs JE. Computed tomographic evaluation of the normal cardiac anatomy. Radiol Clin North Am 2010; 48(4): 701-10.
11. Pannu HK, Flohr TG, Corl FM, Fishman EK. Current concepts in multi-detector row CT evaluation of the coronary arteries: principles, techniques, and anatomy. Radiographics 2003; 23(Suppl 1): 111-25.
12. Sundaram B, Kreml R, Patel S. Imaging of coronary artery anomalies. Radiol Clin North Am 2010; 48(4): 711-27.
13. Oon YY, Khoo SI, Lim HS, Mohd Amin NH, Koh KT, Khaw CS, et al. The Incidence and Clinical Relevance of Coronary Artery Anomalies Detected on Multidetector Computed Tomography in Sarawak. Int J Cardiol 2017; 249(Suppl): S20-1.
14. Villa AD, Sammut E, Nair A, Rajani R, Bonamini R, Chiribiri A. World J Radiol 2016; 8(6): 537-55.
15. Mahowald JM, Blieden LC, Coe JI, Edwards JE. Ectopic origin of a coronary artery from the aorta. Sudden death in 3 of 23 patients. Chest 1986; 89(5): 668-72.
16. Erol C, Seker M. Coronary artery anomalies: the prevalence of origination, course, and termination anomalies of coronary arteries detected by 64-detector computed tomography coronary angiography. J Comput Assist Tomogr 2011; 35(5): 618-24.
17. Angelini P, Villason S, Chan AV Jr, Diez JG. Normal and anomalous coronary arteries in humans. In: Angelini P, editor. Coronary artery anomalies: a comprehensive approach. Philadelphia: Lippincott Williams & Wilkins; 1999: 27-150.
18. Hongsakul K, Suwannanon R. Congenital absence of left circumflex artery detected by computed tomography coronary angiography: a case report. Case Rep Vasc Med. 2012; 2012: 204657.
19. Tzeng YH, Lan GY, Yin WH, Huang CC, Wu YC. Cardiac computed tomography of congenital absent left circumflex coronary artery: a case report. Chinese Journal of Radiology. 2009; 34(4): 273-6.
20. Basso C, Maron BJ, Corrado D, Thiene G. Clinical profile of congenital coronary artery anomalies with origin from the wrong aortic sinus leading to sudden death in young competitive athletes. J Am Coll Cardiol 2000; 35(6): 1493-501.
21. Zenooz NA, Habibi R, Mammen L, Finn JP, Gilkeson RC. Coronary artery fistulas: CT findings. Radiographics. 2009; 29(3): 781-9.